

Editors Alex Galis and Gaby Lenhart

## 3rd ETSI Future Networks Workshop

9-11 April 2013 Sophia Antipolis, France





#### **Preface**

#### **ETSI Future Networks Technologies (FNT) Workshop Series**

In April 2009 ETSI started a series of workshops on standardization related to issues in Future Networks Technologies (FNT). The series of FNT workshop is continued with new editions whenever there seems to be a special need to conduct one.

Europe has dedicated €9.1 billion to funding research in the FP7 program, 2007 - 2013 and more than €10 billion in the Horizon 2020 program of 2014 – 2020, to develop radically new concepts and technologies in ICT. Several hundred million Euros of this is dedicated to R&D on future networks, and many of the largest or most significant research projects are led by ETSI members.

The 1st ETSI FNT workshop was organized when the first phase of these FP7 projects was at a stage where real results were being produced and Europe required sustainability of these investments by actions beyond the actual research projects, such as standardization. It was therefore time to consider pre-standardization, or standardization of some of the results of this research activity, especially on infrastructure or network technology issues. In parallel to this work, the ETSI Technical Committee TISPAN's work program on the NGN was well advanced and the committee was considering requirements for future standardization activities.

This 1st ETSI FNT workshop aimed to discuss the results of related research projects, especially considering standardization or pre-standardization needs. The workshop intended to explore the potential of progressing the results of these projects in ETSI, in TISPAN or in another suitable committee. The key goals of this workshop were to bring together R&D from industry and academia in order to show the status of the art of R&D work in the field of 'Future Network Technologies' and to identify potential needs for standardization or pre-standardization of 'Future Network Technologies' at ETSI.

The objective of the 2nd ETSI FNT workshop, held in September 2011, was to identify potential subjects for standardization or pre-standardization of Future Network Technologies at ETSI. This time the target topics were: architecture, content centric network, taking care of the end user, autonomic network management and network virtualization (http://www.etsi.org/index.php/news-events/events/541-2nd-future-network-technologies-workshop)

ETSI has almost 800 member companies, large and small, from from more than 70 countries on 5 continents and made up of manufacturers, network operators, service and content providers, national administrations, ministries, universities, research bodies, consultancies and user organizations. Since that very first workshop on FNT, these member companies have developed a large amount of standardization work related to Future Network Technologies. This work has been carried out either in 3GPP or in some of the, more than 120, workgroups and sub-workgroups within ETSI technical structure. These workgroups are organized by clusters, of which there are currently 10 within ETSI, such as:

- AFI (Autonomic network engineering for the self-managing Future Internet) where a reference model of a generic
  autonomic network architecture and the required interfaces is defined (http://portal.etsi.org/portal/server.pt/
  community/AFI/344),
- E2NA (End-to-End Network Architectures) who coordinates next generation and future networks technologies, architectures and frameworks for fixed mobile network interconnection (http://portal.etsi.org/portal/server.pt/ community/E2NA/362),
- MOI (Measurement Ontology for IP traffic), who are creating an information model for all parameters that can be
  measured, vocabulary of classes and relations, rules for the measurement (http://portal.etsi.org/portal/server.pt/
  community/MOI/346),
- NFV (Network Functions Virtualisation), who converge NFV requirements, agree common approaches, and validate recommendations (http://portal.etsi.org/portal/server.pt/community/NFV/367),
- NTECH (Network technologies), who deal with service and network interconnection, protocols, security, network management, etc. (http://portal.etsi.org/portal/server.pt/community/NTECH/361),
- and many others, (find more http://www.etsi.org/technologies-clusters/technologies).





#### **ETSI FNT 2013**

The above mentioned developments were the prerequisite for organizing a 3rd ETSI FNT workshop on how to integrate existing and upcoming technologies into a heterogeneous and highly dynamic resource pool. Virtualization and federation allow operation of multiple distinguished networked services, tailored to different needs, on the same physical infrastructure.

The 3rd ETSI FNT Workshop held from 9-11 April 2013 at Sophia Antipolis, was dedicated to "Network Functions Virtualisation (NFV) and Software Driven Networks (SDN)" presenting emerging approaches and technical solutions with a focus on standardization opportunities for Future Networks. Aggregating resources such as processing, storage and communication interfaces across multiple domains to provide any end-to-end service at different abstraction levels in a pervasive manner, entails not only technological challenges, but also new business models in order to capture the value of new network technologies.

This workshop brought together technology and business innovators from both academia and industry. It served as a platform for experts from various disciplines to establish common ground on major challenges with respect to Future Networks. 125 people attended the event.

#### **ETSI FNT 2013 Scope and Results**

The Software Defined/Driven Networks (SDNs) and Network Functions Virtualisation (NFVs), as recent separate research and development trends have the roots in programmable / active network technologies and standards developed a decade ago. In particular, they are associated with the decoupling of forwarding from control and hardware from networking software, using open interfaces to connectivity resources.

The key goals of this workshop were to identify and discuss novel technologies taking into account major industry initiatives, market drivers and requirements for different technologies. The relationship between virtualization technologies and other areas of technology development, including areas of critical commercial and/or technical interdependencies (e.g. Smartphones and 'Apps'), related standardization and/or pre-standardization needs to be considered and developed by ETSI. The benefits and value of standardized technologies needs to be highlighted and the role of open source initiatives and their relationship to standardization needs to be identified and discussed.

7 tracks of presentations (31 papers) formed the program of the FNT 2013 as follows:

- Introduction, keynote on Horizon 2012 and Future Networks general aspects
- Self- management and control for Software Defined Networks
- Software Driven Networks
- Network Functions Virtualisation
- Network Functions Virtualisation and Clouds
- Enabling Techniques
- SDN Content Networking
- Concluding Remarks and Future Challenges

In addition 4 Panels were organised on the following topics:

- Standardization aspects of Management of SDN Functions & Design Goals & characteristics
- Standardization aspects of SDN Functions & Design Goals & characteristics
- Standardization aspects of NFV Functions & Design Goals & characteristics
- Standardization aspects of General Aspects SDN & NFV Architectures & characteristics

The next phase of R&D will involve novel and standardised integration of virtualisation and programmability methods for use and operation on all connectivity, storage and processing resources under new autonomic management interacting with control systems for provisioning of on-demand networking services and applications. This brings into focus relatively new and key topics for the next decade: what are and how do we create the conditions for effective and continuous updating and changing the networking functions without reinventing architectural aspects and related components (e.g. Softwarization of Future Networks and Services).





#### **ETSI FNT 2013 Program Committee**

We had the great honor and pleasure of being joined by the following people on our Program Committee:

- Ranganai Chaparadza, Fraunhofer-Fokus
- Bruno Chatras, Orange
- Jorge E. López de Vergara Méndez, Universidad Autónoma de Madrid
- Julien Maisonneuve, Alcatel-Lucent
- Luca Pesando, Telecom Italia
- Andy Reid, British Telecom

whom we would like to thank for accepting the difficult challenge of selecting the topics to be presented from a vast number of submissions. All these submissions were of very high quality and so the only selection-criterion we were able to apply was their relevance for the given sub-topics from the call for presentations.

Ms. Gaby Lenhart Senior Research Officer, Innovation - ETSI gaby.lenhart@etsi.org Prof. Alex Galis University College London a.galis@ucl.ac.uk



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### **Agenda**

Clicking on presentations titles links to corresponding paper and/or slides

### **SESSION 1: INTRODUCTION AND KEYNOTE**

Session chair: Gaby Lenhart, ETSI

Welcome address

Luis Jorge Romero, ETSI Director-General

**Horizon 2020** 

Bernard Barani, EC DG CONNECT

Workshop overview: scope and objectives

Gaby Lenhart, ETSI

### **SESSION 2: FUTURE NETWORKS GENERAL ASPECTS**

Session Chair: Luca Pesando, Telecom Italia

Towards Future Networks – the importance of early standardization

Alojz Hudobivnik, Iskratel

To be or not to be programmable

Dimitri Papadimitriou, Alcatel-Lucent

**Future Networks: a Service Provider View** 

Andrea Pinola, Telecom Italia

## **SESSION 3: (SELF-) MANAGEMENT & CONTROL FOR SDN (I)**

Session Chair: Ranganai Chaparadza, Fraunhofer Fokus

ETSI-AFI work on SDN-oriented Enablers for Customizable Autonomic Management & Control, defined in the AFI GANA Reference Model

Ranganai Chaparadza, Fraunhofer Fokus

On the relationships between SDN and Autonomic Management & Control Benoît Radier, Orange

Towards the launch on an ETSI AFI activity on Autonomic Management & Control in IPv6-Enabled SDN-based networks

Latif Ladid, IPv6 Forum

A new Model for highly Available Routing and Load Balancing In SDNs.

Pascal Thubert, Cisco



Clicking on presentations titles links to corresponding paper and/or slides

### SESSION 4: (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

Session chair: Bruno Chatras, Orange

**Towards Management of Software-Driven Networks** 

Alex Galis, UCL

Filling the gap of a SDN management layer with the Unified Management Framework (UMF)

Laurent Ciavaglia, Alcatel-lucent

**Semantic alarms** 

Stefan Wallin, Tail-f

## PANEL 1: Standardization aspects of Management of SDN -

**Functions & Design, Goals & Characteristics** 

Panel chair: Bruno Chatras, Orange

Ranganai Chaparadza, Fraunhofer Fokus

Alex Galis, UCL

Latif Ladid, IPv6 Forum

**Laurent Ciavaglia, Alcatel-lucent** 

**Benoît Radier, ORANGE** 

**Pascal Thubert, Cisco** 

Stefan Wallin, Tail-f

SESSION 5: SDN (I)

Session chair: Alex Galis, UCL

SDN and NFV (Network Function Virtualization) for Carriers (Telecom service provider)

Marie-Paule Odini, Hewlett-Packard

**Software Defined Telecommunication Networks** 

Valentin Vlad, Technische Universität Berlin

OpenQFlow: Scalable OpenFlow with Flow-based QoS

Nam-Seok Ko, ETRI

**Service Orientation in Software Defined Networking** 

Anurag Jain, HCL Technologies





Clicking on presentations titles links to corresponding paper and/or slides

**SESSION 6: SDN (II)** 

Session chair: Julien Maisonneuve, Alcatel-Lucent

**NFV ForCES-based abstraction layer** 

Evangelos Haleplidis, University of Patras

**NFV and SDN in Future Carrier Networks** 

Ricardo Guerzoni, Huawei

Peregrine: An Ethernet Switch-based Software-Defined Network Architecture for IaaS

Tzi-cker Chiueh, ITRI

From Opportunistic Networks and Cognitive Management Systems to SDN-based Edge Networks

Panagiotis Demestichas, University of Piraeus

PANEL 2: Standardization aspects of SDN -

**Functions & Design Goals & characteristics** 

Panel chair: Alex Galis, UCL

Tzi-cker Chiueh, ITRI

Panagiotis Demestichas, University of Piraeus

Ricardo Guerzoni, Huawei

**Evangelos Haleplidis,** University of Patras

Anurag Jain, HCL Technologies

Marie-Paule Odini, Hewlett-Packard

Julien Maisonneuve, Alcatel-Lucent

Andy Reid, BT

Nam-Seok Ko, ETRI

Valentin Vlad, Technische Universität Berlin

**SESSION 7: NFV** 

Session chair: Andy Reid, BT

The Scope and Objectives of the ETSI ISG – Network Functions Virtualisation (NFV)

Andy Reid, BT

Towards the Standardization of Transparency and Isolation Metrics for Virtual Network Elements in SDN

Kurt Tutschku, Telekom Austria Group

**NFV Orchestration and Automation principles and atributes** 

Peleg Erlich, Alcatel-Lucent

Unleashing the potential of virtualization by the right toolkits and open estbeds:

Lessons learned from implementing a virtualized 3GPP EPC toolkit

Thomas Magedanz, Fraunhofer Fokus

Implementing scalable and cost-effective Session Border Control on generic server

Dave Reekie, Metaswitch Networks





Clicking on presentations titles links to corresponding paper and/or slides

### **SESSION 8: NFV and CLOUDS**

Session chair: Kurt Tutschku, Telekom Austria Group

Federated identity management and network virtualization environment

Kostas Pentikousis, Huawei

Proposal on Network Functions Virtualization relationship with ITU-T <Y.CCNaaS> (Cloud Computing Network-as-a-Service) from the holistic perspective of a converged network-computing virtualized service provisioning

ByungJun Ahn, ETRI

## PANEL 3: Standardization aspects of NFV -

**Functions & Design Goals & characteristics** 

Panel chair: Andy Reid, BT

ByungJun Ahn, ETRI

Peleg Erlich, Alcatel-Lucent

Kostas Pentikousis, Huawei

Dave Reekie, Metaswitch Networks

Kurt Tutschku, Telekom Austria Group

### **SESSION 9: ENABLING TECHNIQUES**

Session chair: Jorge Enrique López de Vergara Méndez, Universidad Autónoma de Madrid

### Which Information Model for Autonomic Mechanisms?

Imen Gridabenyahia, Orange

#### **Specification Methodology**

Andy Reid, BT

#### Defining ontologies for IP traffic measurements at MOI ISG

Jorge Enrique López de Vergara Méndez, Universidad Autónoma de Madrid

An Efficient Multicast Scheme based on Openflow Technology in Enterprise Networks Hyeonsik Yoon, ETRI





Clicking on presentations titles links to corresponding paper and/or slides

### **SESSION 10: SDN CONTENT NETWORKING**

Session chair: Julien Maisonneuve, Alcatel-Lucent

Information-centric networking through network function virtualization Kostas Pentikousis, Huawei

How to build cost-efficient and fair CDN federations? : All about federating small and heterogeneous content actors.

Ghida Ibrahim, Orange Labs

# PANEL 4: Standardization aspects of General Aspects SDN & NFV - Architectures & characteristics

Panel chair: Julien Maisonneuve, Alcatel-Lucent

Bruno Chatras, Orange Imen Gridabenyahia, Orange Ghida Ibrahim, Orange Labs Jorge Enrique López de Vergara Méndez, Universidad Autónoma de Madrid Kostas Pentikousis, Huawei

Andu Doid DT

Andy Reid, BT

**Stefan Wallin,** Tail-f

Hueonsik Yoon, ETRI

### **WORKSHOP CONCLUSIONS**

Session chair: Alex Gallis, UCL and all session chairs

**Gaby Lenhart, ETSI** 

Ranganai Chaparadza, Fraunhofer Fokus

Bruno Chatras, Orange

Jorge Enrique López de Vergara Méndez, Universidad Autónoma de Madrid

Julien Maisonneuve, Alcatel-Lucent

Andy Reid, BT

Kurt Tutschku, Telekom Austria Group

Luca Pesando, Telecom Italia

#### **WORKSHOP CLOSURE**



#### **Speakers**

## SESSION 1 INTRODUCTION AND KEYNOTES



**Luis Jorge Romero Saro**, Director General of ETSI has over 20 years international experience in the telecommunications sector.

Previously he has held diverse Director positions in Spain, Morocco and Mexico, predominantly with Telefonica. As Global Director for International Roaming and Standards, and Director of Innovation and Standards, he oversaw Telefonica's participation in global standardization activities, and participated directly in the work of the Next Generation Mobile Networks (NGMN) Alliance and in the GSM Association (GSMA).

Before joining ETSI in July 2011, he held the position of Director General of Innosoft and was also a partner and board member of Madrid-based Innology Ventures.



**Bernard Barani** graduated from the École Nationale Supérieure des Télécommunications de Bretagne in 1982. He then served as communications engineer in industry on military infrared systems and then with the European Space Agency on advanced satcom programmes. In 1994, he joined the European Commission Directorate General "Information Society", and was responsible for implementation of research and policy issues of wireless communication, Internet, audio visual systems, Software and Services. He has been Deputy head of the unit dealing with research and policy in the field of RFID, Internet of Things and networked enterprise systems and is currently Deputy head of the unit in charge of research and innovation on Network Technologies in the CONNECT Directorate

General of the European Commission



### Gaby Lenhart, ETSI. Editor

Born 1964

1983 - 87 study of electrical engineering with emphasis on communications electronics at the Technical University Vienna; in parallel study of English and Russian as translator at the University Vienna

2001 - 04 study of ICSS (Intelligent Communication Systems and Services) at the Technikum Vienna Project Leader in the division 'Network Building & Infrastructure at Max-Mobil Austria (now T-Mobile Austria)

2002 - 2005 Standardization Expert in the division "International Standardization at T-Mobile International; Head of Delegation, Chairman of OMA POC

2005 - 2007 Project Leader for Smart Cards and Project Leader for eHealth at ETSI

Gaby is member of various Boards, such as the Steering Committee of the Future Internet Assembly and the Advisory Board of Net!works

Currently she is Senior Research Officer at the Strategy & New Initiatives department at ETSI and, besides foresight, responsible for all aspects of quantum technologies.



#### **Speakers**

## SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

### Towards Future Networks - the importance of early standardization



**Alojz Hudobivnik** works as CTO Adviser in Iskratel, Kranj, Slovenia in area of telecommunication. He received a B.Sc. and M.Sc. in computer science from University in Ljubljana, in 1983 and 1989, respectively. He was involved in product development of No.7 signalling, implementation of broadband access in Slovenia, product management and corporate knowledge management. Last four years he was involved in work of ITU-T Focus Group FN and was Ass.Raporteur of ITU-T Q.21/13 »Future networks«. Presently he is Vice-Chairman of SG13 WP3 "SDN and Networks of Future" and Rapporteur of Q15/13 "Data-aware networking in FN". He represents Iskratel in FTTH Council Europe, he is Chairman of ETSI standardization group by Slovenian NSO and Vice Chairman of SIKOM

### To be or not to be programmable

**Dimitri Papadimitriou** started at Alcatel in 2000. He worked for the Network Architecture team of the Central Research Center (CRC) where he was in charge of multi-layer traffic-engineering research. In 2003, he joined the Alcatel Research & Innovation (R&I) Department dedicated to distributed control/routing algorithmic. Since 2005, he works in the area of Future Internet research now as part of Alcatel-Lucent Bell Labs as Senior Research Engineer. His current research interests include control-theoretic and stochastic modeling of programmable multi-agent systems, swarm intelligence and self-organizing complex systems. He authored numerous peer reviewed papers on network architecture, distributed and dynamic routing, recovery, and performance of multi-layer networks; he holds more than twenty patents. He currently leads the EULER FP7 project that investigates new dynamic routing paradigms for large-scale complex systems and PI for the EC FP7 Network of Excellence on Internet Science. He is also actively involved in the research activities of the Internet Research Task Force/IRTF (Routing and Congestion Control Research Groups), and Internet Engineering Task Force/IETF (where is a member of the Routing Internet Directorate).

#### Future Networks: a Service Provider View



**Andrea Pinnola** is Senior Project Manager in the Technology Plan and Standard Coordination Group of Telecom Italia. Formerly he was head of the Operation Support Systems Qualification Research Unit and responsible of projects for the Operation Support Systems Evolution. Currently he focuses on Technology Planning and Standard Coordination regarding to Machine to Machine (M2M) solutions and Future Networks aspects.

## **Future Networks Workshop**



**Speakers** 

## SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

## ETSI-AFI work on SDN-oriented Enablers for Customizable Autonomic Management & Control, defined in the AFI GANA Reference Model



Ranganai Chaparadza, PhD: ETSI AFI Chairman, & IPv6 Forum member
Ranganai Chaparadza is a researcher in the field of Internet, Future Internet and Telecommunications
Networks. He obtained his PhD in Telecommunications Engineering from Technical University of Berlin,
Germany, and is based in Berlin. He is chairman of the AFI Group in ETSI (http://portal.etsi.org/afi
): "Autonomic network engineering for the self-managing Future Internet". He is also a member of
the IPv6 Forum and is involved in IPv6-Enabled Autonomic Networking. He initiated and led the very

successful European Commission-funded FP7-EFIPSANS IP Project as Technical Manager and contributor. His interests: (1) Autonomic Network Engineering for Self-Managing Networks; (2) The evolution of the AFI GANA Architectural Reference Model for Autonomic Networking, Cognitive Networking and Self-Management; (3) Standardization initiatives for Autonomic Networking. and Self-Management; (4) IPv6 and its evolution; (5) Building AFI Liaisons with BBF,3GPP,NGMN,TMF,ITU-T-SG13&SG2, IPv6 Forum, and IEEE and other Groups. He has plenty of peer reviewed scientific publications in Conferences, Journals and Workshops, and has served as Chair, Keynote-speaker and TPC member for a number of International Workshops. He serves as co-Chair of IEEE MENS Workshop@Globecom. Other areas of expertise/experience include: Formal-Methods (ITU-T & ETSI SDL/ASN.1/TTCN-3 standardized-languages) and their application to Protocol Engineering; OMG's Model Driven Engineering Techniques for Development and Testing of Complex Systems; GPRS/UMTS protocol verifications; Network Management; Routing and Traffic Engineering in IP protocols. Previously he also worked in ETSI Specialist-Task-Force-276 on Standardized Test Specifications for core IPv6 Protocols (ETSI Conformance & InterOperability Test Specifications for IPv6). Some of recent and past Projects: ECfunded FP7-EFIPSANS Project, FP6-ANA (Autonomic Network Architecture), and Siemens-ICN & BMBF.

#### On the relationships between SDN and Autonomic Management & Control



**Benoit Radier** is a Research Engineer in Informatics and Telecommunication. He joined France Télécom R&D Lannion, France, in 2000. He received an electrical engineering diploma from the "Institut Supérieur de l'Electronique et du Numérique" (ISEN), Brest, and a doctoral degree in computer science from "Université Pierre et Marie Curie" (UPMC) in 2009. Since 2007, his current research activities are in the fields of Autonomic Networking such as autonomic mobility, Generic Autonomic Network Architecture (ETSI), context awareness, knowledge plane. Towards Future Networks - the importance of early standardization

### Towards the launch on an ETSI AFI activity on Autonomic Management & Control in IPv6-Enabled SDN-based Networks



Ranganai Chaparadza, PhD: ETSI AFI Chairman, & IPv6 Forum member See biography above

### A new model for highly Available Routing and Load Balancing in SDNs



**Pascal Thubert** is a senior telecom R&D engineer specialized in IPv6, routing & meshing, as combined with wireless & mobility. He participated to a number of standards, mostly with the IETF (9 RFCs on NEMO, RPL, 6loWPAN, and multiple drafts) but also ISA100, IEC, ETSI.



#### **Speakers**

# SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

#### Towards Management of Software-Driven Networks



Alex Galis - Editor (a.galis@ee.ucl.ac.uk; www.ee.ucl.ac.uk/~agalis)

Alex Galis is a Professor In Networked and Service Systems at University College London. He has co-authored 9 research books including a review of the precursor of the SDN technology "Programmable Networks for IP Service Deployment" ISBN 1-58053-745-6, Artech House Books, and more that 190 publications in journals and conferences in the Future Internet areas: networks, services, management and clouds. He acted as PTC chair of 14 IEEE conferences and

reviewer in more than 100 IEEE conferences (www.ee.ucl.ac.uk/~agalis).

He participated in a number of EU projects including overall technical leadership of the MISA, FAIN, CONTEXT and AUTONOMIC INTERET projects. He was Vice Chair of the ITU-T Focus Group Future Networks (www.itu.int/ITU-T/focusgroups/fn/index.html).

### Filling the gap of a SDN management layer with the Unified Management Framework (UMF)



**Laurent Ciavaglia** is currently research manager at Alcatel-Lucent Bell Labs France in the Networking Technologies research domain, where he coordinates a team specialized in autonomic and distributed systems.

Since 2010, Laurent is also leading the FP7-UNIVERSELF project (www.univerself-project.eu). In recent years, he has been working on the design, specification and evaluation of carrier-grade networks including several European research projects dealing with network control and management. Laurent is also member of the Industry Advisory Board of the FP7-Network of Excellence NESSOS.

Laurent is vice-chair of the ETSI Industry Specification Group on Autonomics for Future Internet (AFI), working on the definition of standards for self-managing networks. Laurent is also participating to the IETF/IRTF as part of his activities in standardization.

Laurent has co-authored more than 40 publications and holds 35 patents in the field of telecommunication networks. Laurent also acts as member of the technical committee of several IEEE, ACM and IFIP conferences and workshops, and as reviewers of referenced international journals and magazines.

#### **Semantic Alarms**



**Stefan Wallin** contributes more than 20 years of network and service management experience to Tail-f, specializing in OSS and NMS systems, and network management standards. He has presented at a wide variety of international network engineering and management conferences. Before Tail-f, he worked as a OSS solutions architect at DataDuctus. Mr. Wallin also served as a network management specialist at Ericsson and a research engineer at the University of Linköping. He holds a M Sc degree in Computer Science from Linköping University and received his doctorate in network management from

Luleå University of Technology.



Speakers SESSION 5 SDN (I)

#### SDN and NFV (network Function Virtualization) for Carriers (Telecom service provider)



Marie-Paule Odini is a seasoned HP executive, bring over 25 years of telecom experience. She has deep expertise in both the networking and IT environments, bridging voice and data.

Marie-Paule is the HP CTO for Europe, responsible for the Communication and Media Solution organization, focused on customer innovation and emerging trends. She leads the technology discussions for M2M, Analytics, Cloud and NFV-SDN. She seats on ETSI, ATIS and other standard bodies.

She is co-chairman of ETSI NFV SWA WG. She is also a frequent industry speaker and editor in professional magazines, blogs on HP Telecom IQ and tweets on CMS twitter account.

Marie-Paule prior responsibilities include managing HP's worldwide VoIP program, HP's wireless LAN program, and HP's Service Delivery program. Since joining HP in 1987, she has held positions in technical consulting, sales development and marketing in Europe and in the Americas. Those roles have focused on strategic and operational responsibility for Networking, IT and operations in the telecom domain.

#### **Software Defined Telecommunication Networks**



**Valentin Vlad** is a master student at the "Technische Universität Berlin, Germany, Faculty for Informatics, specializing in Communication Systems. He received his bachelor diploma in Computer Science at the Technical University of Cluj Napoca, Romania in 2009. He joined the Next Generation Network Infrastructures (NGNI) competence center of the Fraunhofer FOKUS institute in 2009, focusing his work on the core network mobility aspects of the OpenEPC platform.

### OpenQFlow: Scalable OpenFlow with Flow-based QoS



Nam-Seok Ko received the B.S. degree in computer engineering from Chonbuk National University, Jeonju, South Korea, in 1998 and the M.S. degree in information and communications engineering from Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea, in 2000. In 2000, he joined Electronics and Telecommunication Research Institute (ETRI), Daejeon, South Korea and has participated in several projects including developments of ATM switching systems and flow-based routers. Currently he is also working towards the Ph.D. degree with the Department of Information and Communications Engineering, KAIST, Daejeon, South Korea. His research interests include network architecture, network protocols, traffic engineering and software defined networking.

#### Service Orientation in Software Defined Networking



**Anurag Jain** is Deputy General Manager, Engineering and R&D Services (ERS) Practice Group within HCL and his current role is to define and develop solutions for Strategic Business Service Line Units within ERS for Acceleration of Device and Product Launch. He is particularly focussed towards developing technology solutions and IPs in Wireless and Unified Communications domain which includes LTE, SDN and Video. With more than 17 years of overall experience and last 13 years with HCL, he has leaded the

development of various solutions and delivery of large engagements in Telecom and Networking. Holds Engineering Degree in Electronics and Communications from National Institute of Technology Jaipur and has presented several papers in international conferences.



Speakers SESSION 6
SDN (II)

#### NFV ForCES-based abstraction layer



Evangelos Haleplidis received his diploma in Electrical Engineering from the University of Patras in 2002. He is currently a Ph.D. student in the Department of Electrical and Computer Engineering in the University of Patras. He is the main author of two RFCs, and author/co-author of several drafts in regards to the ForCES architecture. His main field of interest is network protocols and network services. He has around 12 publication in conferences related with his research interests. He is a global member of ISOC and the Technical Chamber of Greece and is actively working with IETF's

ForCES working group.

#### NfV and SDN in Future Carrier Networks



Riccardo Guerzoni, HUAWEI European Research Center

Riccardo worked as senior radio planner at Nokia Networks from 1999 to 2007, in the last 2 years managing the development of an automatic radio access optimization prototype.

From 2007, he joined Accanto Systems as Professional Services Manager, boosting expertise on Customer Service Assurance, QoS and diagnosis models in mobile, fixed and converged networks.

He is Senior Solution Architect at Huawei European Research Center since 2011, exploring Future Carrier Networks technologies and business models.

#### Peregrine: An Ethernet Switch-based Software-Defined Network Architecture for IaaS



Dr. Tzi-cker Chiueh is currently the General Director of the Cloud Computing Center for Mobile Applications (CCMA) at ITRI and Professor in the Computer Science Department of Stony Brook University. He received his BSEE from National Taiwan University, MSCS from Stanford University, and Ph.D. in CS from University of California at Berkeley in 1984,1988, and 1992, respectively. He received an NSF CAREER award, and several best paper awards, including that from the 1999 IEEE Hot Interconnect Symposium, the 25th Annual Computer Security Applications Conference and the 2008 IEEE International Conference on Data Engineering (ICDE). Before joining ITRI, Dr. Chiueh served as the director of Core Research in Symantec Research Labs. Dr. Chiueh has published over

180 technical papers in referred conferences and journals. His current research interest lies in data center networking, cloud storage systems, and software security.

#### From Opportunistic Networks and Cognitive Management Systems to SDN-based Edge Networks



Panagiotis Demestichas is a Professor at the University of Piraeus, Department of Digital Systems. Since September 2011 Prof. Demestichas is also the Head of the Department. He has been actively involved in a number of national and international research and development programs. His research interests include the design and performance evaluation of high-speed, wireless and wired, broadband networks, network management, software engineering, algorithms and complexity theory, and queuing theory. Currently he serves as the deputy leader of the Unified Management Framework workpackage in the ICT UniverSelf Project. From July 2010 to December 2012 he served as the Project

Coordinator of the ICT OneFIT (Opportunistic Networks and Cognitive Management Systems for Efficient Application Provision in the Future Internet) Project. Moreover, he was the technical manager of the FP7 ICT E3 (End-to-End Efficiency" (E3) project. He is the chairman of Working Group C (WGC), titled "Communication architectures and technologies", of the Wireless World Research Forum (WWRF). He has more than 150 publications in international journals and refereed conferences. He is associate editor of the IEEE Communication letters and on the Board of Editors of the Journal of Network and Systems Management.



Speakers SESSION 7
NFV

### The Scope and Objectives of the ETSI ISG – Network Functions Virtualisation (NfV)



**Andy Reid** is currently architect for BT's project on network functions virtualisation. He is has been particularly concerned with removing packet performance bottlenecks in hypervisors and is now concerned with the operations and management on virtualised network functions and their supporting infrastructure platform. Andy has a long history in telecoms strategy and architecture and has a particular concern with modelling, including functional modelling, data modelling, operational modelling, and performance modelling. In more recent years he has also done a substantial amount economic modelling for pricing, regulation and competition law.

## Towards the Standardization of Transparency and Isolation Metrics for Virtual Network Elements in SDN



**Kurt Tutschku** holds the Chair of Future Communication (endowed by Telekom Austria) at the University of Vienna. His main research interest include future generation communication networks, network virtualization, network federation, Quality-of-Experience, and the modeling and performance evaluation of future network control mechanisms and services in the emerging Future Internet, particular mechanisms based on P2P algorithms. He obtained his diploma and Ph.D. in Computer Science from the University of Wuerzburg, Germany. In 2008, he received the Habilitation degree ("'State Doctoral Degree"') in Computer Science and communication networks from the University of Wuerzburg. From

February 2008 to August 2008, he worked for the National Institute for Information and Communication Technology (NICT) in Tokyo, Japan.

Kurt Tutschku is closely cooperating with industry. He has accomplished and is leading industrial research projects with companies such as Telekom Austria, Nokia Siemens Networks, BTexact, DATEV e.G., Bosch and Bertelsmann AG. In addition, Kurt Tutschku leads multiple funded academic collaborations such as the Austrian WWTF project on the "Optimization of the Future, Federated Internet". Furthermore, he and his team contribute in directly to various Future Internet testbed projects such as GENI/GpENI (US), Akari (Japan), or G-Lab (Germany). Kurt Tutschku was also member of the steering board of the European FP7 Network-of-Excellence "EuroNF – Anticipating the Network of the Future: From Theory to Design", co-coordinated the joint research agenda and work in EuroNF, was member of the steering committee of the European Future Internet Assembly, and is reviewer for the European Commission in FP7 and the European CHIST-ERA program.

Kurt Tutschku was and is involved in the organization of multiple conferences. Amongst other, he was co-chair of the ICC 2011 NGN symposium, the Future Internet Symposium 2011, and workshop and tutorial co-chair at 2011 International Teletraffic Congress. He is TPC co-chair of the 2013 International Teletraffic Congress. Kurt Tutschku is member of the IEEE, ACM, GI, and OCG.

#### NFV Orchestration and Automation principles and attributes



**Peleg Erlich** is a Senior Solution Architect of Cloud Solutions, in Alcatel-Lucent, focusing on future networks and NFV with over 16 years of experience in telecommunication industry. Formerly he was Senior Manger of Broadband Access Solution team at Huawei European Research Center working closely with Tier1 operators on Access network and next generation PON . Previously he was a Board Member of the FTTH Council Europe and at the same time was a Senior Director of Product Management and Marketing where he led and managed the Product Marketing and managements activities for xPON technologies and FTTH networks. Peleg holds a B.Sc. degree in Electronic Engineering from RMIT

university, Melbourne, Aus. and MBA from Heriot-Watt University, Edinburgh, UK





Speakers SESSION 7
NFV

# Unleashing the potential of virtualization by the right toolkits and open testbeds: Lessons learned from implementing a virtualized 3GPP EPC toolkit



**Thomas Magedanz** (PhD) is full professor in the electrical engineering and computer sciences faculty at the Technische Universität Berlin, Germany, leading the chair for next generation networks (www.av.tu-berlin.de) since 2004. In addition, he is director of the next generation network infrastructure competence center of the Fraunhofer Institute FOKUS (www.fokus.

fraunhofer.de/go/ngni) since 2000. Since more than 20 years Prof. Magedanz is working in the convergence field of fixed and mobile telecommunications, the internet and information technologies, which resulted in many international R&D and consultancy projects centered around the prototyping of advanced Service Delivery and Control Platforms for fixed and mobile Next Generation Networks for major international network operators and equipment manufacturers. In the course of his research activities he published more than 250 technical papers/articles and his OpenXXX testbed toolkits are used in many R&D labs around the globe. In addition, Prof. Magedanz is senior member of the IEEE and holds guest professorships at the University of Cape Town in South Africa and Universidad de Chile in Santiago de Chile.

### Implementing scalable and cost-effective Session Border Control on generic server



**Dave Reekie**, Senior Vice President, Engineering. As one of the small group of talented engineers that designed the Metaswitch system architecture, Dave combines detailed product knowledge with rigorous project management skills. His engineering and management abilities have been proven over his 15+ years with the company, as he has consistently delivered complex, challenging projects across a broad range of telecommunications technologies including SS7, SMTP, LDAP/X.500, and SNA. Dave graduated with a first class degree in Engineering from Cambridge University.



**Speakers** 

SESSION 8
NFV and CLOUDS

#### Federated identity management and network virtualization environment



Kostas Pentikousis is a senior research engineer at Huawei Technologies in Berlin, Germany and a standards delegate to IETF. Before that, he was a senior research scientist at VTT Technical Research Center of Finland working on information-centric networking (ICN). As an expert in this emerging area, he served as the lead guest editor for the IEEE Communications Magazine feature topic on ICN. Kostas received his Ph.D. in computer science from Stony Brook University for his thesis on "ECN,

power consumption, and error modeling in TCP simulation studies" (2004). During his studies, he interned at Computer Associates in Islandia, NY, developing network management software. He co-authored more than 90 journal articles, conference papers and book chapters, and presented well-attended tutorials on energy-efficient networking at IEEE ICC and IEEE VTC-Spring (2010). Dr. Pentikousis conducts research on Internet protocols and network architecture and is known for his work on mobile networks and management. His contributions have ranged from system design and implementation to performance evaluation. At Huawei he worked on 3GPP EPC research topics beyond Rel. 12 and has been awarded four patents in this area. Since 2012, his research focus shifted to carrier-grade software-defined networking (SDN) and network virtualization.

Proposal on Network Functions Virtualization relationship with ITU-T <Y.CCNaa\$> (Cloud Computing Network-as-a-\$ervice) from the holistic perspective of a converged network-computing virtualized service provisioning



**Byung Jun AHN** is a principal researcher at ETRI, Korea, since 1986. His current research areas include the convergence of computing and networking, Internet traffic managements, network virtualization, service-oriented architecture, and Cloud computing. He has led many research projects in telecommunications traffic management and Internet router systems technologies. Dr. AHN is participating Cloud computing related standardization activities at ITU-T SG13, particularly on network aspects of them. Dr. AHN received his Ph.D. degree in Computer Engineering from Iowa State University.



#### **Speakers**

## SESSION 9 ENABLING TECHNIQUES

#### Univerself: Which Information Model for Autonomic Mechanisms?



Imen Grida Ben Yahia is a senior research engineer at Orange Labs'. She is involved in R&D projects and activities, where she is contributing and guiding various tasks related to autonomic management with particular focus and interest on Self-healing mechanisms, Policy Based Management, information/knowledge engineering, as well as tasks in the field of workflows management for the OSS/OAM improvement. In 2008, Imen received a Ph.D in Communication Networks from Paris.VI University and Telecom SudParis. She has participated to several EU projects and is currently involved in UniverSelf project, for the specification of a Unified Management Framework to enable the deployment of autonomic mechanisms. She is the author/co-author of more than 40 papers in international

conferences and journals.

#### **Specification Methodology**



**Andy Reid** is currently architect for BT's project on network functions virtualisation. He is has been particularly concerned with removing packet performance bottlenecks in hypervisors and is now concerned with the operations and management on virtualised network functions and their supporting infrastructure platform. Andy has a long history in telecoms strategy and architecture and has a particular concern with modelling, including functional modelling, data modelling, operational modelling, and performance modelling. In more recent years he has also done a substantial amount economic modelling for pricing, regulation and competition law.

### Defining ontologies for IP traffic measurements at MOI ISG



Jorge Enrique Lopez de Vergara Méndez is an associate professor in the Electronics and Communication Technologies Department of the Universidad Autónoma de Madrid (Spain). He is also co-founder of the spin-off Naudit High Performance Computing and Networking. He received his MSc degree in telecommunications from Universidad Politécnica de Madrid (Spain) in 1998 and finished his PhD in telematics engineering at the same university in 2003, where he held a research grant. He has participated in several Spanish and EU research projects, and has co-authored more than 70 papers in

international conferences and journals. He is also chairing the ETSI Measurement Ontology for IP traffic ISG. His current research topics include network, service, and distributed application management and monitoring, focusing on the defintion and integration of information models.

#### An Efficient Multicast Scheme based on Openflow Technology in Enterprise Networks



**Hyeonsik Yoon** received his BS and MS in electronics engineering from Kyungpook National University, Daegu, Rep. of Korea, in 1993 and 1995, respectively. He was a senior researcher at LG Information & Communications Corporation, Rep. of Korea, from 1995 to 2000. In 2000, he joined ETRI, Daejeon, Rep. of Korea, and he has worked on several projects, including routers, EPON, GPON, MPLS, and ATM systems. His research interests are routing protocols, mobility technology and SDN(OpenFlow).

## Future Networks Workshop



#### **Speakers**

# SESSION 10 SDN CONTENT NETWORKING

### Information-centric networking through network function virtualization



Kostas Pentikousis is a senior research engineer at Huawei Technologies in Berlin, Germany and a standards delegate to IETF. Before that, he was a senior research scientist at VTT Technical Research Center of Finland working on information-centric networking (ICN). As an expert in this emerging area, he served as the lead guest editor for the IEEE Communications Magazine feature topic on ICN. Kostas received his Ph.D. in computer science from Stony Brook University for his thesis on "ECN, power

consumption, and error modeling in TCP simulation studies" (2004). During his studies, he interned at Computer Associates in Islandia, NY, developing network management software. He co-authored more than 90 journal articles, conference papers and book chapters, and presented well-attended tutorials on energy-efficient networking at IEEE ICC and IEEE VTC-Spring (2010). Dr. Pentikousis conducts research on Internet protocols and network architecture and is known for his work on mobile networks and management. His contributions have ranged from system design and implementation to performance evaluation. At Huawei he worked on 3GPP EPC research topics beyond Rel. 12 and has been awarded four patents in this area. Since 2012, his research focus shifted to carrier-grade software-defined networking (SDN) and network virtualization.

# How to build cost-efficient and fair CDN federations? : All about federating small and heterogeneous content actors.



#### **Ghida Ibrahim**

As a PhD candidate, Ghida Ibrahim works on the evolution of future content distribution services. Since her PhD is done jointly with a leader in the telecommunications industry in France, she especially focuses on the Telco position with respect to future content distribution services. She seeks to identify and develop solutions aiming to enhance the Telco role in this context.

In March 2011, Ghida joined the "Networks and IT" department of Telecom ParisTech as a PhD candidate doing her PhD jointly with the "Network Architecture for Services Deployment" department of Orange Labs. The first phase of her PhD allowed her to own a good knowledge of content distribution services ecosystem and to track the main evolution trends at this level.

Prior to starting her PhD, Ghida has graduated as a telecommunications and networks engineer jointly from Telecom ParisTech (Paris) and "Ecole Supérieure d'Ingénieurs de Beyrouth" (Beirut). She has done many internships and technical projects in France and Lebanon in both research and IT fields. These include a six months internship about "IP flow mobility in EPC" in Orange Labs (Paris), a two months internship about graphical interfaces development in the IT department of Blom bank, Beirut and an "Intelligent Home" project in Libatel, Beirut. She has also participated to many workshops in Europe. She has recently graduated as a DPM (doctoral program in management) fellow from ENPC MBA Paris.

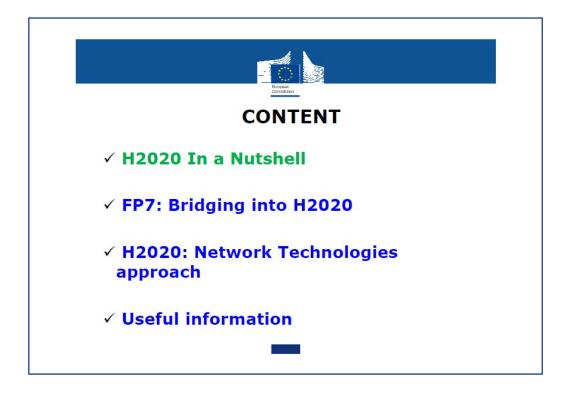
Ghida has won two Excellency awards from the "Ecole Supérieure d'Ingénieurs de Beyrouth" for being the top of promotion for two consecutive years. She has also obtained the "Bourse Master Ile de France" scholarship in order to pursue her joint degree with Telecom ParisTech and a full scholarship from both Orange and ANRT in order to pursue her doctoral studies. She was also chosen as the doctoral ambassador of the ParisTech institute.



SESSION 1
INTRODUCTION AND KEYNOTES

Horizon 2020







## SESSION 1 INTRODUCTION AND KEYNOTES



### What is Horizon 2020?

Commission proposal for an € 80 billion R&I funding programme (2014-20) → after MFF decision by Heads of States ≈ - 12%

Part of proposals for next EU budget, complementing Structural Funds, education, etc.

A core part of Europe 2020, Innovation Union & European Research Area

Addressing EU2020 policy challenges



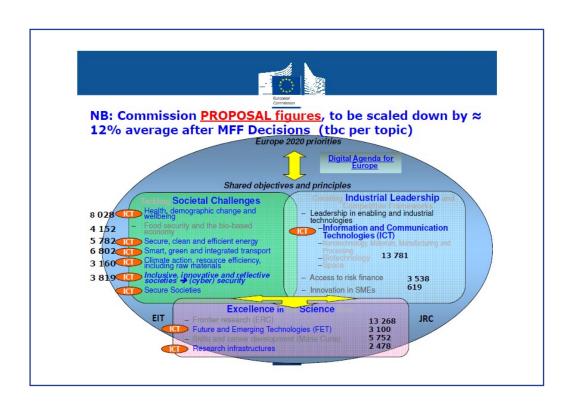


### New approach:

- A single programme bringing together three separate programmes/initiatives
- More innovation, from research to retail, all forms of innovation. Better articulation of research and innovation
  - Strengthened support for high-tech SMEs
  - Greater flexibility and responsiveness (open, light & fast)
  - Dialogue with Venture Capital
  - New actors
- Focus on societal challenges facing EU society, e.g. health, clean energy and transport
- Simplified access, for all companies, universities, institutes in all EU countries and beyond.



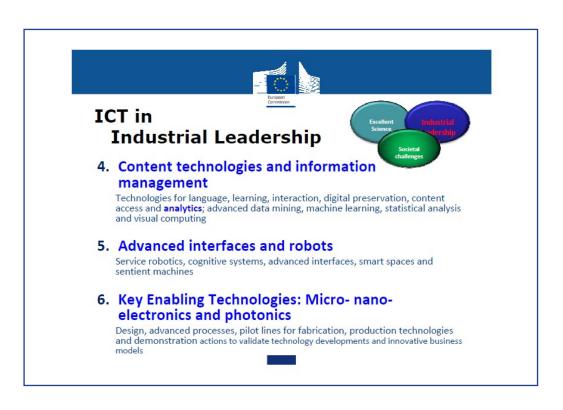
## SESSION 1 INTRODUCTION AND KEYNOTES

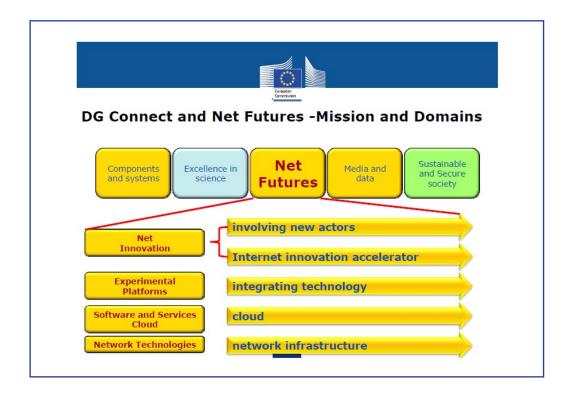






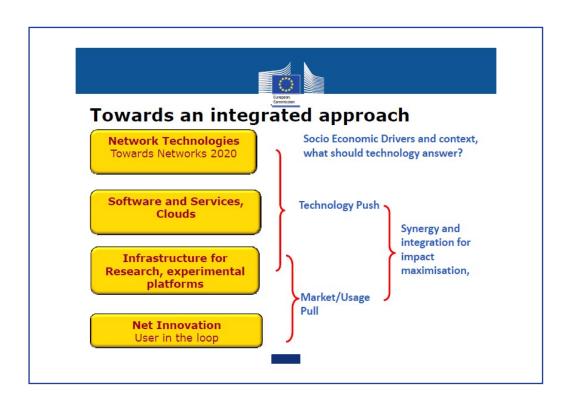
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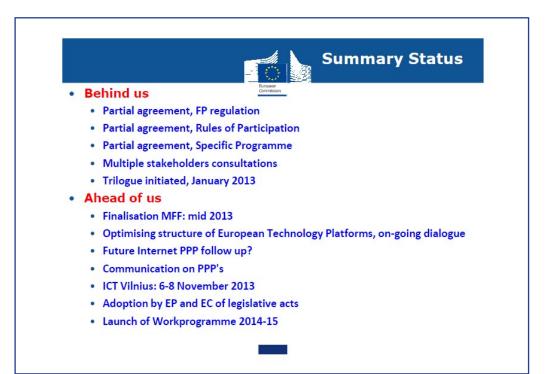






## SESSION 1 INTRODUCTION AND KEYNOTES







## SESSION 1 INTRODUCTION AND KEYNOTESS



- √ H2020 In a Nutshell
- √ FP7: Bridging into H2020
- √ H2020: Network Technologies approach
- ✓ Useful information



# Network Technologies: Moving into the Horizon 2020 era

- Multiple consultations, clusters;
- ETP's Net!Works SRA (v10, July 2012), http://www.networks-etp.eu/
- Links to external bodies (WWRF)
- Call 8
- EU-Japan call
- Call 11
- Workshops (like this one)



# SESSION 1 INTRODUCTION AND KEYNOTESS



### Network focus: Trends driving EU Research

- Data explosion, content
  - · High capacity networks
  - Architectures, e.g. CCN, ICN



- SDN, open programmable and virtualised networks
- E2E SLA, cloud interoperability/integration
- Mobility
  - High capacity wireless, spectrum efficient and flexible technologies
  - Low EMF characteristics
  - Next gen converged and global Mobile networks









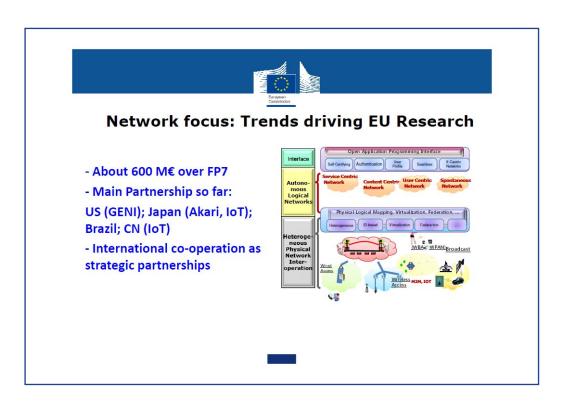


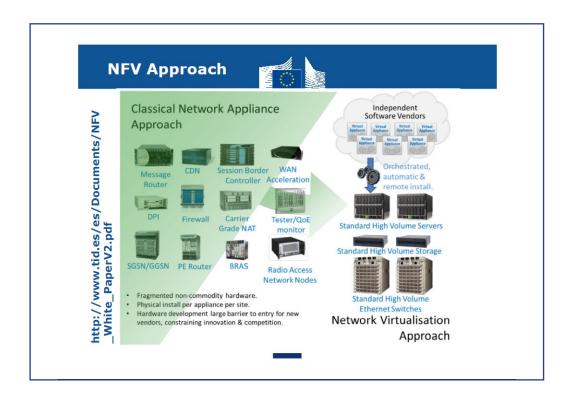
- Sustainability
  - Green networks, drastic energy reduction/user
  - all optical beyond IP routing
- Flexibility, low OPEX
  - Flexible self-management across multiple domains.
  - Big data usage, QoE
  - · Leveraging network data in higher level applications
- Objects connectivity
  - IoT, spectrum efficient technologies
  - Integration environment, superstacks?
- · Security, tesbeds..
- NFV: for Network Management





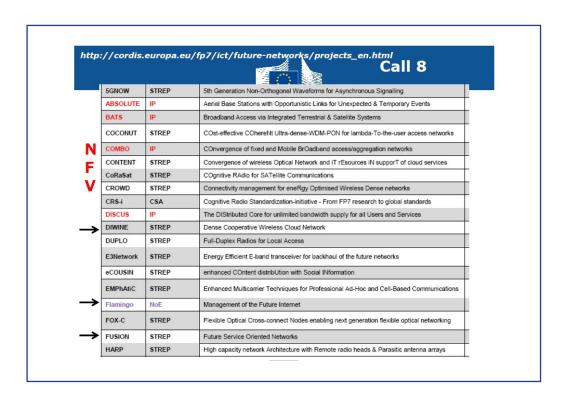
## SESSION 1 INTRODUCTION AND KEYNOTES

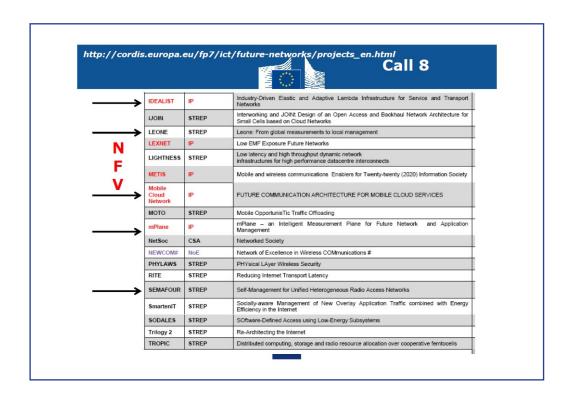






## SESSION 1 INTRODUCTION AND KEYNOTES







## SESSION 1 INTRODUCTION AND KEYNOTES



### **International Cooperation**

#### 10.1: EU-Japan research and development Cooperation

Optical Com; Wireless Coms; Cybersecurity, improved resilience against cyber threats; Cloud and IoT; Global scale experiments over federated testbeds; Green & content centric networks

#### 10.2: EU-Brazil research and development Cooperation

Cloud Computing for Science; Sustainable technologies for a smarter Society; Smart Services and applications for a Smarter Society; Hybrid broadcast-broadband TV applications and services

## 10.3: International partnership building and support to dialogues

Support to dialogues between the EU and strategic partner countries and regions and to foster cooperation with strategic third country organisations in collaborative ICT R&D.

Plus a number of "targeted openings" with other third countries is available 19 within specific objectives

Challenge 1



### **Important milestone: Work Program 2013**

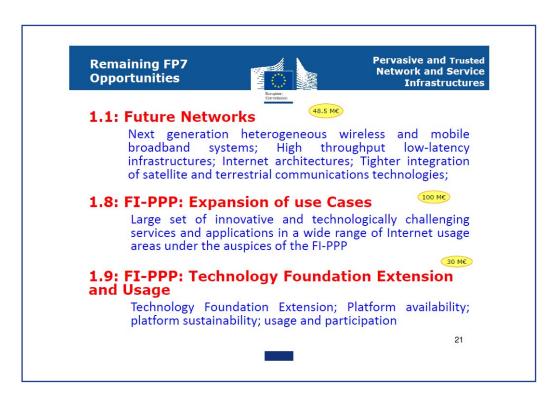
## Pervasive and Trusted Network and Service Infrastructures

- Continue roadmap based research
- Network technologies, call 11
- To leverage new constituencies (innovative SMEs)
- Software systems laying the basis for the future European Cloud strategy
- To open the Future Internet PPP platform following an open innovation model

20



## SESSION 1 INTRODUCTION AND KEYNOTES





#### CONTENT

- √ H2020 In a Nutshell
- √ FP7: Bridging into H2020
- √ H2020: Network Technologies approach
- ✓ Useful information



## SESSION 1 INTRODUCTION AND KEYNOTES



### **Our Priorities**

## <u>Priority 1: Integrated and ubiquitous fixed and mobile network infrastructures</u>

To reinforce the European know-how with leadership on ultra-fast broadband access and core networks based on infrastructure able to economically support a thousand fold growth in traffic by 2020. This covers, among others, R&D+I on wireless, optical and satellite communication technologies.

#### **Priority 2: Smart networks and novel architectures**

To develop European industrial leadership on networks and architectures capable of supporting novel classes of Internet usage and innovative applications like content/information-centric, distributed cloud computing, Machine to Machine and the Internet of Things. It encompasses software defined and virtualised networks enabling low cost management and high service versatility.

#### Priority 3: Enabling network technologies for innovation

To reinforce industrial, academic and SME partnerships to develop and experiment sustainable network technologies, that are ultra-fast, low power, low energy, low radiation, and of highest spectrum efficiency.



### **Current Preparatory actions, framework**

- Work programme 2014-15 preparation, LEIT budget decrease ≈ -12% ?
- WP1 contemplated budget for ICT LEIT TBD.
- Future Internet in FP7 ≈ 26%, target baseline (will need adaptation for new priorities)
- Innovation to be inserted in the baseline;
- Network technologies, called upon to represent a significant share.



## SESSION 1 INTRODUCTION AND KEYNOTES



### Timing

- Orientation paper, available December 2012
- Orientation paper cleared at Commissioner level, February 2013
- Drafting WP 2014-15: on-going;
- Target availability of WP 2014-15: < Summer 2013
- PPP's: proposal available May (preferably) July time frame; Q: What after Future Internet PPP of today?
- Communication on partnerships instruments (ETP, PPP, JTI): July 2013 target
- Signature of Contractual agreement with retained PPP's: before end of 2013



#### Standards in H2020

- Emphasis through the innovation dimension
- Opportunities at multiple levels:
  - · Regular research projects;
  - PPP's;
  - Transverse actions, e.g. IoT;
  - Dedicated support (e.g. SME instruments)
- Restructured Clusters, RWP
  - RAS, CaON; FI, IERC
  - http://ec.europa.eu/digitalagenda/events/cf/fnc11/item-display.cfm?id=10185



## SESSION 1 INTRODUCTION AND KEYNOTES



#### CONTENT

- √ H2020 In a Nutshell
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- √ Useful information





# FuNeMS 2013: Future Network & Mobile Summit

http://www.futurenetworksummit.eu/2013/

Workshops proposal deadline:
Workshops acceptance notification:
Papers submission deadline:
Skhibition proposal deadline:
Papers acceptance notification:
Skhibition acceptance notification:
Papers final submission:
Papers final submission:
Papers registration:

11 January 2013
Papuary 2013
Papuary 2013
Papers submission deadline:
Papers final submission:
Papers final s





# SESSION 1 INTRODUCTION AND KEYNOTES



## FuNeMS 2013: Panel on Virtualised Networks

http://www.futurenetworksummit.eu/2013/default.asp?page=panel-virtnet

**Dr Diego R. LOPEZ** (chair) head of the Technology Exploration activities, GCTO Unit, Telefónica I+D.

Part 1: Network virtualisation "quo vadis"

- 1) Dr Aki Nakao, University of Tokyo: a research perspective;
- **2) Dr Yaron Wolfsthal,** DGM, Systems Research, IBM Haifa Research Laboratory, infrastructure virtualisation: an IT vendor perspective;
- **3) Dr Krishan Sabnani,** ALU, Senior Vice President, Networking Research: a telecom vendor perspective

Part 2: "SDN for Carrier grade networks"

- 4) Dr Andreas Gladisch, head of department Deutsche
- 5) Dr Jörg-Peter Elbers , V.P Advanced Technology, ADVA

Optical Networking: SDN & OpenFlow



### **Future Internet Assembly 2013, Dublin**

- 8 To 10 May 2013
- High profile plenary day, 3 streams
- 12 Working sessions
- http://www.fi-dublin.eu/





# SESSION 1 INTRODUCTION AND KEYNOTES



# EU-Japan Workshop on R&D Co-operation in the field of Networked Technologies & Systems

Date: 18 April

Venue: Marivaux Hotel Congress & Seminar Centre -Boulevard Adolphe Maxlaan 98 - 1000 Bruxelles/Brussel

> http://cordis.europa.eu/fp7/ict/futurenetworks/eujapan2013 en.html

#### 4 Themes:

- Optical networks;
- High density Local Area Networks;
- Experiments/Testbeds;
- Cloud/IoT infrastructures
- → MAIL to Caroline.Limon@ec.europa.eu

### Sites to drill further



#### **Network Technologies**

http://cordis.europa.eu/fp7/ict/future-networks

 ${\tt CNECT-FUTURE-NETWORKS@ec.europa.eu}$ 

#### **Project Summaries & Presentations**

 $http://cord is.europa.eu/fp7/ict/future-networks/projects\_en.html\\$ 

## EC Communication guide on how to best spread the word on the EU R&I:

http://ec.europa.eu/research/science-society/document\_library/pdf\_06/communicatingresearch\_en.pdf

#### **Net-Tech Future Magazine:**

http://cordis.europa.eu/fp7/ict/future-networks/net-tech-future/

#### Horizon 2020

www.ec.europa.eu/research/horizon2020

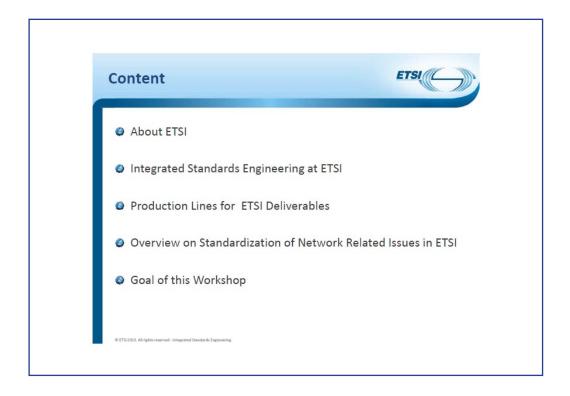




# SESSION 1 INTRODUCTION AND KEYNOTES

# Workshop overview: scope and objectives

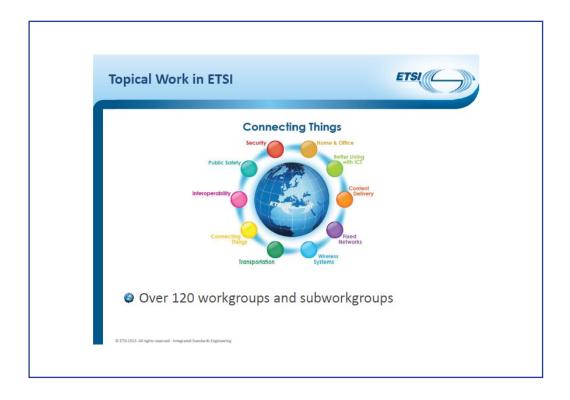






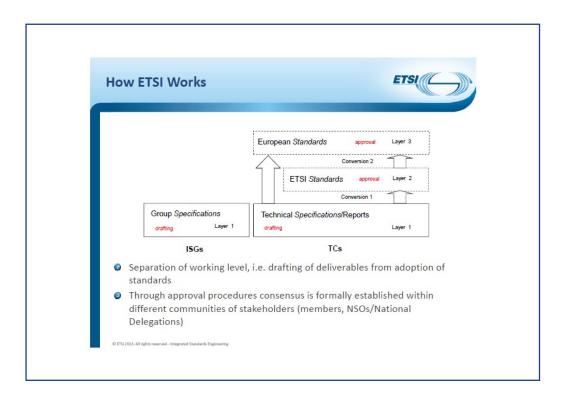
# SESSION 1 INTRODUCTION AND KEYNOTES







# SESSION 1 INTRODUCTION AND KEYNOTES







## **SESSION 1 INTRODUCTION AND KEYNOTES**

#### Standardization of FNT-Related Issues in



- AFI (Autonomic network engineering for the self-managing Future Internet)
- Reference model of a generic autonomic network architecture and the required interfaces, ...
  - http://portal.etsi.org/portal/server.pt/community/AFI/344
- E2NA (End-to-End Network Architectures)
  - Coordination of next generation and future networks technologies, architecture and framework for fixed mobile network interconnection
  - http://portal.etsi.org/portal/server.pt/community/E2NA/362
- MOI (Measurement Ontology for IP traffic)
  - Information model for all parameters that can be measured, vocabulary of classes and relations, rules for the measurement, ..
  - http://portal.etsi.org/portal/server.pt/community/MOI/346
- NFV (Network Functions Virtualisation)
  - Converge NFV requirements, agree common approaches, validate recommendations
  - http://portal.etsi.org/portal/server.pt/community/NFV/367
- NTECH (Network technologies)
  - · Service and network interconnection, protocols, security, network management,...
  - http://portal.etsi.org/portal/server.pt/community/NTECH/361
- Find more <a href="http://www.etsi.org/technologies-clusters/technologies">http://www.etsi.org/technologies-clusters/technologies</a>

#### **Goal of the Present Workshop**





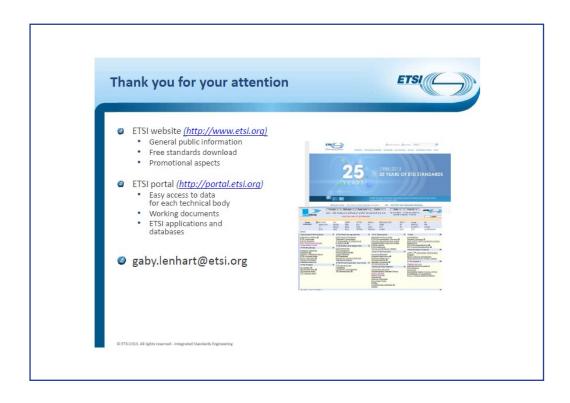
- Identify issues which require to be solved through standardization
- identify technologies for standardization as solution elements for ongoing work in ETSI committees/groups







# SESSION 1 INTRODUCTION AND KEYNOTES







# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

### Towards Future Networks – the importance of early standardization

#### Abstract:

There have been continuous efforts and progresses regarding the research and development of Future Networks (FNs) technologies in recent years, such as network virtualization and software defined network (SDN), information centric networking (ICN), cloud networking, autonomic management, and open connectivity. ITU-T has started working on the standardization of FNs in late 2009, and it has developed its initial results and Recommendations that lay out the essential directions for subsequent detailed work. In my presentation, i will present the background and the context of current FNs' standardization, the deliverables and future plans originated from the standardization work performed by ITU-T. I see all novel technologies discussed at this WS as candidate technologies to fulfill FN requirements. I will focus on standardization opportunities for Future Networks and invite all to contribute and collaborate in this process for human well.





# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

### **Future networks:**

### New architecture != new services

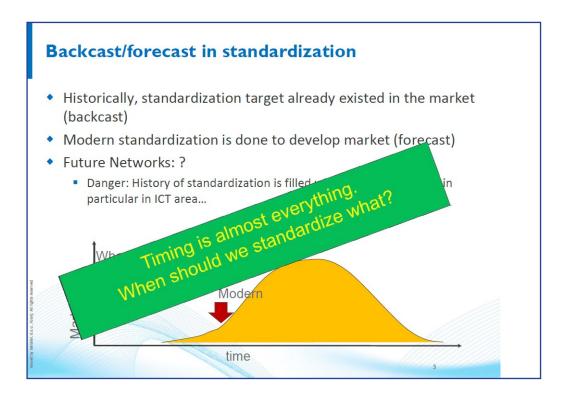
- New architecture becomes necessary when balance among important issue varies
  - <u>Line cost</u> versus <u>Node cost</u>: Optical fiber reduced line cost: we can simplify node by sending more complicated (text-based) control messages
  - Storage cost: Hard-disk cost is still decreasing
- New service emerges when new end-user device emerges
  - Personal Computer → internet
  - Mobile phone → made everything personal
  - Bigger computer (Data center) → cloud (GFLOPS history)
  - Cheap sensors → M2M

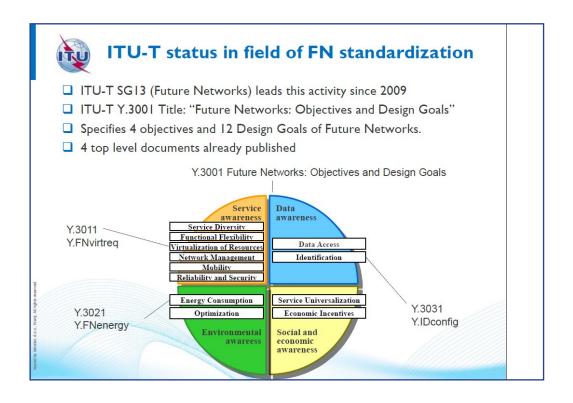
# **Examples of networking concept:**

		PSTN(telephony)	IP(Internet)	Data Centric Network
	Time	1930's -	1980's -	2020's -
	Usage	voice communication	WEB	M2M
	Type of Communication	Human to Human	Human to Machine	Machine to Machine
	Infrastructure	circuit switching	packet switching	object distribution
	Strength	QoS	connectivity	<u>mobility</u>
	Weakness	efficiency	reliability, QoS, mobility	delay
sued by teleratel, d.a.a., Franț. All rights reserved	Mechanism	Sender specifies terminal ID(phone number) and set-up end-to-end circuit passage.	Sender specifies terminal location (IP address) and send out packet flows.	Sender registers an object with an ID attached, and receiver specifies the ID to retrieve it.



# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS



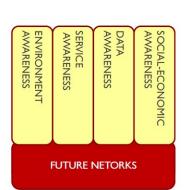




# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

# Four FN Objectives

- Environment awareness
  - FNs should be environmental friendly.
- Service awareness
  - FNs should provide services that are customized with the appropriate functions to meet the needs of applications and users.
- Data awareness
  - FNs should have architecture that is optimized to handling enormous amount of data in a distributed environment.
- Social-economic awareness
  - FNs should have social-economic incentives to <u>reduce barriers</u> to entry for the various participants of telecommunication sector.





# 12 - Design Goals

- I. FNs should accommodate a wide variety of traffic and support diversified services (Service Diversity)
- 2. FNs should have flexibility to support and sustain new services derived from future user demands (Functional Flexibility)
- 3. FNs should support virtualization so that a single resource can be used concurrently by multiple virtual resources. FNs should support isolation and abstraction (Virtualization of resources)
- 4. FNs should have mechanisms for retrieving data in a timely manner regardless of its location (Data Access)
- 5. FNs should have device, system, and network level technologies to improve power efficiency and to satisfy customer's requests with minimum traffic (Energy Consumption)
- 6. FNs should facilitate and accelerate provision of convergent facilities in differing areas such as towns or the countryside, developed or developing countries (Service Universalization)

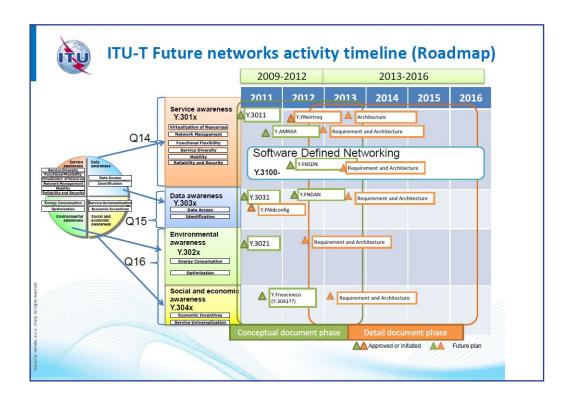


# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS



# 12 - Design Goals (Cont.)

- FNs should be designed to provide sustainable competition environment to various participants in ecosystem of ICT by providing proper economic incentives (Economic Incentives)
- 8. FNs should be able to operate, maintain and provision efficiently the increasing number of services and entities (Network Management)
- FNs should be designed and implemented to provide mobility that
  facilitates high levels of reliability, availability and quality of service in an
  environment where a huge number of nodes can dynamically move
  across the heterogeneous networks (Mobility)
- FNs should provide sufficient performance by optimizing capacity of network equipments based on service requirement and user demand (Optimization)
- 11. FNs should provide a new identification structure that can effectively support mobility and data access in a scalable manner (Identification)
- 12. FNs should support extremely high-reliability services (Reliability and Security)





# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

# Candidate technologies for achieving the design goals:

- Network Virtualization (Virtualization of Resources)
  - Enables creation of logically isolated network partitions over shared physical network infrastructures so that multiple heterogeneous virtual networks can simultaneously coexist over the shared infrastructures; it allows the aggregation of multiple resources and makes the aggregated resources appear as a single resource
- SDN (Software Defined Networking)
- Data/Content-oriented Networking (Data Access)
- Energy-saving of Networks (Energy Consumption)
  - · Forward traffic with less power
  - · Control device/system operation for traffic dynamics
  - · Satisfy customer requests with minimum traffic
- In-system Network Management (Network Management)
- Distributed Mobile Networking (Mobility)
- Network Optimization (Optimization)
  - Device / System / Network level optimization (Path optimization, Network topology optimization, Accommodation point optimization)
- DTN (Delay-tolerant networking)
  - To provide robustness even in presence of link/network disconnections (e.g., Automobile, train, ships, airplane, ...)
- .

## Concept of network virtualization (LINP: Logically Isolated Network Partition) Network virtualization is required to be capable of providing multiple virtual infrastructures those are LINP3 isolated each other. The virtualized infrastructures may be created over the single physical infrastructure Each virtual network is isolated each other and is programmable to satisfy the user's demand on the functionality and amount User's demand is conveyed to LINP manager which is required to coordinate infrastructures so that appropriate network resource is provided to the user



# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

#### **Identification Framework for FNs** High-level requirements for identifiers Future Networks Communication Objects Services unique in given scope unambiguous for the given category some persistent IDs and some temporary IDs recommended to have ID structure helpful for Identification Framework mapping between IDs of different categories both static and dynamic mapping should be possible between IDs of different categories ID Discovery Service flexible structure for future enhancement security friendly structure Identification Framework Logically connects communication Service ID Node ID objects to physical networks Includes node IDs, data IDs, user IDs, ID Mapping Service service IDs and location IDs in its Includes four components: ID Discovery Service ID Spaces Location-based forwarding forwarding ID Mapping Registries and Vetworks **ID Mapping Service**

# Y.FNsocio-economic



# Is this technology good for society? Economically reasonable?

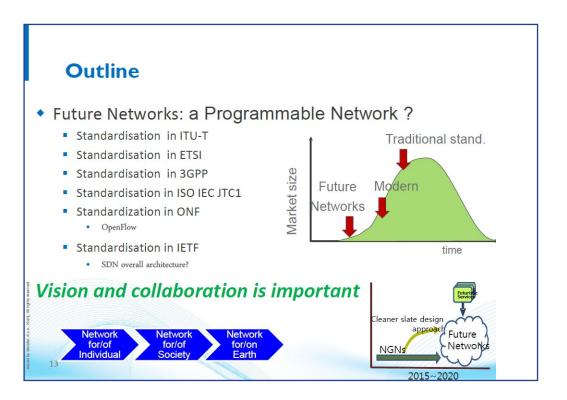
When a technology is given , this "guide":

- Lists and describes methods to assess socio-economic effect of the technology
- Analyze potential tussles among parties
- Helps design/select appropriate technology for Future Networks

Some interfaces/mechanisms are too integrated, and difficult to improve because too many parties are involved



# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS



### Questions on FN standardization

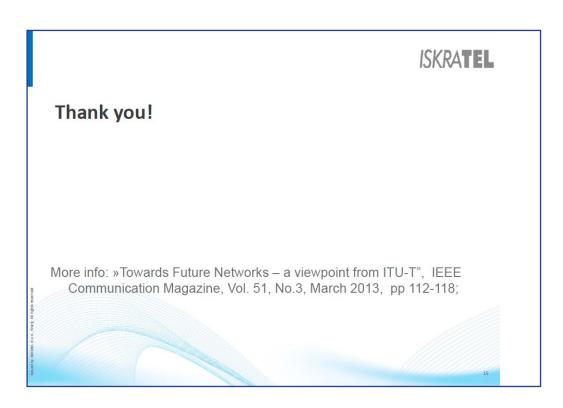
- To design FN, wider collaboration than traditional ICT framework is necessary!
  - Today's promising areas are all interdisciplinary ones between ICT and other industries (Cloud: computer, smart grid: power, IoT: health, vehicle, etc.)
  - ICT has become an infrastructure of every industry, so we need to learn their needs to design future networks (We can't design smart grid ready network without understanding power industry's requirements)
- Do we have enough options?
  - Are R&D/industry proposals mature enough?
- Is the emerging market clear enough?
  - Can we expect enough participation from industries so early?
     (ITU-T is contribution driven no progress without contribution!)
     Diferent SDOs, Research Communities (FP7/Horizont 2020, ...) and Forums are invited to contribute.
- If we specify standards, do market respect our specifications?

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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS





# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

### To be or not to be programmable

#### Abstract:

SDN research directions as outlined in IRTF RG [1] outlines i) The need for more flexibility and programmability at the data plane level and ii) The need for higher-level languages for programming together with testing and debugging. There are three fundamental challenges behind these directions (assuming that local function or states can be transformed into network function or states effectively). The first fundamental question is whether the resulting programs should be designed to transform/manipulate network states or manipulate/transform network functions. Hence, we would have basically two choices: use either a programming language that is specialized for state programming or function programming (e.g. Haskell, LISP). The second fundamental challenge is related to concurrency as the programming of states or functions are unlikely to be performed serially (due to the number of interacting states and functions in a "feature-rich" network); in turn, several executions will be required to perform simultaneously, and potentially interacting with each other. The last fundamental challenge is related to the on-line verification of the execution of the programs manipulating network states or functions. This last challenge may have been overlooked but one should consider that it will be almost impossible to build and/or anticipate at design-time a complete set of primitives to transform/manipulate all the states or functions that network programmers would like to operate on.

After detailing these fundamental challenges, the paper will outline the main alternatives to possible address them along with the underlying but inevitable design and performance trade-offs. For each of them, this paper will evaluate the related standardisation aspects, in particular, 1) the identification of the programming components and interfaces to ensure interoperability, 2) the possible roles of standardization bodies and their impact 3) the definition of a standardization approach to enable the deployment of the proposed technologies.

[1] D.Meyer, Research Directions in SDN, SDNRG Meeting, Atlanta (GA), USA, Nov.2012





# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

#### Introduction

SDN research directions as outlined in IRTF RG outlines

- i) need for more flexibility and programmability at data plane level
- $\Rightarrow$  What does it mean from CS perspective ? and implications ? and
- ii) need for higher-level languages for programming together with testing and debugging
- $\Rightarrow$  Program testing fails to prove program correctness

Consequently, 3 main challenges

- Programming language and Abstraction (programmable abstractions)
- Concurrency
- Automated verification

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### **Objectives**

- · Need for programmability ?
  - Operate network function/states (instead of protocol/engine configuration)
  - Control network execution (instead of control protocol procedures/states)
  - Function and execution (decisions) at domain/network instead of node-level

Note: SDN = new term given to programmable networks

#### A survey of programmable networks

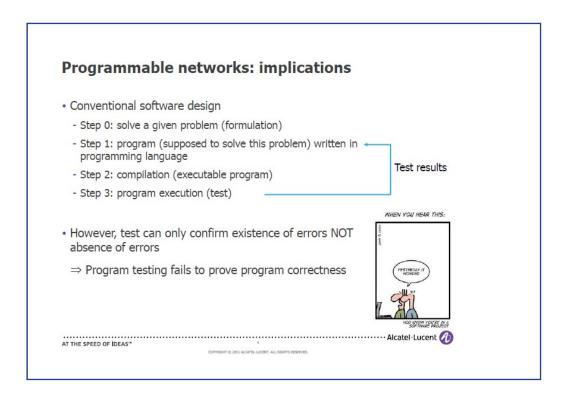
A.T.Campbell et al., ACM SIGCOMM Computer Communication Review, Volume 29 Issue 2, April 1999

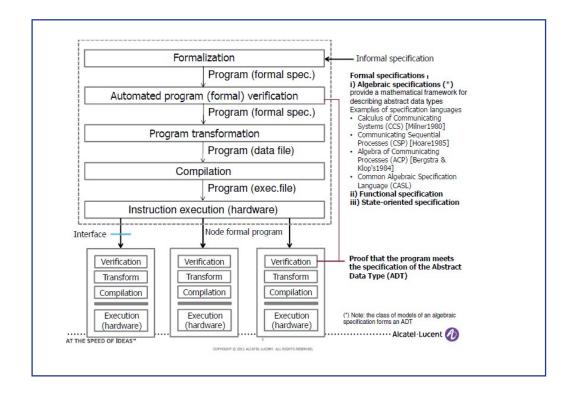
- · Multiple tradeoffs
  - Flexibility vs Performance
  - Horizontal vs Vertical integration
  - Complexity (node) vs Cost (operation)

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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS







# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

### Critical question: which formal language?

- · Formal specification language
  - Algebraic or axiomatic specifications (see previous slide)
  - Functional specification (operations are modelled as functions on data) match functional programming languages (LISP, Scheme, Haskell, etc.).
- ↔ Other (more) applied specification languages (VDM, Z): imperative or state-oriented specification
  - Execution of an operation may change the state of an algebra
  - Requires algebras with state: evolving algebras or abstract state machines
- <u>Tradeoff</u>: state oriented specification languages are more complex but "closer" to the (real) system

Moreover, doesn't necessarily need to be "unique": formal specification language to choose depends also on network functions and objects it manipulates

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### **Imperative vs Functional Programming**

- Functional programming: form of declarative programming involves composing the problem as a set of functions to be executed by defining carefully the input to each function, and what each function returns
- Imperative (procedural) programming: code describes in exacting detail the steps that the computer must take to accomplish the goal (sometimes referred to as algorithmic programming)

Characteristic	Imperative	Functional  What information is desired and what transformations are required	
Programming task	How to design algorithms and how to track changes in state.		
State changes	Important	Non-existent	
Order of execution	Important	Low importance	
Primary flow control	Loops, conditionals, and function (method) calls	Function calls, including recursion	
Primary manipulation unit	Instances of structures or classes	Functions as first-class objects and data collections	

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#### **Problem**

- These challenges are identical to the most critical issues in computer science (... moving 30 years old problems to 80 year old problems cf.
   Turing-Church thesis -- Every effectively calculable function is a computable function)
- · Functional vs declarative language

Main selection criteria: data types (strength, safety, expressive, composition, checking), I/O, performance and verification

Despite advantage of FP, declarative language still preferred because of Von Neumann computer model

VonNeumann bottleneck: logical operations are performed one after another; thus, the instructions are executed sequentially which is a slow process (serial logic operation)

- $\to$  Speed of program execution limited by (inherently sequential) rate at which data/instructions move between memory and CPU
- ⇒ Use of concurrency ?

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#### **Programmable abstractions**

- ADT (definition): set of data structures/objects defined by the set of operations that may be performed on it (without defining how), and the mathematical properties of those operations
  - ADT  $\equiv$  algebra in which the data sets and the operations can be programmed
  - Example Graph G=(V,E) -as mathematical object
  - Graph formal entity (graph) with set of operations (add, remove, etc.)
  - Data structure (underneath): table, list, array
  - <-> what is the relationship with nodes and networks ?
- Principles
- Modularization to decompose into independent programming tasks
- Information hiding to protect the data structure from outside interference or manipulation
- Encapsulation of data structures and their routines to manipulate structures into one unit
- Key point: formalize the relationship(s) between aggregated representation of node/network data and ADT

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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

# Programmable abstractions Abstraction: data => abstract data type

(control) action => control flow

Define ADT (for network level) and relationships
 Topology: G=(V,E) –most common ADT (but other exists)

 $V=\{node\} - E=\{link\}$ 

+ link attributes (e.g. spatial (e.g. unused capacity), administrative (e.g. weight or cost), associated destinations, etc.)

+ node attributes (commonly referred to as resources)

- Buffering capacity
- Switching fabric capacity
- Transmission capacity

#### Sequence of packets: there are multiple choices

- Spatio-temporal statistical distribution(s)
- Matrix representing <s,d> pairs + attributes
- Mixes + attributes (rate, size, burstiness)

- Etc.

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ADT at "node level"

Link-level/interface: TX/RX, encoding, etc.

Node-level: line cards, fabric, etc.

#### **Automated verification**

- Objective
  - Demonstrates correctness of software design in conformance with its specification
  - Does not demonstrate correctness of specification itself (doesn't validate correctness of the specification)
- · Distinction between
  - Formal verification
  - Formal equivalence verification (equivalence checking): compares two models to check their equivalence
  - Formal properties verification (model checking)
  - Functional verification: black box
  - Structural verification: white box

Not covered



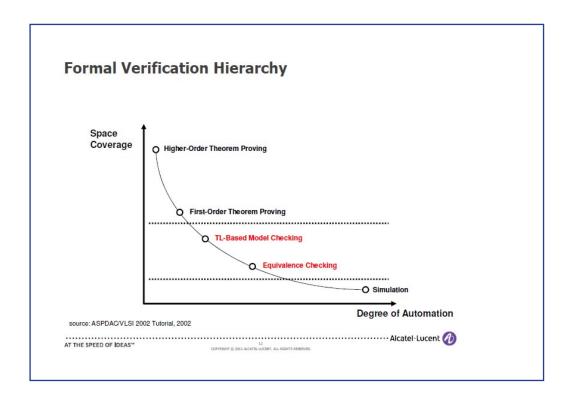
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### **Formal Property Verification**

- Basic steps
  - Property specification: using a language for formally specifying functional requirements and behaviors of a function (taking into account performance constraints)
  - Analysis: using a procedure for establishing  $\,$  that requirements (properties) hold
- Model checking (MC): method to automatically decide whether a temporal logic (TL) formula is satisfied in a FSM model
  - Automatic method for verifying finite state concurrent systems
  - Formal method for proving functional properties (specifications) on the behavior of program design
  - Prove a property by showing it holds for all possible input combinations, across all execution paths
  - Methods
  - Explicit Model Checking [Clarke & Emerson, 1981]
  - Symbolic Model Checking [McMillan, 1992]
  - LTL Model Checking [Vardi & Wolper, 1986]

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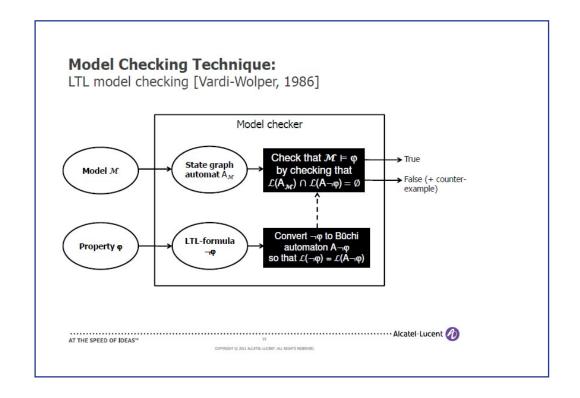


## **SESSION 2 FUTURE NETWORKS GENERAL ASPECTS**

### **Model Checking**

- Input
  - Model and Initial State: convert a design into a formalism accepted by a model checking tool; design often modeled as automaton
    - States and State transitions
  - Often represented as state graph
  - Specification: state the properties that the design must satisfy; (often) expressed in temporal logic (which can assert how the behavior of the system evolves over time)
    - -> Propositional logic with temporal aspect
    - Describes ordering of events without explicitly using the concept of time
    - - Linear Temporal Logic (LTL): add temporal operators to predicate logic (addition of predicates and quantifiers to basic Boolean logic)
      - Computational Tree Logic (CTL): formulas are constructed from path quantifiers and temporal operators
- Verification (automatic)
- Visit each state and evaluate specification
- Output
  - Terminates with a positive answer when the property holds for the original state graph
- Otherwise, it produces a counterexample AT THE SPEED OF IDEAS\*

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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

### Standards perspective

- Proposed method ("IT-centric"): more effort at design time to save at run time (to ensure provable operational gain)
  - Centered on formal specification language and ADT
  - IRTF/IETF already following different track
- · Is ETSI the right place to consider
  - "Distributed multi-level programming" architecture ?
  - Specification of formal specification language (if specialized) ?
  - Based on selection criteria and applicability (understanding of requirements and needs)
  - and even reconsider implications of computer architecture model (VonNeumann bottleneck) ?

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We can only see a short distance ahead, but we can see plenty there that needs to be done.



I.—COMPUTING MACHINERY AND INTELLIGENCE

By A. M. TURING

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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS



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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

#### Future Networks: a Service Provider View

#### **Abstract:**

Projections in number of users of future networks are counting for billions of humans, devices and applications. This will require enhancing the flexibility and manageability of our networks while reducing the overall costs of ownership.

ETSI NFV, ONF SDN/OF e ITU-T Future Networks are aiming to address the growing complexity of the network of the future with complementary and sometime overlapping approaches. Together they aim at greater cost savings and much faster service innovation and deployment. Cloud Computing and IT technologies are pervasive elements in the new approaches to future networks, both as enablers and as part of the problems to be addressed.

#### Telecom Italia Presentation will focus on:

- the Telecom Italia understanding of the foreseen network evolution within the standard organizations;
- Identification from a Service Provider standpoint of the needed changes, issues and how new service segments (M2M / IoT) can be addressed;
- Recognizing that Cloud Computing is a strong push towards such evolution and that current Service Providers
  are growing in this area;
- What are the challenges in terms of operation and management of the future networks;
- How can the future networks technologies be deployed in different segments of a Service Provider network;
- How standard bodies can answer to the growing needs of SPs and their Customers related to Future networks.







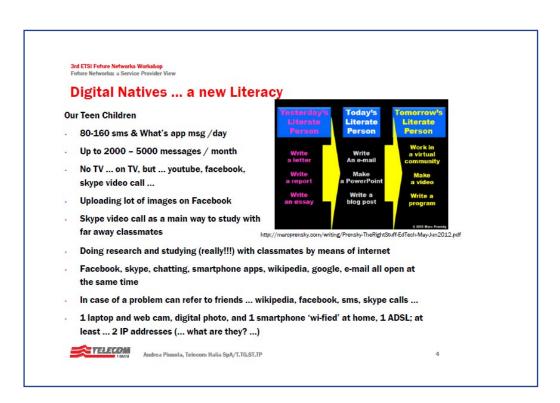
# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS







# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS



# eDemocrazy - technology and elections **OBAMA TECH TEAM** 4Gb/s, 10k requests per second, 2,000 nodes, 3 datacenters, 180TB and 8.5 billion requests. Design, deploy, dismantle in 583 days to elect the President. #madops http://arstechnica.com/information-technology/2012/11/built-to-**5 STAR MOVEMENT (ITALIAN ELECTION)** Beppegrillo.it within the 50 most accessed web site in Italy No TV appearence, but a dedicated TV channel on internet Online video during the 'Tsunami Tour' politics meetings At the final meeting 150.000 people online Online subscription and funding, public funding refused Supporters coordinating by means of internet Resulted in being the first Italian party in the Chamber of Deputies and the second in the Senate Andrea Pinnola, Telecom Italia SpA/T.TG.ST.TP



## **SESSION 2 FUTURE NETWORKS GENERAL ASPECTS**



### **Main Aspects**

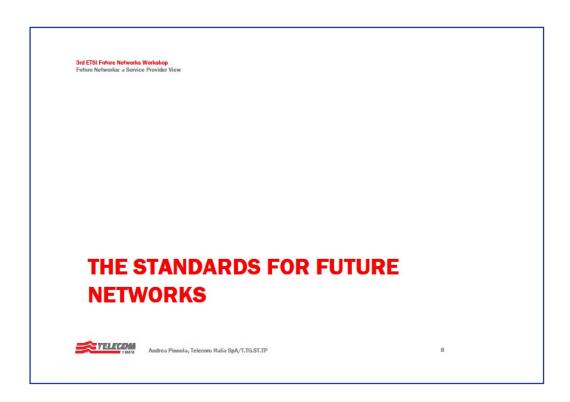
- Huge Growth of connected devices and communication needs
- Different Uses, Users (Human and Not Human ) and Traffic Loads
- · Network expected to be available and capable every time
- Growing complexity (number of nodes, interfaces, protocols, configurations, connections, hw, sw ...)
- Different Vendors and capabilities
- ... Strong Role for Innovative Standards

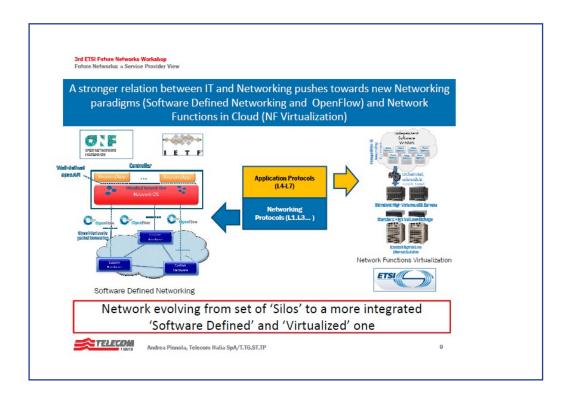


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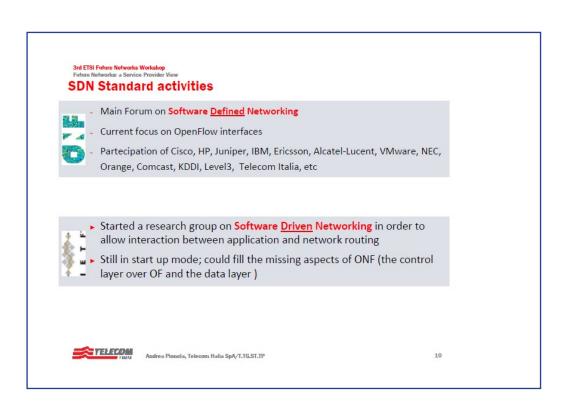
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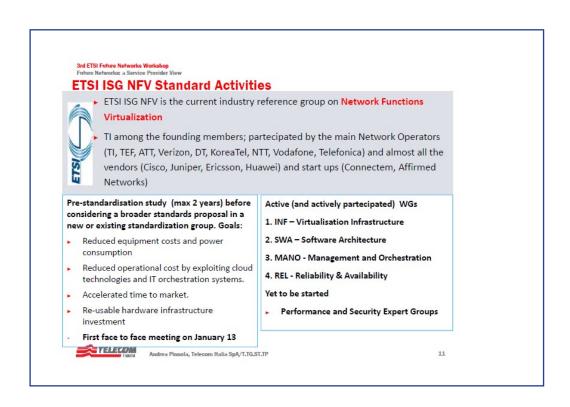






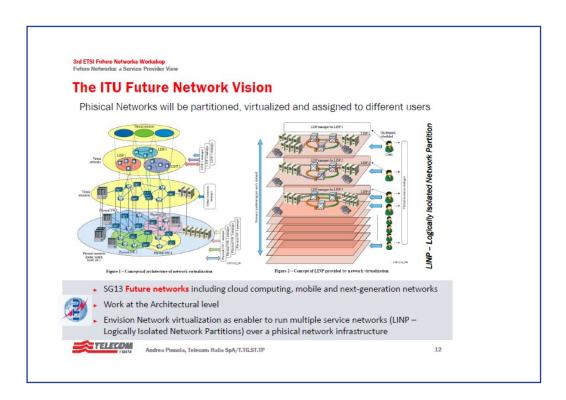
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### **SESSION 2 FUTURE NETWORKS GENERAL ASPECTS**



3rd ETSI Future Networks Workshop Future Networks: a Service Provider View

#### The network ain't what it used to be

- Based on a common infrastructure, 'Virtual' Networks will be mounted and dismounted for different uses and users in a flexible way
- · We expect Virtual Networks growth and reduction based on different needs and loads

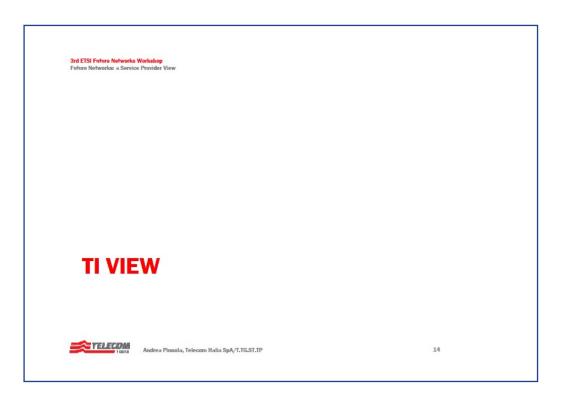
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## **SESSION 2 FUTURE NETWORKS GENERAL ASPECTS**



3rd ETSI Future Networks Workshop Future Networks: a Service Provider View

#### **TI Standard Activities**

#### **ISG NFV**

- ► Actively partecipating to the ISG NFV: editor of use case document of the Network Operator Council
- ► Interest in Mobile Core Virtualization

#### SDN

- ▶ Monitoring the evolution of SDN activity in ONF and the other involved Standard Bodies (IETF, ITU)
- ▶ Improve understanding of what a software defined evolution means for the network

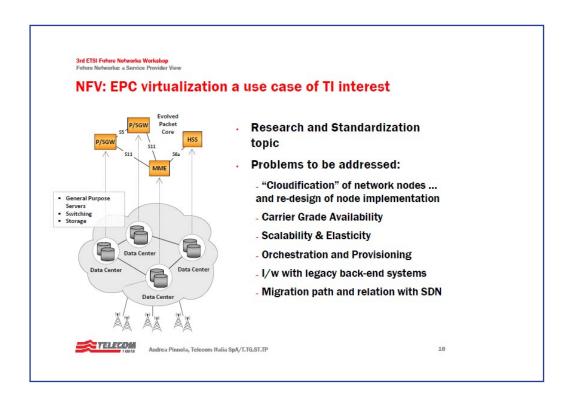


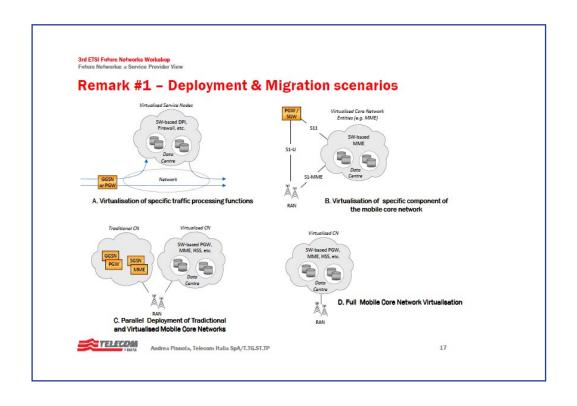
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# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS









### **SESSION 2 FUTURE NETWORKS GENERAL ASPECTS**

3rd ETSI Future Networks Workshop Future Networks: a Service Provider View

#### Remark #2: Management

- Need for standardization of common management interfaces with open standards within a service oriented architecture (SOA)
- · Reduce the effort to interoperate with current OSS / BSS systems (note: there will be always legacy systems ahead)
  - Network Discovery, Inventory, Fault and Configuration Management
  - Customer DB on CRM
- · Easy Programmability of new networks, common language to configure and manage new networks
- · Deployment testing and verification, management interface verification



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3rd ETSI Future Networks Workshop Future Networks: a Service Provider View **CONCLUSIONS** Andrea Pinnola, Telecom Italia SpA/T.TG.ST.TP 19





# SESSION 2 FUTURE NETWORKS GENERAL ASPECTS

3rd ETSI Future Networks Workshop

#### Summary

- IP-based Networks are already <u>radically</u> changing the world, and will continue
- · Need a strong and innovative role of the Standards
- Deployment and Management are major concerns
- Manage synergies among SDOs towards a common objective avoiding overlapping



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SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

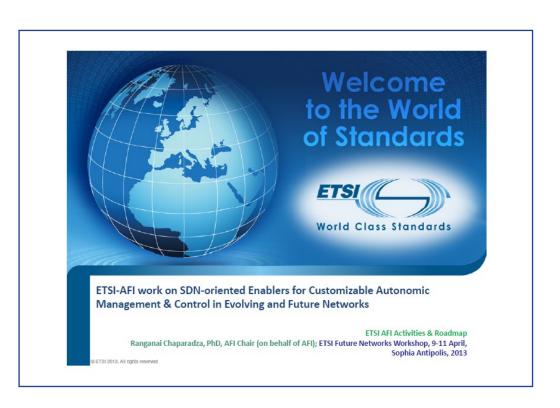
ETSI-AFI work on SDN-oriented Enablers for Customizable Autonomic Management & Control, defined in the AFI GANA Reference Model

#### **Abstract**

Software-Driven Networking (SDN) is a superset of what is known today as Software-Defined Networking. OpenFlowbased Software-Defined Networking is only a subset of the broader picture of SDN. On the other hand, Autonomic Management & Control and SDN share the same objective of enabling programmable, manageable, dynamically self-adaptable and cost-effective networks and services. Programmability must be supported at various layers and abstractions of the network. The soon-to-be-published ETSI AFI GANA Reference Model for Autonomic Networking, Cognitive Networking and Self-Management, defines SDN-oriented Enablers for Customizable Autonomic Management & Control, via the customizability of Autonomics' Decision-Making-Logics/Engines and customized algorithms. The defined SDN-oriented enablers include: primitives for programmability of managed entities; operator-loadable control-logic/strategy; Decision-Making-Elements (DEs) as second party logic that can be loaded into network elements or manufactured and embedded by manufacturers as interpreters and executers of loadable run-time executable behavioral models (specifiable as FSMs or Start-Charts, etc) that can be uploaded into network elements at runtime to control element and resource behaviours; profile-based and policy-based control. The enablers also include viable approaches to integrating AFI GANA Knowledge Plane Functional Blocks with OpenFlow-based SDN and other emerging SDN-oriented frameworks. OpenFlow-based SDN is based on the 4D architecture. Principles from 4D and other models such as MAPE, Knowledge Plane for the Internet, FOCALE, CONMan, GENI and ANA, are unified within the AFI GANA Reference Model as a more holistic Autonomics Reference Model. The GANA Model extends 4D in order to still allow for intelligence in network elements, rather than removing intelligence from network elements, meaning that GANA is a Hybrid Model that enables to combine centralized management & control and distributed control. In contrast to 4D and OpenFlow Controllers, a Modular Approach is taken to defining the elements of the AFI GANA Knowledge Plane (KP). The presentation also includes the additional value the AFI GANA Model brings to SDN, such as modularization of the control-software (DEs of the KP) and Reference Points Definitions; Functional Blocks (FBs) that add value to SDN—which include FBs for publish/subscribe services for information and resource auto-discovery, and Model-Based Translation Services for easing programmability and design of control software. Though the SDNoriented enablers are being standardized by AFI, their application/instantiation in specific reference architectures onto which the AFI GANA Reference Model is being instantiated still call for further standardization work involving detailed behavior specifications of the associated FBs and communication-flow on Reference Points. It is because all these get more elaborated with implementation-oriented details during the analysis of specific use-cases and requirements for autonomic management & control in the target architecture (scope of AFI WI#3). The primitives for programmability support also need to be further defined and elaborated in the ongoing standardization work in ETSI. Also, ETSI AFI plans to create a Work Item specifically addressing Autonomicity-awareness in SDN (as sub-Work Item of AFI WI#3)



# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)



# Outlook Brief Presentation of ETSI AFI Group Activities, Liaisons and Roadmap ETSI AFI GANA Reference Model for Autonomic Networking, Cognitive Networking and Self-Management Autonomic Manage ent & Control = Autonomics in the Management Plane + Autonomics in the Control Plane b. Enablers for SDN and Programmability, and Virtualization support in the AFI GANA Reference Model c. AFI is compiling an open white paper on SDN "Software-Driven Networking": Identifying Standardization Gaps in Software-Driven Networks (SDN), and ETSI-AFI work on SDN-oriented Enablers for Customizable Autor Management & Control The Value the AFI GANA Model brings to SDN in its broader picture: Modularization of Logically centralized Control Software (GANA Network Level DEs in the GANA Knowledge Plane) and Reference Points Definitions Primitives for Programmability at various layers S Run-time Executable Behavioral Models to complement Policy-Control with dynamic policies The role of the GANA MBTS in SDN The role of GANA ONIX in SDN Interworking GANA Knowledge Plane Decision Elements and OpenFlow-based Controllers



# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# AFI = Autonomic Network Engineering for the Self-Managing Future Internet [Autonomic Future Internet]

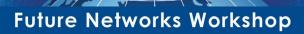
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  IDus Forum [member]
- IPv6 Forum [member]
- Chunghwa Telecommunication Co. [member]
- · Telcordia Technologies [member]
- WIT/TSSG [member]
- Greek Research & Technology Network (GRNET) [member]
- · University of Athens [member]
- University of Piraeus Research Center [member]
- Thales [member]
- AGH University of Science and Technology [member]
- ETRI [member]
- NCSR Demokritos [participates under participant agreement]
- Athlone Institute of Technology [participates under participant agreement]
- King's College London (KCL) [participates under participant agreement]

# Autonomics and Self-Management Technology

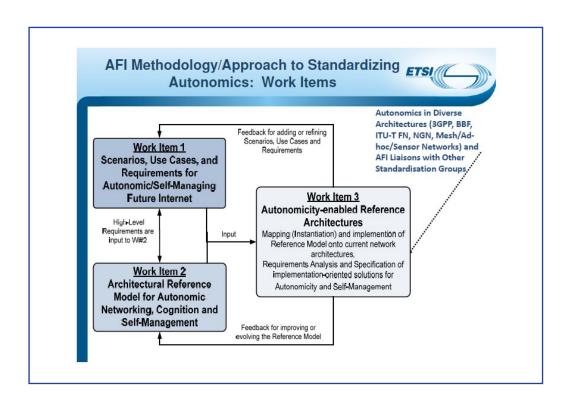


- □ Introduce Intelligence ("autonomic" and "cognitive" processes) into the node/device architectures as well as within the overall network architecture, to enable Self-Management and Control of Resources. Self-\* Features: Auto-Discovery of Information and resources, Self-Configuration, Self-Diagnosis, Self-Repair, Self-Healing, Self-Optimization, Self-Protection
- □ The architecture of a Network Element e.g. a Router, Switch, an element in the 3GPP/LTE/SAE environment, an End-System, etc, should be enhanced with special types of Functional Blocks and Interfaces for Autonomic Management and Control of resources.
- □ ETSI-AFI Standardizing: → A <u>Standardizable evolvable holistic</u> <u>Architectural Reference Model for Autonomic Network Engineering, Cognitive Networking and Self-Management: called GANA (Generic Autonomic Networking Architecture)</u>
  - → Can be "instantiated" onto diverse Architectures to create "*Autonomicity-enabled Architectures*" e.g. Autonomicity-enabled BBF arch, Autonomicity-enabled 3GPP, ...NGN, FN, etc......
- Some of the Management Problems requiring Autonomic/Self-Management (Self-\*) Solutions: Deployment and Provisioning; Faults/Failures, Congestions, Predictions and Forecasting, Performance





# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)



# AFI Liaisons with diverse Groups in SDOs and Fora

- @ AFI and Broadband Forum (BBF): Autonomicity and Self-Management in BBF Architecture
- AFI and 3GPP: Autonomicity and Self-Management Functions in the Backhaul and Core Networks to complement SON in the RAN and also their global synchronization with SON
- AFI and NGMN: NGCOR Requirements calling for Autonomics-Awareness in the Management Architecture
- AFI in Multi-SDO Initiative: AFI to specify Autonomics and Self-Management for various NGCOR Use Cases and the Converged Management of Fixed and Mobile Networks
- AFI and TMF (liaison soon to be established on evolution of Information & Data Models as impacted by Autonomics and Self-Management)
- AFI and ITU-T SG13: Autonomic Management and Control in FN Architecture and in NGN
- AFI and ITU-T SG2: Autonomic Management and Control in NGN and other Architectures
- AFI and CAC in the USA and also with NIST: contacts established with CAC and regular exchange of invitations and information)
- AFI and IEEE (envisaged, contacts have been established)
- AFI with some WGs in IETF (envisaged, contacts have been established)

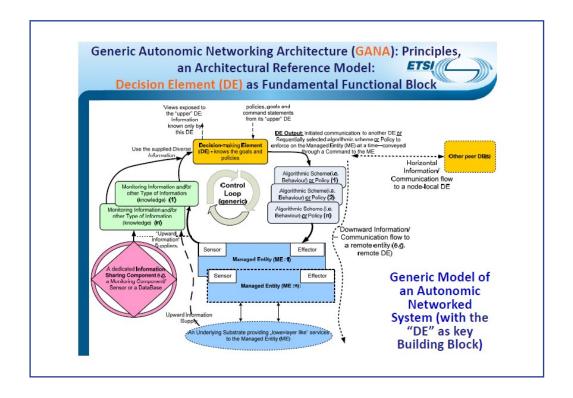
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# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

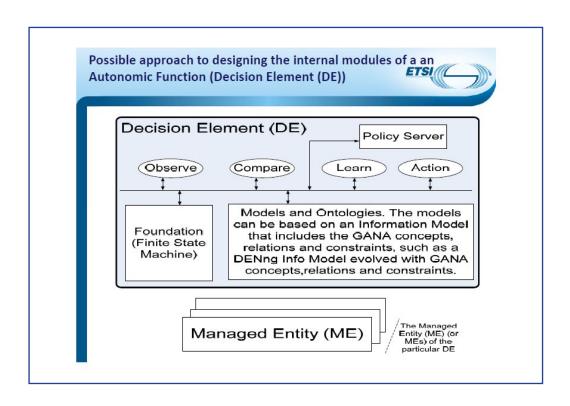
# Autonomic Management & Control complements SDN (in its broad picture), and Customizable Autonomics

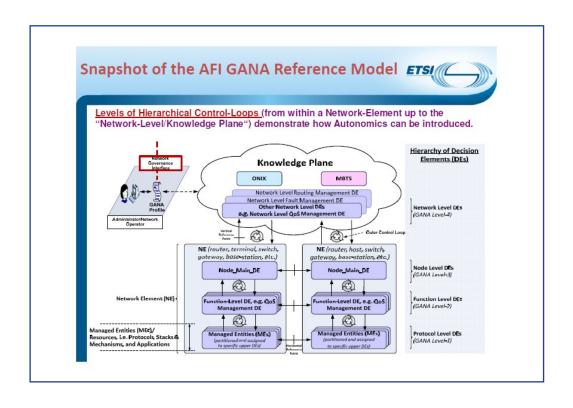
- Autonomic Management & Control and SDN share the same objective of enabling programmable, manageable, dynamically self-adaptable and cost-effective networks and services.
- Autonomic Management & Control = Autonomics in the Management Plane + Autonomics in the Control Plane (whether distributed or centralized)
- Autonomic Management & Control in networks is about Autonomics (i.e. control-loops) introduced in the Management Plane as well as Autonomics (i.e. control-loops) introduced in the Control Plane (whether the control-plane is distributed or centralized).
- Why Customizable Autonomics?
  - Algorithms per-se, for Decision Elements (DEs) that govern autonomic behaviour according to the AFI GANA Reference Model, can not be standardized
  - There are DE Algorithms that would provide for Vendor Differentiation
  - Some Algorithmic Schemes may be agreed by Vendors as required to be orchestrated by DEs in an E2E collaboration
  - Network Operators and other parties would need to provide for additional complementing autonomic control-logic (behavior or algorithms) to complement DE vendor's autonomic behavior, by uploading the logic during network operation





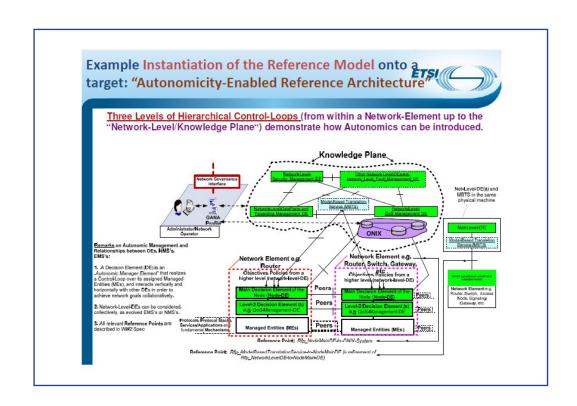
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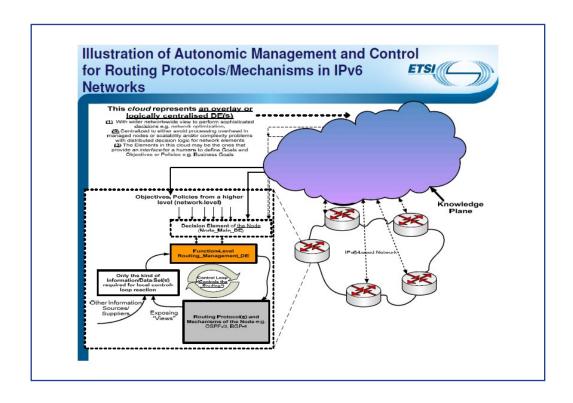






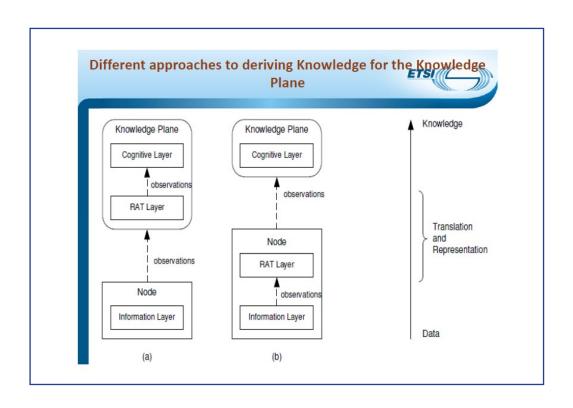
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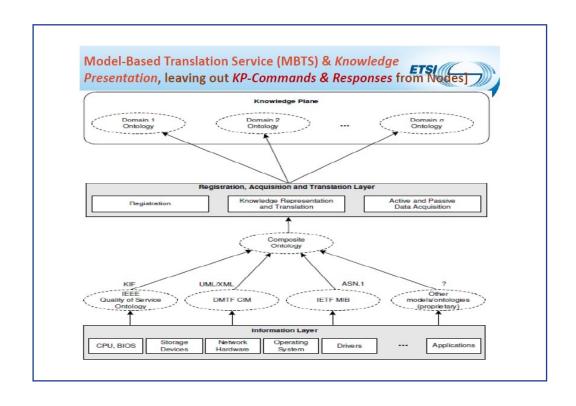






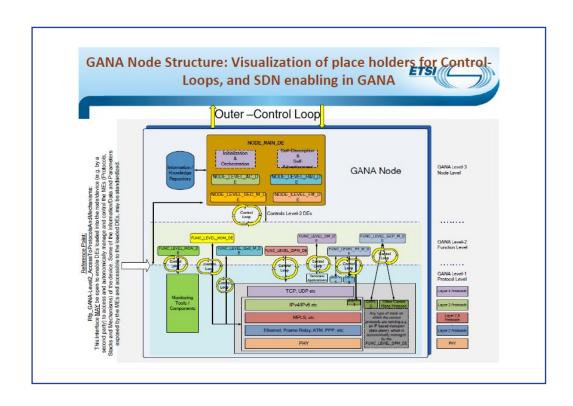
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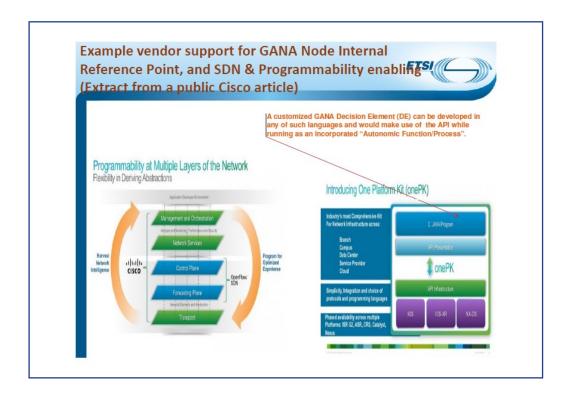






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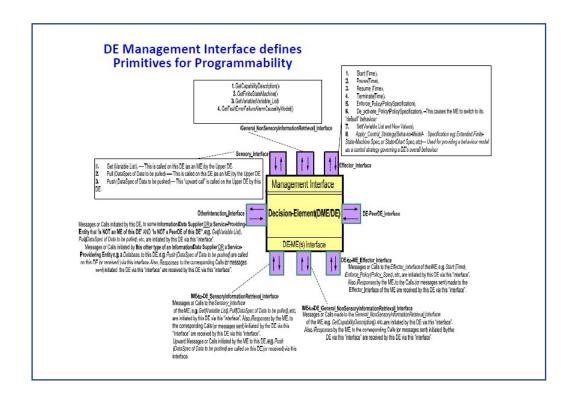
# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# Primitives for Programmability: SDN-oriented Enablers for Autonomic Management & Control



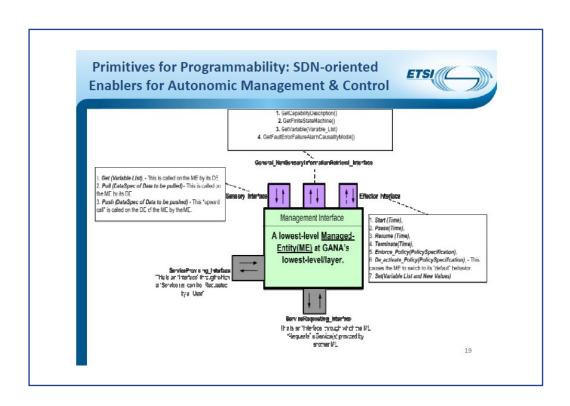
### SDN-oriented enablers for Customizable Autonomic Management and Control,

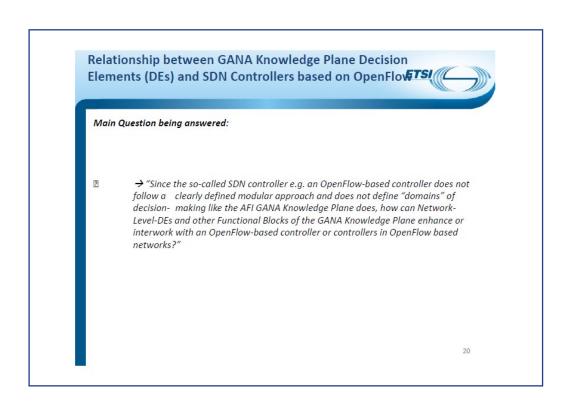
- 1. Primitives for programmability and Operator-loadable control-logic;
- Customizability of Decision-Elements as Network Operator loadable logic (into network elements) or Vendor DEs as interpreters of loadable run-time executable behavioral models (specified as Finite-State-Machines or Start-Charts, etc) uploaded into network elements at run-time;
- 3. Static Instantiation of Decision Elements (DEs) versus Dynamic Instantiation of DEs
- Languages and Methods for expressing High-Level Network Objectives/Goals and Utility
  Functions that govern autonomic functions (i.e. DEs) of the nodes and the network as a
  whole
- Profile and Policy-based control; and Dynamic Policy Control with Dynamically generated Policies;
- Also viable approaches to integrating GANA Knowledge Plane Functional Blocks with OpenFlow-based Controllers.





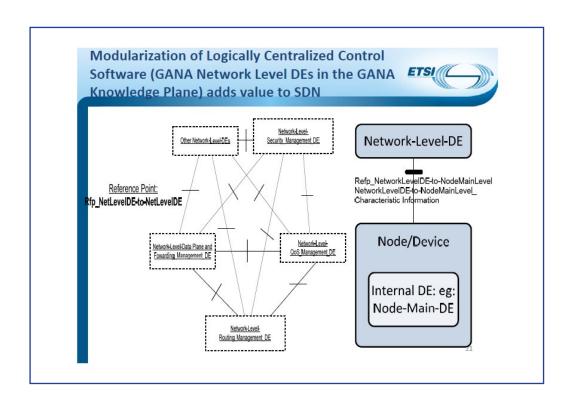
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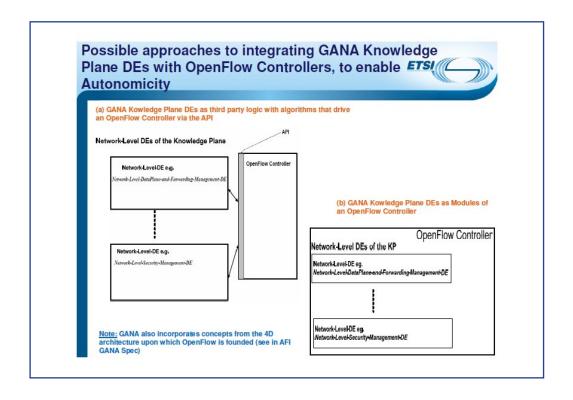






# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)







# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

### The role of the GANA MBTS in SDN



MBTS part of the GANA Knowledge Plane is Model-Based-Translation Service (MBTS) that forms an intermediation layer between the Knowledge Plane and the network elements. The concept of the MBTS is inherited and extended from FOCALE framework as described in the AFI GANA Specification, and is further elaborated with additional aspects as described in the specification.

The MBTS brings value to SDN as follows:

- Offers a set of libraries that perform translation and mediation services between the GANA
  Knowledge Plane and Network Elements (NEs).
- OpenFlow protocol can be added to the management and control protocols that the MBTS employs in its services, such as SNMP, NetConf, COPS, CMIP, TR069 from BBF, etc.
- GANA Knowledge Plane DEs and MBTS perform the broader management and control that complements OpenFlow-related control.
- MBTS can be used as the component that builds knowledge (for example using Ontologies).
- The MBTS may also store knowledge into the ONIX or retrieve knowledge from ONIX if ONIX is being used as a system for exchanging knowledge (apart from other types of information).

### The role of GANA ONIX in SDN



### ONIX (Overlay Network for Information eXchange):

a distributed scalable system of Information Servers dedicated to providing information publish/subscribe/query-and-find paradigm as a services that enable various entities to query and find information and/or to store information that can be shared, to effect advanced Auto-Discovery of information and resources in an autonomic network.

ONIX servers facilitate advanced Auto-Discovery of Elements plugged into the network, their Capabilities, Network Resources, Configuration-Data/Profiles/Policies, pointers to Information and Resources, etc. The ONIX can bring value to any network for which its services towards advanced auto-discovery and automation would be very useful, including in SDN networks.

The AFI GANA Reference Model specification provides Methods for Knowledge representation and presentation (Ontologies needed) to the domains of the Knowledge Plane identified by the Network-Level-DEs of the Knowledge Plane. The MBTS can also play a role together with ONIX, in Knowledge presentation to Network-Level-DEs.

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# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# How Research Projects can contribute to AFI Work



- Research projects can contribute by adopting and applying the AFI GANA Reference Model as well as the Autonomicity-Enabled Reference Architectures created as a result of Instantiation of the Reference Model, such as Autonomicity-Enabled BBF Arch; Autonomicity-Enabled NGN/IMS Arch; Autonomicity-Enabled 3GPP Arch; Autonomicity-Enabled Mesh Arch, in their ongoing work on Autonomic Management & Control, in order to provide useful feedback to AFI.
- Research results from various projects can be contributed in evolving the Frameworks being Standardized in ETSI AFI, by:
  - Mapping their own experimented and validated architectural components to the Functional Blocks (FBs) defined in the GANA Reference Model and elaborating the autonomic behaviours of the GANA FBs (as becoming commonly shared autonomics architectural components) maintained in AFI Specs.
  - Various autonomic behaviours from different types of Use Cases validated in research projects can be used in elaborating the behaviours of GANA FBs in target Autonomicity-Enabaled Reference Architectures.
- Research results can also be contributed to the outlined envisaged new Work Items in AFI
   Therefore, research results can be contributed to the Autonomics Standards, in elaborating behaviours of the GANA Functional Blocks instantiated in the various implementationoriented reference architecture(s).

# The role of Algorithm Providers in Standardized Autonomics



Algorithm providers from communities can contribute to the Specification of some behavioral aspects or features of respective GANA DEs instantiated in node and network architectures.

- DEs need to collaboratively, selectively and adaptively orchestrate various algorithmic schemes during network operation.
- Alternatively, the types of schemes/algorithms a DE (e.g. from a vendor) should be able to selectively orchestrate, possibly in collaboration with other peer DEs, could be agreed in standardization as "Requirement" on DE capabilities.
- These subjects are open and need discussion in AFI, because DE algorithms per-se can't be standardized, but they rather offer the possibility for both: customizability (i.e. various algorithms can be selectively and dynamically uploaded and bound to a DE), and vendor differentiation (vendors may realize own DE algorithms). Researchers can present in AFI various types of validated algorithms, and decisions will be made on whether to support them for orchestration by DEs.

Research results from various projects can be contributed in evolving the related Frameworks being Standardized in ETSI AFI.

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# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)



To Join the AFI Initiative and AFI Work Items:

Send e-mail to Ranganai Chaparadza, to get advice on how to join and which Work Items you may want to consider:

ran4chap@vahoo.con

Also please access the site(<a href="http://portal.etsi.org/afi">http://portal.etsi.org/afi</a>): for forms and sign the forms and send to the ETSI contact person (Estelle), or you may contact the ETSI contact first in order to be advised on signing the forms, etc.

Estelle.Mancini@etsi.org

Thank You ..!

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# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# On the relationships between SDN and Autonomic Management & Control

### Abstract:

Software-Defined Networking (SDN) is a quite recent approach under consideration for providing flexible and programmable networks. Autonomic networking is another approach, developed to simplify network operations by automating management functions through self-\* capabilities. We first present the SDN and the ETSI/AFI autonomic management related frameworks. Then, we identify complementarities between these frameworks; their differences and how they could interact with each other.

SDN-based networks can be managed without automation through existing management systems. However, Autonomic networking mechanisms could steer SDN-structured networks as well as conventional networks. Autonomics paradigm can apply to legacy infrastructures as well as to new ones (Physical resources & Virtual resources). Indeed, it can change the behavior of any type of managed entities enabling real time management, thereby blurring the difference between the control plane (CP) and the management plane.

In this context, Autonomics could enhance SDN framework by self-managing different applications used in the CP and orchestrating them. Various decision elements (DEs) already defined in autonomic architecture should be matched and interfaced with the applications and services defined in SDN, this leads to using, Knowledge Plane (KP) as defined in Autonomics world, as a hook to providing environment awareness to SDN. This enables cross-operators and multivendor view through this SDN becoming Autonomics —Aware.

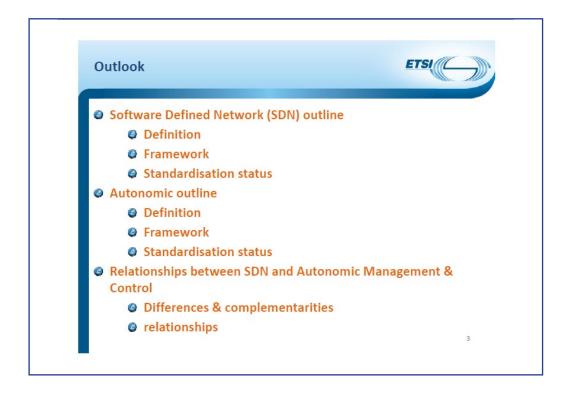
The combination of both paradigms will shape foundation of new topics to be addressed by standardization community from Interface, Data Model, Protocols, ...view point. This helps the industry taking profit from both technologies by supplying new product lines and ease their adoption by the operators as powerful infrastructure to providing market with added value advanced services.





# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

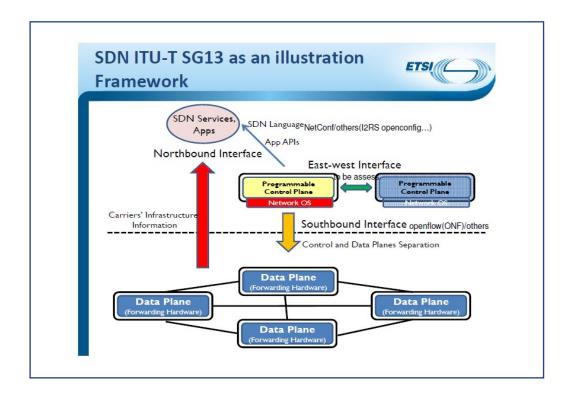






# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# Software-Defined Networking definition No consensus on SDN framework or definition SDN aims at providing flexible programmable control network ITU-T as an illustration defines Software Defined Networking (SDN) as a networking technology which allows centralized, programmable control planes, data plane abstraction and separation of control and data (a.k.a forwarding) planes so that network operators can control and manage directly their own (possible virtualized) resources.





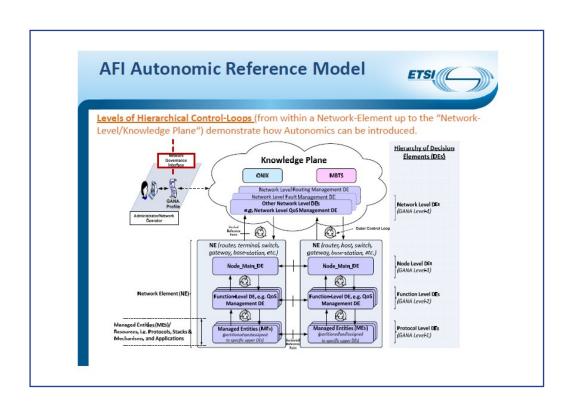
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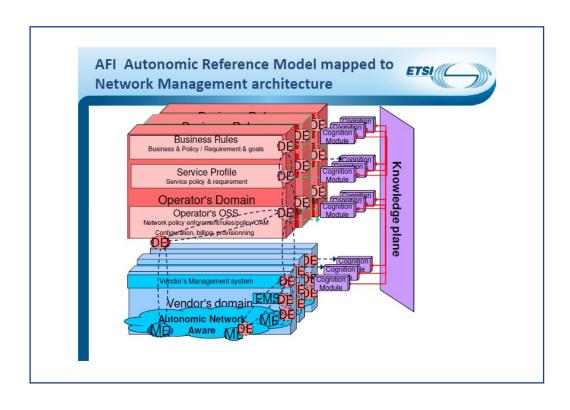
# SDN is considered in various standardisation organisation (ONF/ITU-T/IETF/IRTF/ETSI) ITU-T sg13 Q21 draft Recommendation Y.FNsdn, 2013 IETF Forces RFC 3746, 2004 IZRS july 2013 ONF White paper "Software-Defined Networking: The New Norm for Networks" 2012

# Autonomic network AFI Definition Standardization (ETSI/ISG/AFI) Autonomic aims at providing flexible management & control network Autonomics = Control Loops (interworking Hierarchical Fast Control-Loops in devices/nodes and Slow control-loops in outer Management & Knowledge Planes) Autonomic Management & Control = Autonomics in the Management Plane & Autonomics in the Control Plane (whether distributed or centralized) AFI defines autonomic networking as an Autonomic system with Cognitive capabilities; systems, which determine their behaviour, in a reactive or proactive manner, based on the external stimuli (environment aspects), as well as their goals, principles, capabilities, experience and knowledge. Process Monitor Longitive Capabilities, become and knowledge.



# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)







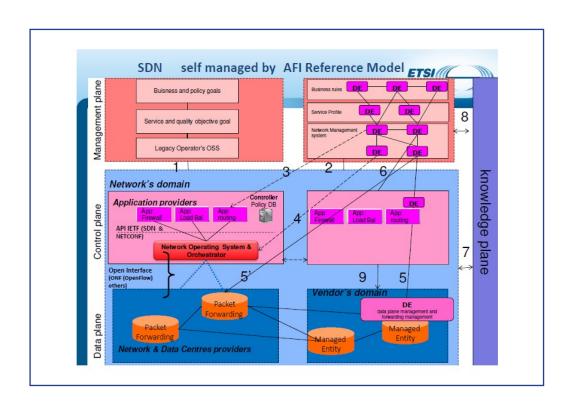
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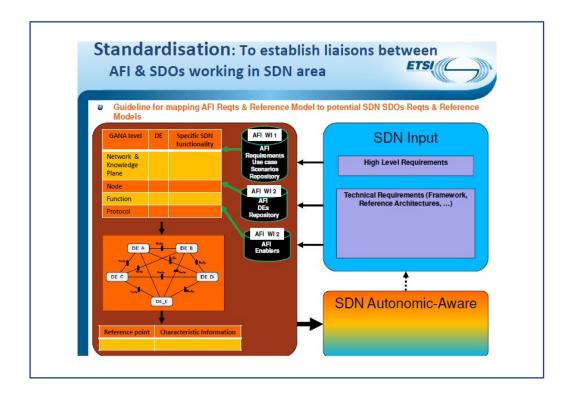
# AFI main Requirements / Enablers AFI designed an end to end management framework and its instantiation in different network architectures (Mesh/ad hoc/IMS/NGN/...) AFI main Enablers for graceful introduction of manageable Autonomics: Manage the behaviour of (legacy/future) infrastructure Trust autonomic in operational (legacy/future) management Modularity/Composability, Cooperation, Orchestration of (conflicting) decision elements (DEs) Knowledge Plane, context aware, cognitive mechanisms, system modelling, service models, service discovery Network Governance mechanisms / policy-based management continuum Virtualisation, Mobility management Programmability Bootstrapping mechanism, Self healing, fault detection, diagnosis, repair and recovery (Cross-layer) Monitoring Mechanisms

### **Differences & complementarities** SDN Autonomic Management & Control loop (ETSI/ISG/AFI) Programmable, manageable and cost-Programmable, manageable and costeffective network Distributed/Hybrid/Centralised Centralised (logically) Manage the behaviour of legacy / future Control the (virtualised) network infrastructure Orchestration/cooperation/coordination Orchestration/cooperation/coordination decision elements services Governance (end to end policy continuum Control policy continuum (business managed entities) Cross domain management Cross domain control Cognitive capabilities (knowledge plane) Programmable management Plane & Programmable control plane control loop



# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

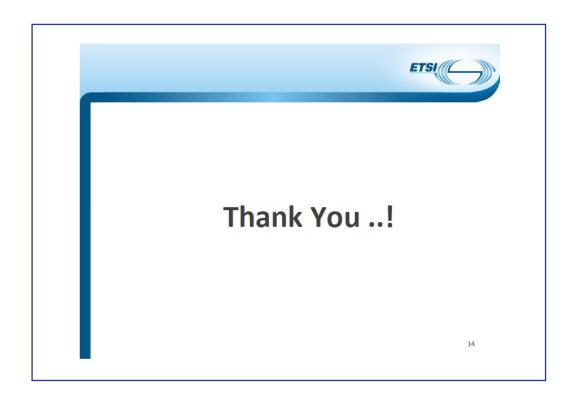








# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)







# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

Towards the launch of an ETSI AFI activity on Autonomic Management & Control in IPv6-Enabled SDN-based networks

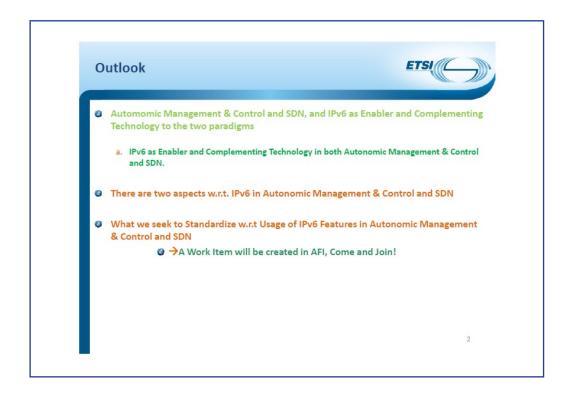
### **Abstract:**

IPv6 is a mature and proven technology and is now being deployed globally, with increasing momentum. New IPv6 protocols continue to be added to core IPv6 protocols, making IPv6 the basis for the far reaching Internet of the Future. In various areas, IPv6 is seen as bringing many unique benefits when combined with emerging technologies such as Autonomic Management & Control, Clouds, SDN, IoT/M2M, etc. Benefits include network automation, and scalability to clouds, thanks to IPv6 features. With the momentum on deployment of IPv6 rising, comes the question on what standardization requirements should be considered in environments in which IPv6 is brought into technologymixing with technologies such as SDN and Autonomic Management & Control. Autonomic Management & Control and SDN share the same objective of enabling programmable, manageable, dynamically self-adaptable and costeffective networks and services. Control software can automate and optimize management & control aspects that the network itself should not or cannot. Regarding IPv6, there are two aspects that need to be considered from SDN and Autonomic Management & Control point of view: (1): IPv6 features that enable the following: network automation, self-configuration and autonomic network setup and operation (thanks to the IPv6 features that enable auto-discovery of information, nodes and resources); dealing with scalability problems in 'node/device addressing' in clouds and other environments; energy-efficient networking (thanks to true-end-to-end principle in IPv6, and much more). Other important features include: neighbor-discovery and use of link-local addresses for auto-configuring the network and forming secured peerings; 2) use of RPL for basic communication, independent of the routing protocols used in the topology once things are autonomically setup, either through the help of a central computer or not. (2): The second aspect is the autonomic management & control aspects themselves in an IPv6-enabled SDN-based network. It means autonomic behaviours that rely on IPv6's enabling features for autonomic setup and operation of networks plus the behaviours of Decision-making-Elements(Engines) i.e. DEs in AFI GANA Reference Model terminology, that autonomically configure and manage IPv6 protocols and any other protocols in such an environment throughout the network operation phase. There is room for extensions to IPv6 that can be considered within the community tasked with studying Autonomic Management & Control in IPv6-enabled SDN-based Networks, which include the following: Extensions for control-information exchange in networks for use in collaborating control-loops (i.e. in DEto-DE communication); IPv6 protocols for supporting publish/subscribe paradigm to enable advanced auto-discovery of information and resources. This presentation will discuss the kind of Specifications that can be produced in ETSI AFI on Autonomicity Behaviors of the Functional Blocks from the ETSI AFI GANA Reference Model instantiated in various Reference Architectures such as BBF, 3GPP, Mesh, M2M, NGN/IMS architectures, with consideration of SDN operations in such networks and the AFI approach to integrating GANA Knowledge Plane DEs with OpenFlow Controllers while enabling Autonomicity and Self-Management in the broader picture than SDN. How to exploit the results from the ECfunded FP7 EFIPSANS project and future research projects will also be discussed. ETSI AFI, IPv6 Forum and ONF would benefit from understanding the benefits of technology mixing of SDN, IPv6 and Autonomic Management & Control.



# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)







# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

### IPv6 Today and as Future Internet Technology



- IPv6 is a mature and proven technology and is now being deployed globally, with increasing momentum.
- New IPv6 protocols continue to be added to core IPv6 protocols, making IPv6 the basis for the far reaching Internet of the Future.
- In various network setups and operations, IPv6 is seen as bringing many unique benefits when combined with emerging technologies such as Autonomic Management & Control, Clouds, SDN, IoT/M2M, etc
- Benefits include network automation, and scalability in addressing, route aggregation and forwarding and traffic steering functions, thanks to IPv6 features.

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# IPv6 as Enabler and Complementing technology in both Autonomic Management & Control and SDN

Regarding IPv6, there are two aspects that need to be considered from SDN and Autonomic Management & Control point of view:

(1): IPv6 features that enable the following:

- Network Automation,
- Self-configuration and autonomic network setup and operation (thanks to the IPv6 features that enable auto-discovery of information, nodes and resources);
- Scalability in 'node/device addressing';
- Energy-efficient networking (thanks to true-end-to-end principle in IPv6 and much more!).
- EC-funded FP7 EFIPSANS Research project came up with Extensions to IPv6 (aka IPv6++) necessitated by Autonomic Management and Control
- FP7 EFIPSANS proposed Extensions to IPv6 for Autonomics can now be exploited, and more Extensions are necessary, and contributions to IETF



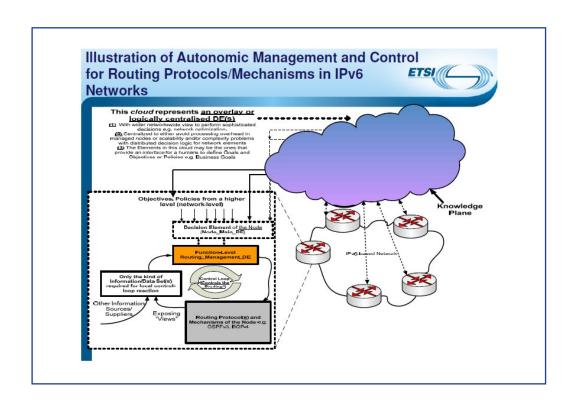
# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# IPv6 as Enabler and complementing technology in both Autonomic Management & Control and SDN

(2): The autonomic management & control aspects themselves in an IPv6-enabled SDN-based and/or simply IPv6-based autonomic network:

- Autonomic behaviours that rely on IPv6's enabling features for autonomic setup and operation of networks
- The behaviours of Autonomic Functions (i.e. Decision-making-Elements(Engines) in the AFI GANA Reference Model terminology) that autonomically configure and manage IPv6 protocols and any other protocols in such environments throughout the network operation phase.
- Research results on Autonomicity and enabling IPv6 features and necessary extensions to IPv6, can be exploited in this regard, with SDN being considered, as well as additional IPv6 features that can potentially be introduced as extensions.

5





# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# What we seek to Standardize in Autonomic Management & Control and SDN, and IPv6 usage



 Specific IPv6-Feature(s) Usage Requirements in Autonomicity-Enabled SDN facilitating reference architectures

i.e "Based on Mappings of AFI GANA to particular SDN facilitating Architecture"

- Specific IPv6-Feature(s) Usage Requirements in Autonomicity-Enabled 3GPP and Non-3GPP Mobile Network Reference Architectures. Plus SDN?? → Priority is Autonomics i.e "Based on AFI GANA Instantiation in particular Target Architecture"
- Specific IPv6-Feature(s) Usage Requirements in Autonomicity-Enabled Broadband Forum (BBF) Reference Architecture. Plus SDN?? → Priority is Autonomics
- Specific IPv6-Feature(s) Usage Requirements in Autonomicity-Enabled NGN/IMS
   Architecture. Plus SDN?? → Priority is Autonomics
- Specific IPv6-Feature(s) Usage Requirements in TISPAN CDN Reference Architecture .
   Plus SDN?? → Priority is Autonomics
- Specific IPv6-Feature(s) Usage Requirements in Autonomicity-Enabled Wireless Ad-Hoc/Mesh and Sensor Networks. Plus SDN?? → Priority is Autonomics



### A Work Item will be created in AFI, Come and Join!

To Join the AFI Initiative and AFI Work Items:

Send e-mail to Ranganai Chaparadza, to get advice on how to join and which Work Items you may want to consider:

ran4chap@yahoo.com

Also please access the site(<a href="http://portal.etsi.org/afi">http://portal.etsi.org/afi</a>): for forms and sign the forms and send to the ETSI contact person (Estelle), or you may contact the ETSI contact first in order to be advised on signing the forms, etc.

Estelle.Mancini@etsi.org

Thank You ..!



# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

### A new Model for highly Available Routing and Load Balancing In SDNs

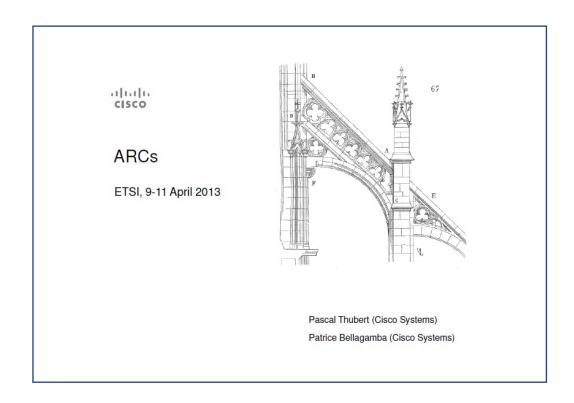
### **Abstract:**

IPv6 Software Driven Networking enables operations and new types of flows under the control of supervisory components evolved from Path Computing Engines.

New techniques must be applied to leverage the new capabilities of the model. One such technique, called ARCs, was recently introduced at the IETF and in the context of the IoT6 European project. ARCs propose a different approach to routing, fast rerouting and load balancing for unicast, bicast and multicast traffic. ARCs can apply to corporate and Service Provider networks, and operate as a routing overlay to an existing SPF-based fabric.

The talk with present the ARC concept, propose an algorithm to build an ARC topology along SPF premises, and compare ARCs with the Maximally Redundant Tree approach that is also discussed at the IETF in the context of fast rerouting.

The ideas presented will serve as input to the work of AFI and NFV Groups in ETSI, to see how ARCs and related algorithms can be employed by the the autonomic management & control logic. For example, the Decision Elements in the AFI GANA Knowledge Plane, responsible for the autonomic management of forwarding & data plane, could perform the orchestration and autonomic management for dynamic setup of ARCs. These aspects need to be discussed in AFI as well, while following and liaising with groups working on related subjects in IETF, typically the Routing Area WG at this point.





# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)

# **Centralized Routing Goals**

- Distributed was created for high availability (DARPA)
- Centralized can optimize routing from God's view Traffic Engineering Deterministic Routing
- Yet must provide additional reliability measures Multipath redundancy Duo/bicasting
- Room for both centralized and distributed Centralized for optimization and virtualization Distributed for autonomic and ultra available

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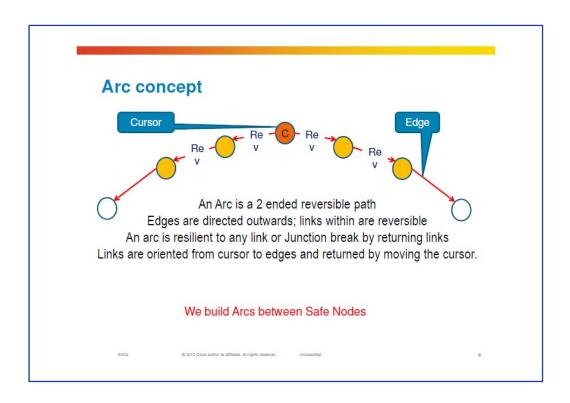
# Problem: routing availability

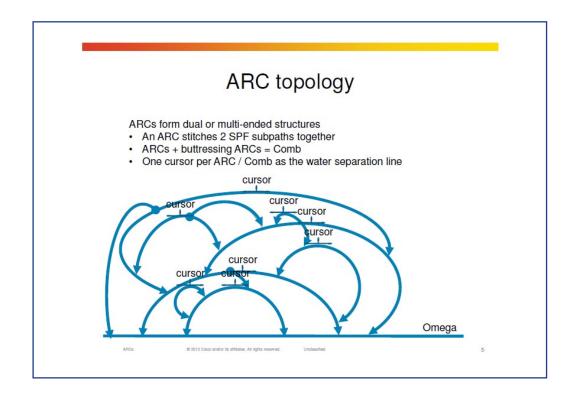
- Classical trees and Directed Acyclic Graph (DAG) topologies do not provide non-congruent alternate routes for all nodes
- State of the art Fast Reroute (FRR) tolerates 1 failure but may drop traffic or loop upon 2
- Yet accidental damage to a fiber harness hits multiple links (Shared Risk Link Group)
- Same goes for interferences in wireless

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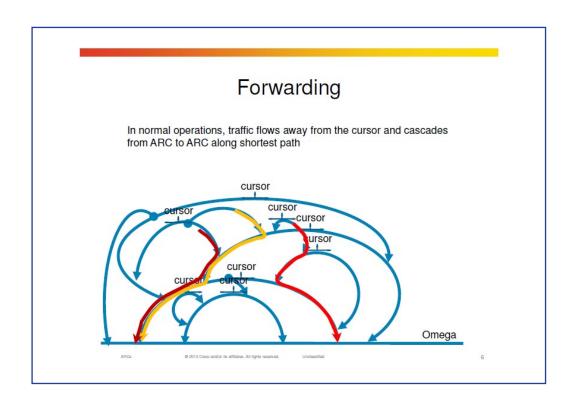
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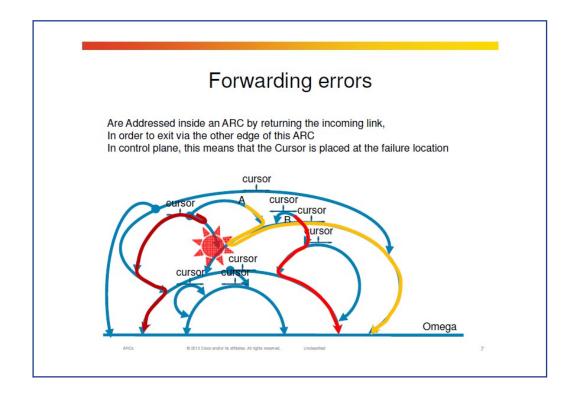






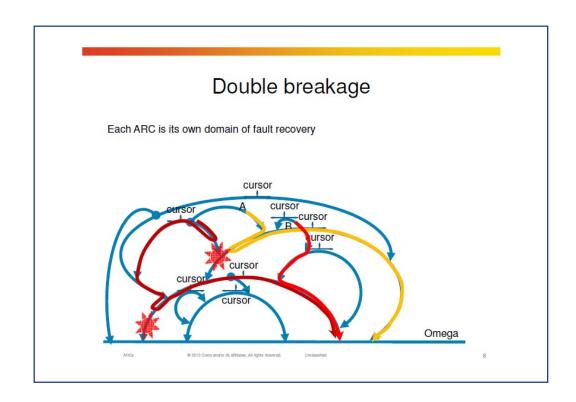
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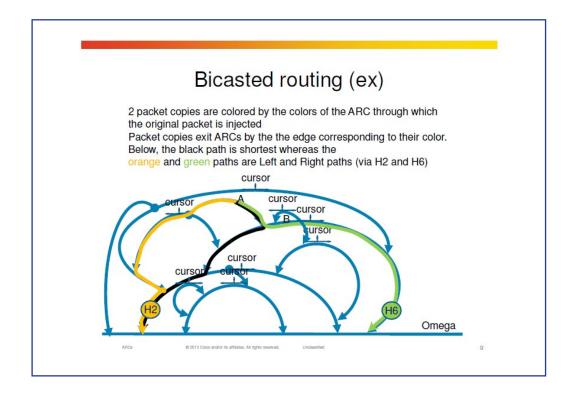






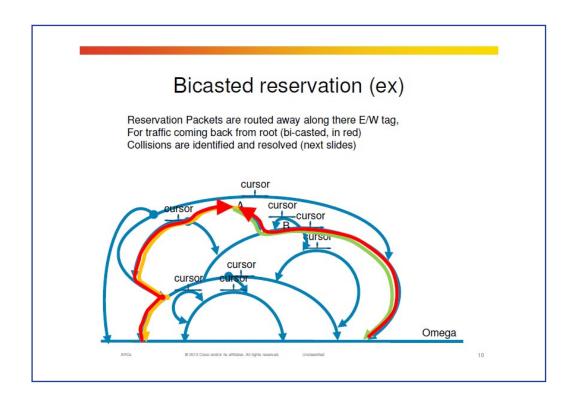
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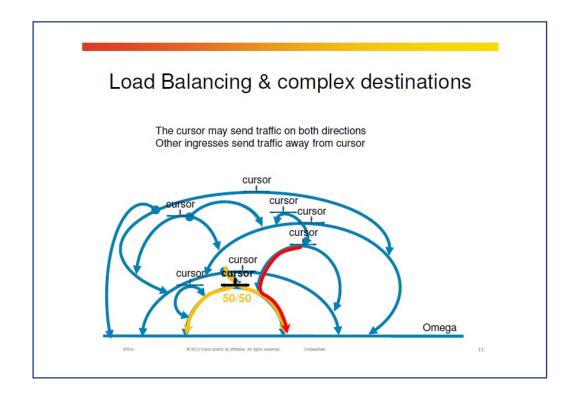






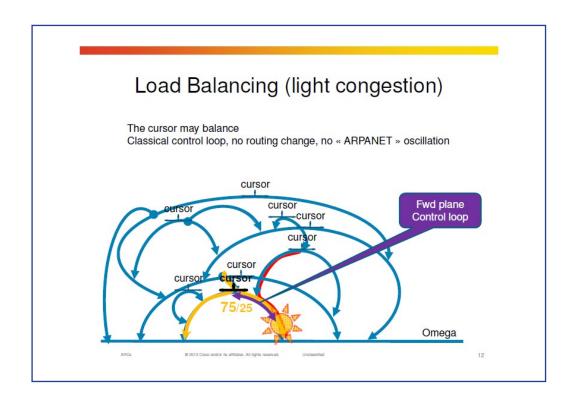
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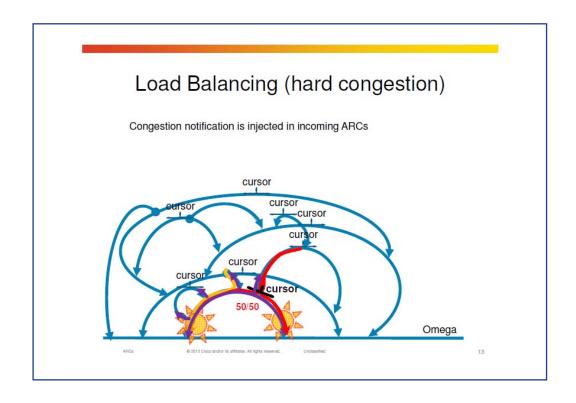






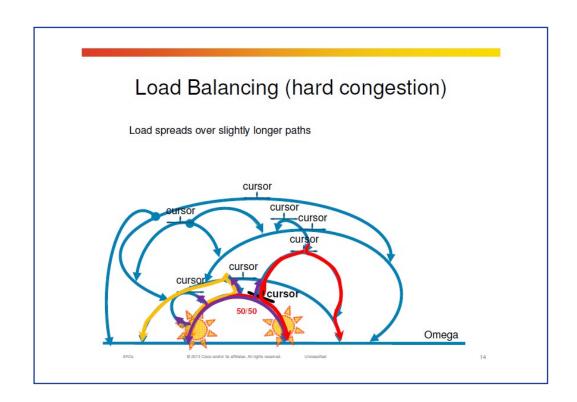
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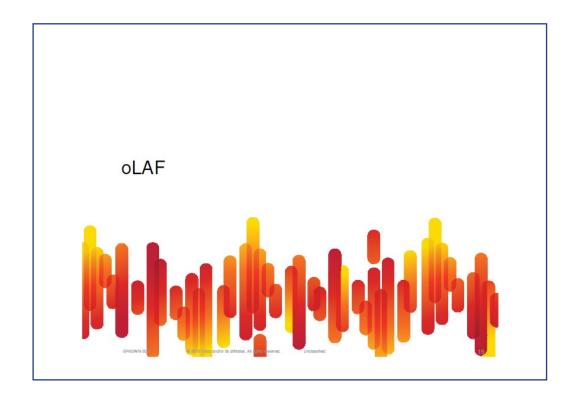






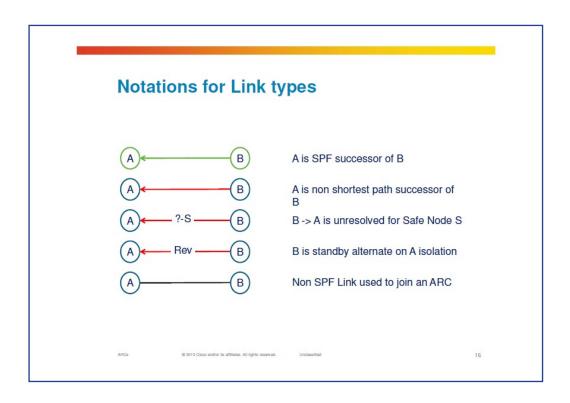
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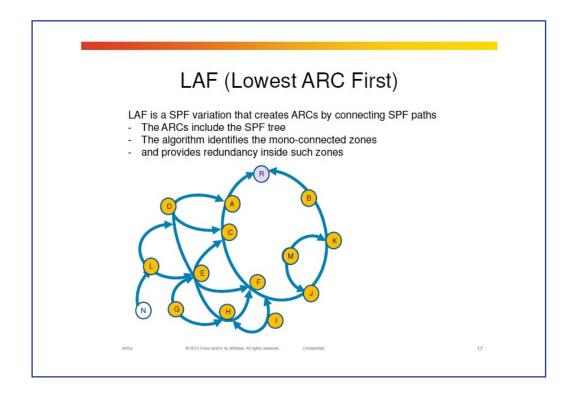






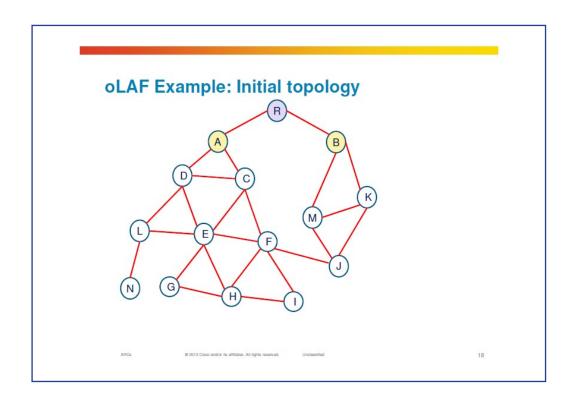
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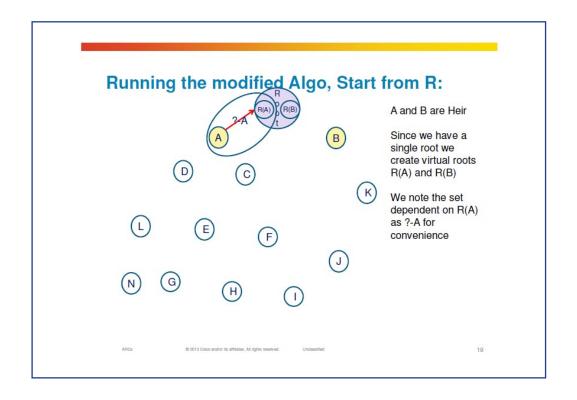






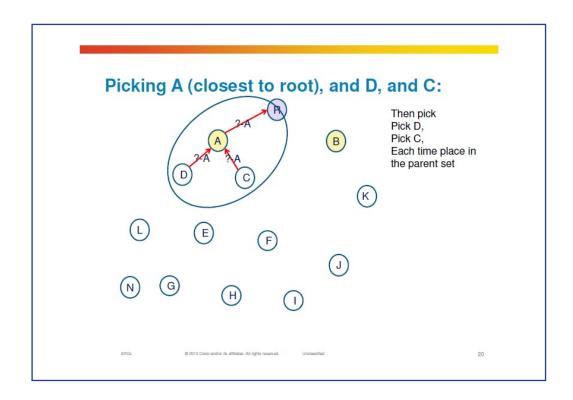
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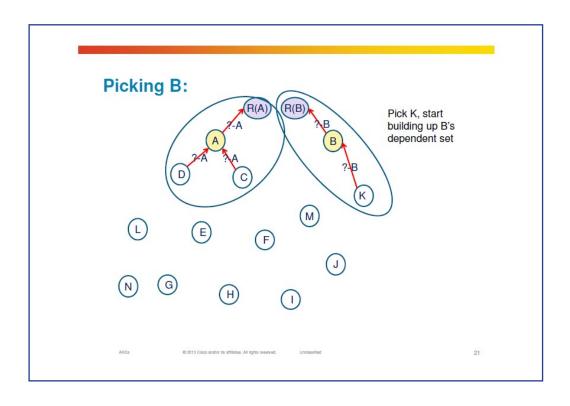






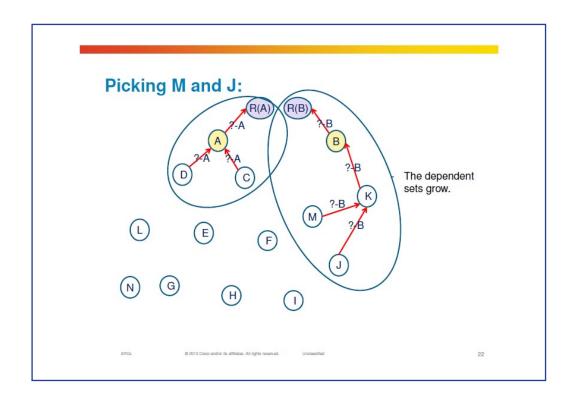
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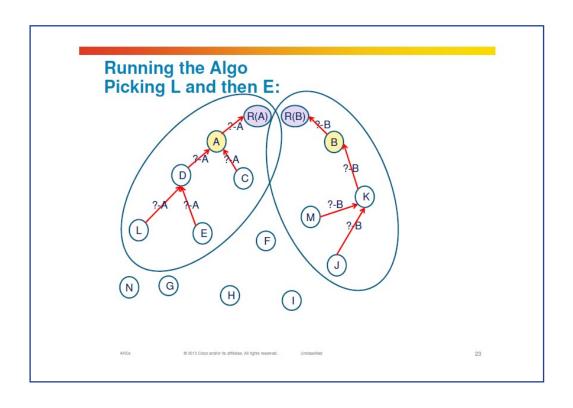






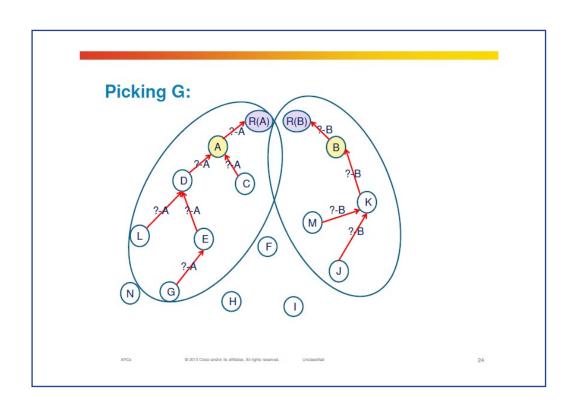
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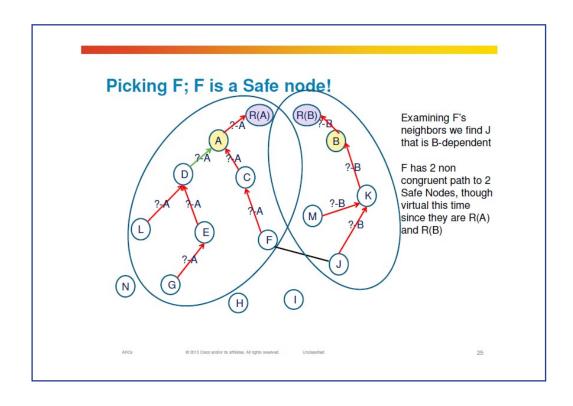






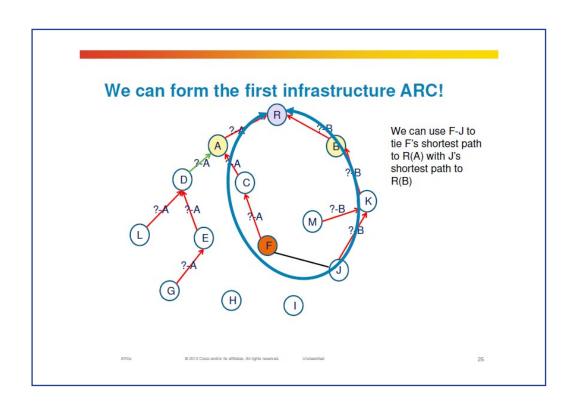
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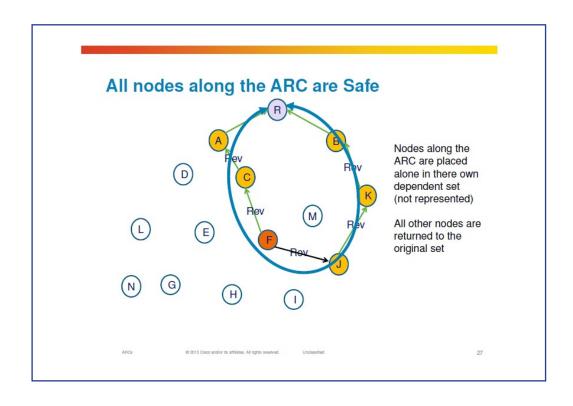






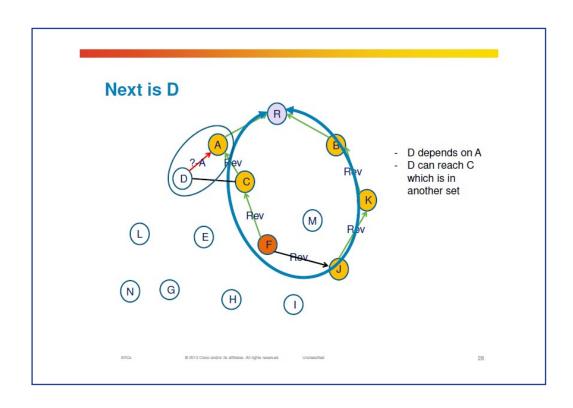
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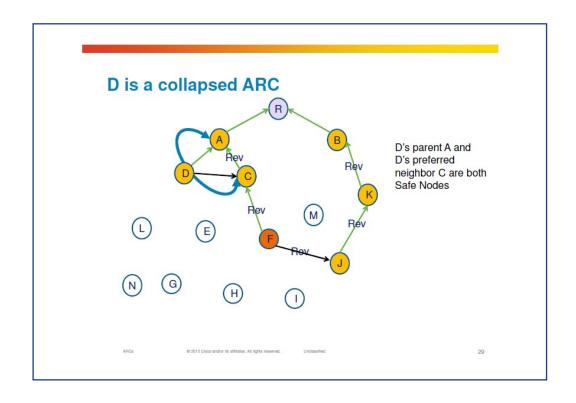






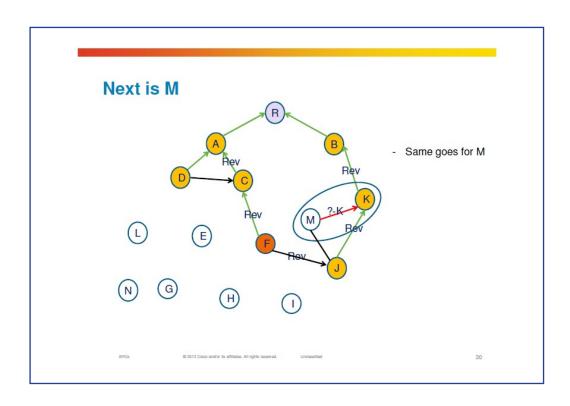
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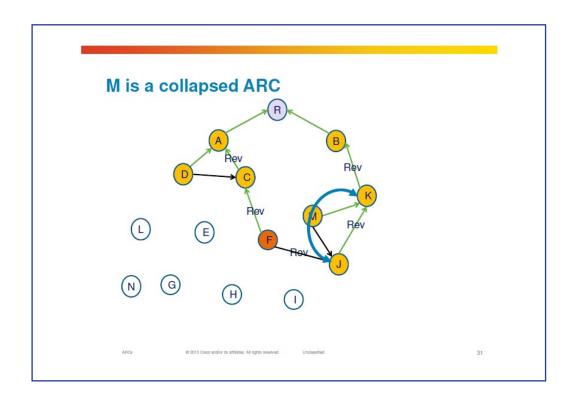






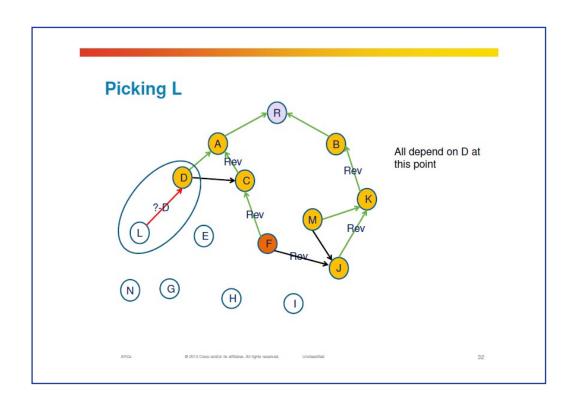
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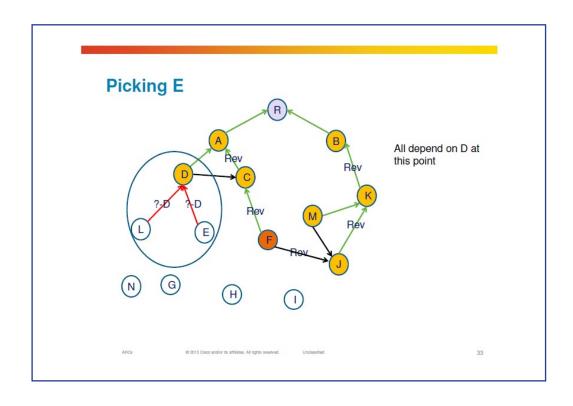






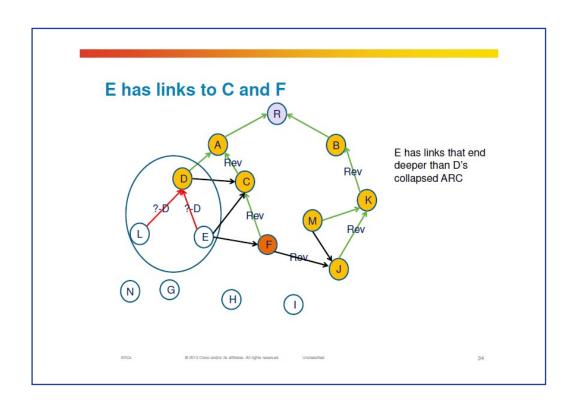
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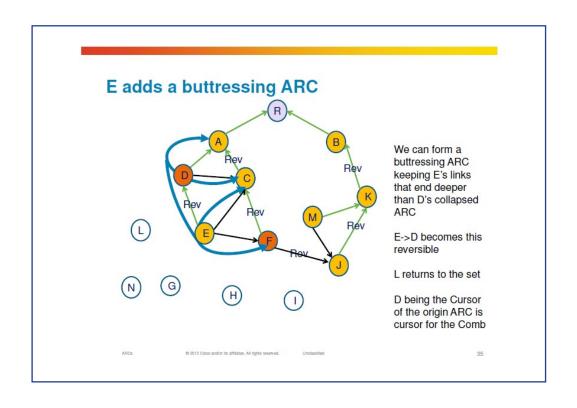






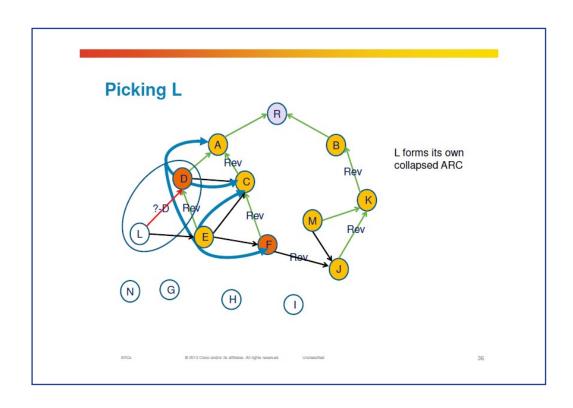
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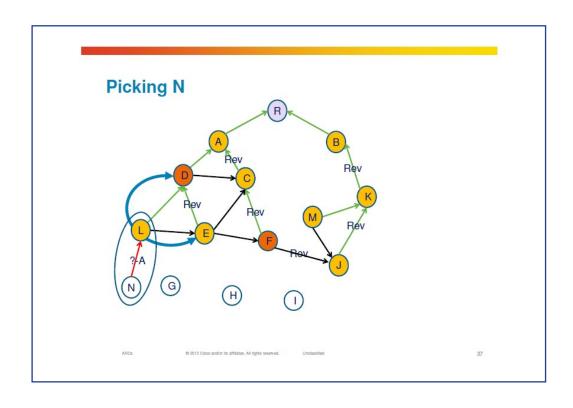






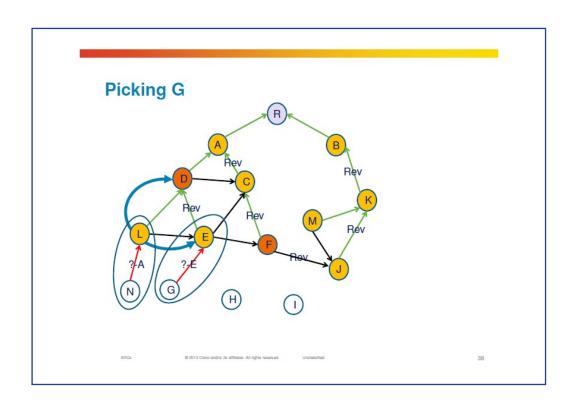
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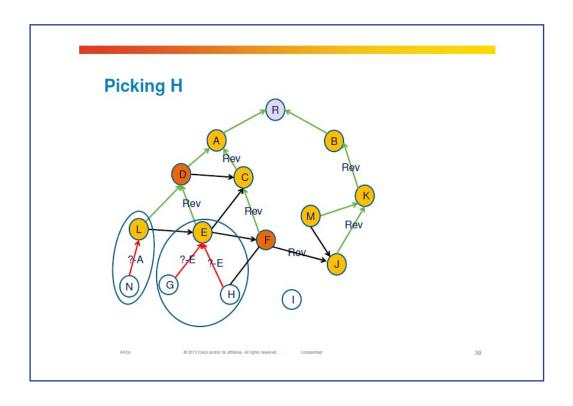






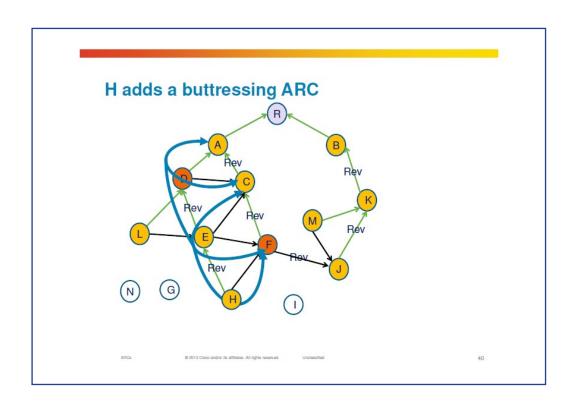
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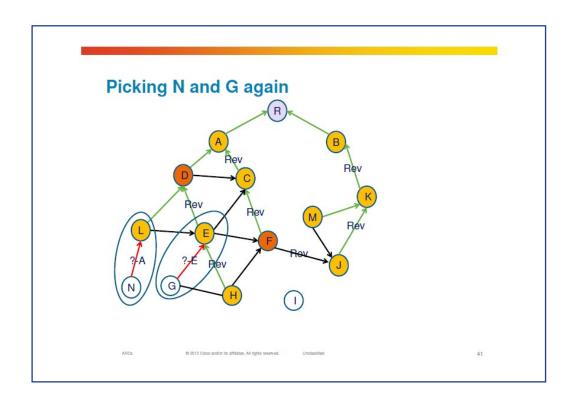






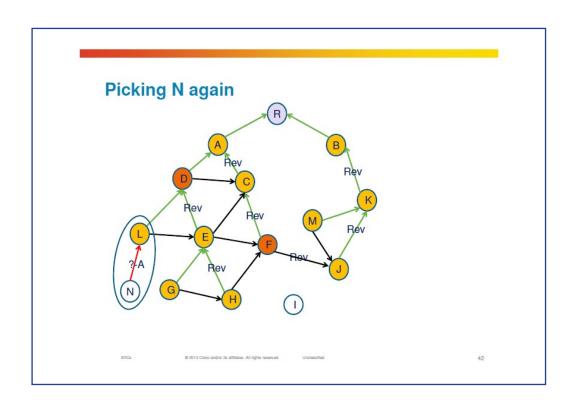
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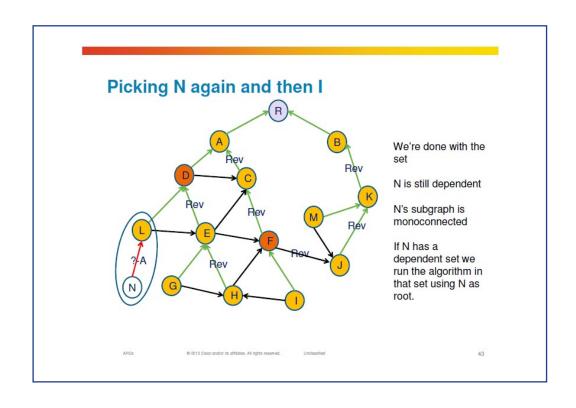






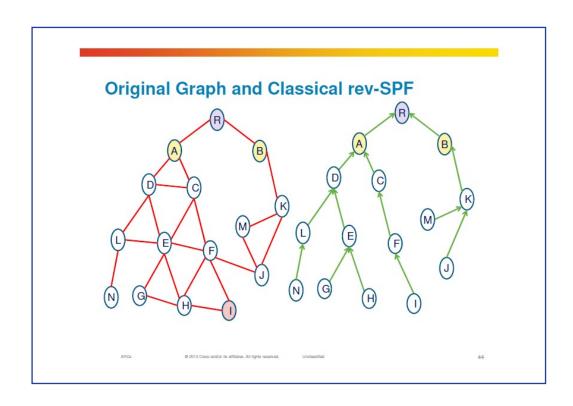
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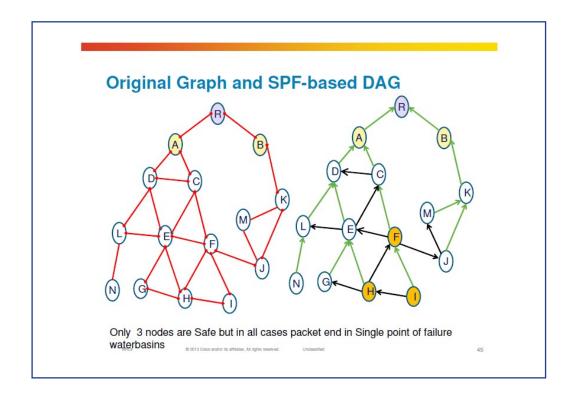






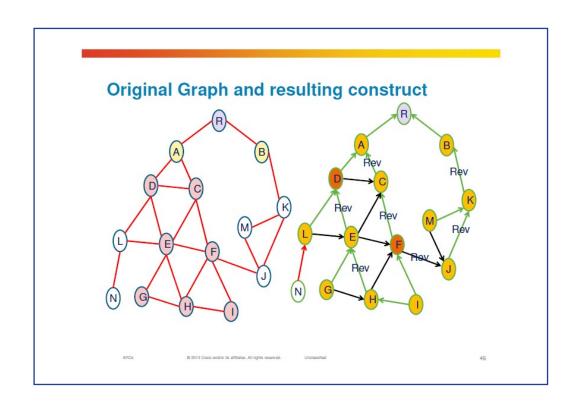
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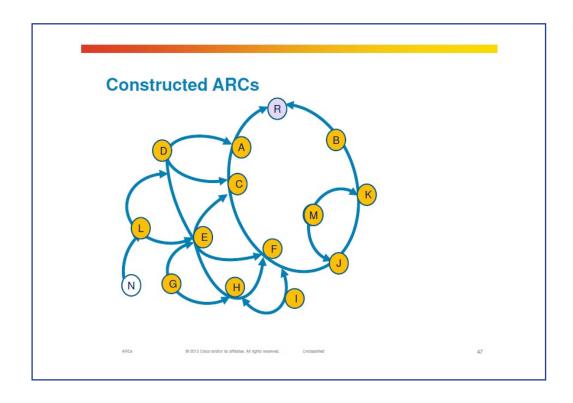






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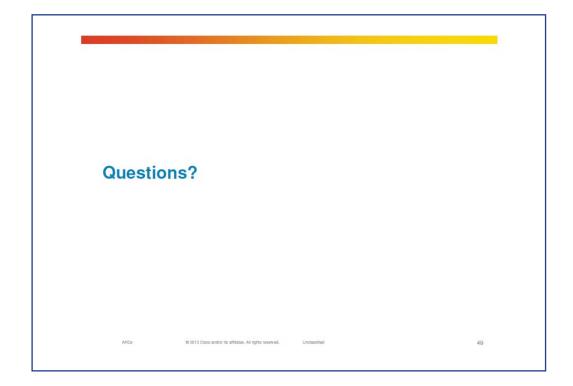






# SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)









SESSION 3 (SELF-) MANAGEMENT & CONTROL FOR SDN (I)





## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

#### **Towards Management of Software-Driven Networks**

#### Abstract:

#### I. INTRODUCTION AND CONTEXT

The Software-Driven Networks (SDNs) are flexible, scalable, robust and intelligent networks, meeting the requirements coming from users and operators and coping with constraints imposed by heterogeneous underlying network environments (e.g., fixed or wireless). They are realized through programmable network infrastructures that support on-demand instantiated software-driven features. Software-Driven Networking design goals include: network programmability and elasticity [2], [7]; integrated virtualisation of network, storage and processing resources, including the limited resources in smart-objects [6]; and in-network management, i.e., 'SDN as a Service' [1]. A non-exhaustive list of the SDN features is detailed below:

Interworking – SDNs are represented by the inter-connection and inter-operation of several heterogeneous and dynamic networks sharing their virtualized resources to support provisioning of any service in a pervasive manner [8]. Service Access – SDNs should offer service providers qualified access mechanisms to a set of network embedded resource-facing services, providing scalable, self-managed and inexpensive network infrastructures on demand [5]. Service Provisioning – SDNs should support the complete lifecycle of sophisticated services by combining existing elements in new and creative ways [3], [4].

Network Empowerment characteristics are: Service-, Content-, Knowledge-, Environmental-, Energy-, Economic - and Social- awareness [6].

We demonstrate an SDN infrastructure providing basic communication services over dynamic topologies and embedded network management operations self-optimizing the communication flow. Novel management abstractions as well as sophisticated mechanisms and algorithms are tackling the communication flow optimization problem from both top-down and bottom-up viewpoints. The management abstractions follow the Universal Management Framework (UMF) specifications [1], an emerging management infrastructure for future networks (see Figure 1).

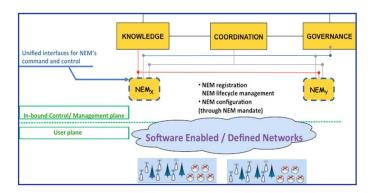


Figure 1 - UMF deployed in an SDN environment

The UMF is an innovative management framework that aims to solve challenging network problems and address the growing management complexity of the highly decentralized and dynamic environment of resources and systems in the Future Internet. The Network Empowerment Mechanisms (NEMs) [1], encapsulate autonomic functions (closed control loops/algorithms) that can be embedded into legacy and future networking systems and services in a "plugand-play" / "unplugand-play" way.

The NEMs require basic services to be provided by the UMF, namely the UMF core services: Governance (GOV) handling high-level management of the infrastructure; Knowledge (KNOW) providing information/knowledge manipulation abstractions; and Coordination (COORD) offering coordination services (e.g., conflict detection and avoidance).

We elaborate the demo scenario and test-bed description in the following section. In section III, we provide our conclusions.



## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

#### II. DEMO SCENARIO AND TESTBED DESCRIPTION

In this demonstration, we involve two NEMs managing SDNs, the KNOW and GOV UMF core services and a number of visualization tools, elaborated below.

The two intelligent management components (i.e., NEMs) we use are the Virtual Infrastructure Management (VIM) and the Placement Optimization (PO) NEMs. The VIM NEM manages the virtual infrastructure through providing management/control functions, such as virtual topologies/paths establishment, traffic monitoring and deployment of nodes providing network services (e.g., aggregation points). Basic VIM functions and algorithms are elaborated in [10], [11]. The PO NEM optimizes the data flow through adapting the position of the communicating nodes in response to the dynamic network conditions (i.e., real-time topology and traffic status). It uses novel placement algorithms (i.e., the Pressure and PressureTime algorithms) that were extensively validated (theoretically and experimentally) in papers [9], [10].

The demo run involves the KNOW core service that provides intelligent information / knowledge handling abstractions in the UMF (see figure 2). The GOV core service deploys the VIM and PO NEMs at the beginning of the experiment and follows their run-time lifecycle.

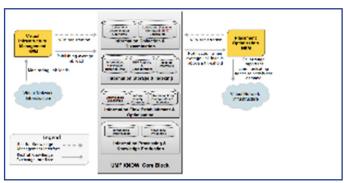


Figure 2 - Basic demo components and their interactions with KNOW

At the beginning of the demo, the GOV deploys the two NEMs. Part of the deployment is their registration to the KNOW. This involves the exchange of information related requirements and constraints. The basic interactions between the VIM, PO NEMs and the KNOW core service are shown in Figure 2. The VIM NEM starts publishing real-time network monitoring information (i.e., the link loads and topology information) - the topology changes very frequently (i.e., grows every few seconds). The PO NEM subscribes to be notified whenever link load is above a specific threshold. This triggers redeployment of communication nodes (i.e., information aggregation points, in our example) in order to reduce the communication overhead.

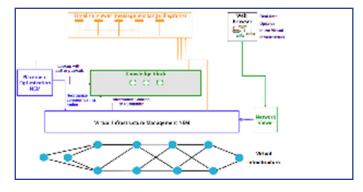


Figure 3 - Basic demo components, the virtual infrastructure and the visualization tools





## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

As we show in figure 3, we visualize the updates in the dynamic topology / communication node placement, the message-exchange diagrams for all interactions and the behaviour of the VIM and PO NEMs, including real-time monitoring information and topology status as well as the behaviour of the internal KNOW core service functions. A visualization tool we call UMF dashboard shows the GOV activities, including the run-time NEMs life-cycle status. Our SDN implementation is a software-based service and network test-bed - the Very Lightweight Software Driven Network and Services Platform (VLSP) developed at UCL. VLSP uses very lightweight virtual router elements that can be combined in order to build any network topology. It provides facilities to start and stop virtual routers on-the-fly, together with the ability to create and destroy network connections between virtual routers dynamically. Furthermore, these lightweight routers have an application layer interface that provides the capability to start and stop Java software applications. We tested the VLSP with a topology of 700 virtual nodes. We implemented from the scratch all the required components, including the virtual routers (i.e., more than 100000 lines of code).

#### III. CONCLUSIONS

We demonstrate how SDNs could be managed using the UMF architecture. We show how novel optimization algorithms and mechanisms can be associated with carefully designed management abstractions, in order to provide flexible management services on top of dynamic SDNs.

#### Acknowledgment

This work is partially supported by the European Union UniverSELF project [1] under grant agreement n° 257513.

#### References

- [1] UniverSELF project http://www.univerself-project.eu/
- [2] A. Galis, S. Denazis, C. Brou, C. Klein, "Programmable Networks for IP Service Deployment", ISBN 1-58053-745-6, pp 450, June 2004, Artech House Books, www.artechhouse.com
- [3] A. Galis, S. Clayman, L. Lefevre, A. Fischer, H. de Meer, J. Rubio-Loyola, J. Serrat, S. Davy -"Towards In-Network Clouds in Future Internet" in Lecture Notes in Computer Science, Vol. 6656, 465 pp, ISBN 978-3-642-20897-3, 4th May 2011
- [4] J. Rubio-Loyola, A. Galis, A. Astorga, J. Serrat, L. Lefevre, A. Fischer, H. de Meer, "Scalable Service Deployment on Software Defined Networks", IEEE Communications Magazine/ Network and Service Management Series, Dec. 2011.
- [5] A. Galis, H. Abramowicz, M. Brunner, D. Raz, P. Chemouil, S. Clayman, et all "Management and Service-aware Networking Architectures (MANA) for Future Internet Position Paper:" Invited paper IEEE ChinaCom, 26-28 August 2009.
- [6] ITU-T Y.3001Recommendation "Future Network Vision Objectives and Design Goals"; Y.3011 Recommendation: "New Framework of network virtualization for Future Networks"; Y.3021 Recommendation "New Framework of energy saving for Future Networks" 2011- http://www.itu.int/en/ITU-T/focusgroups/fn/Pages/Default. aspx
- [7] NEBULA project website, http://nebula.cis.upenn.edu
- [8] N. McKeown et al. (2008-04). "OpenFlow: Enabling innovation in campus networks". ACM Communications Review. Retrieved 2009-11-0
- [9] G. Clegg, R., Clayman, S., Pavlou, G., Mamatas, L., Galis, A. "On the Selection of management and monitoring nodes in dynamic networks" IEEE Transactions on Computers, 6 March 2012.
- [10] S. Clayman, R. G. Clegg, L. Mamatas, G. Pavlou and A. Galis, "Monitoring, Aggregation and Filtering for Efficient Management of Virtual Networks", CNSM 2011.
- [11] L. Mamatas, S. Clayman, M. Charalambides, A. Galis and G. Pavlou, "Towards an Information Management Overlay for Emerging Networks", IEEE/IFIP NOMS 2010, 19-23 April 2010, Osaka, Japan.



## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)



## Towards Management of Software-Driven Networks

3rd ETSI Future Networks Workshop
Sophia Antipolis 9th April 2013



Prof. Alex Galis
University College London
a.galis@ucl.ac.uk

## **Content List**

- SDN Context and Advances A view point
- Self-Management Functionality in SDN
- An SDN management testbed
- Concluding Remarks

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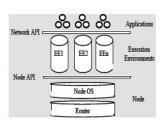


**SESSION 4** (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

## Some current SDN's Systemic Limits

- O Networks are becoming both a connectivity and service execution environment
- →Work towards a service and management aware connectivity
  - Computation, storage and connectivity Virtualised separately (but not in an integrated way)
- Work towards a flexible and cost effective integrated virtual infrastructure with elastic usage and sharing resources
   Silos and disparate systems with limited extensibilities which created a segmentation of networking & computation
- → Programmability: dynamic and autonomic activation of network and service functions
  - O Need for Software driven features:
- Programmability and Elasticity Integrated Virtualisation of Connectivity Storage and Processing Resources In-Network Management Service awareness
- Energy awareness Content awareness Knowledge awareness Economic awareness Extensibility with new features

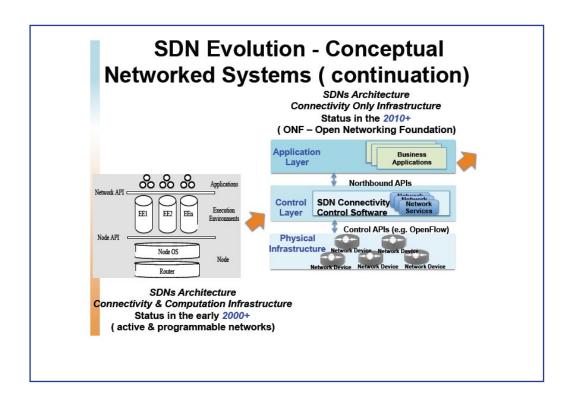
## **SDN Evolution - Conceptual Networked Systems**

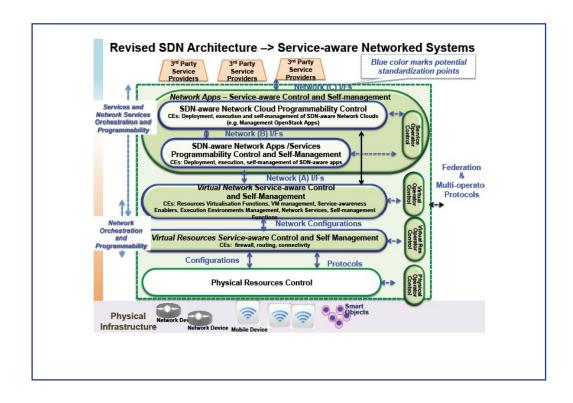


SDNs Architecture Connectivity & Computation Infrastructure Status in the early 2000+ ( active & programmable networks)



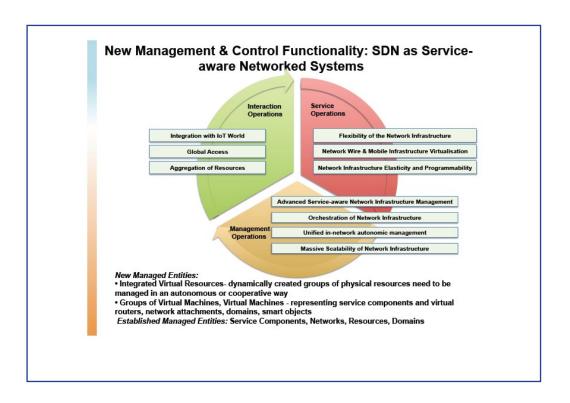
## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

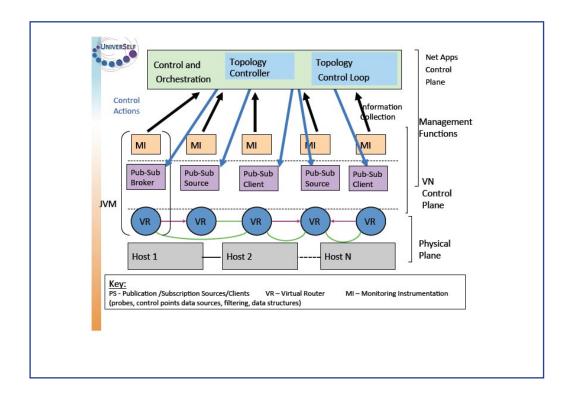






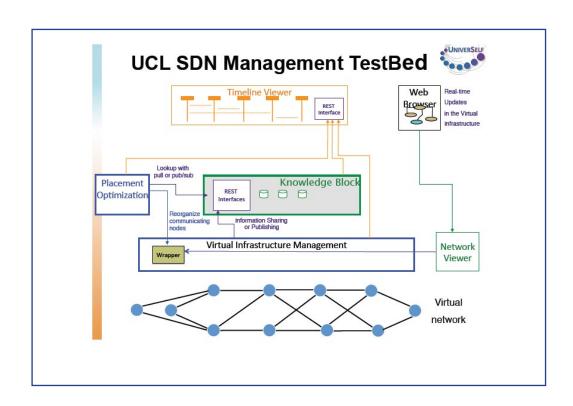
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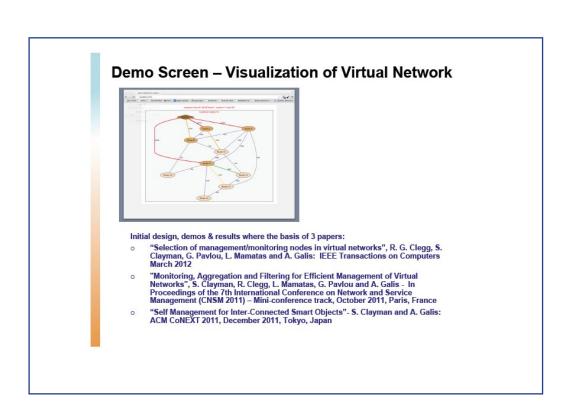






## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)









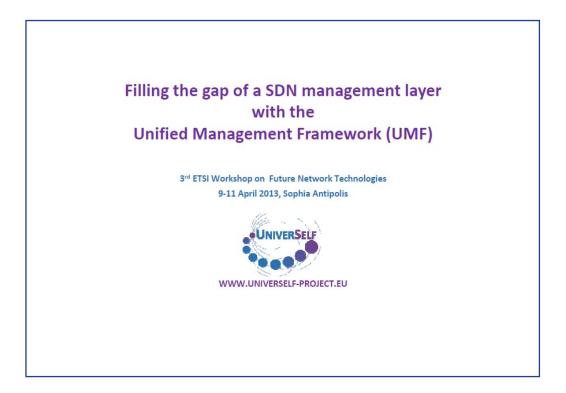
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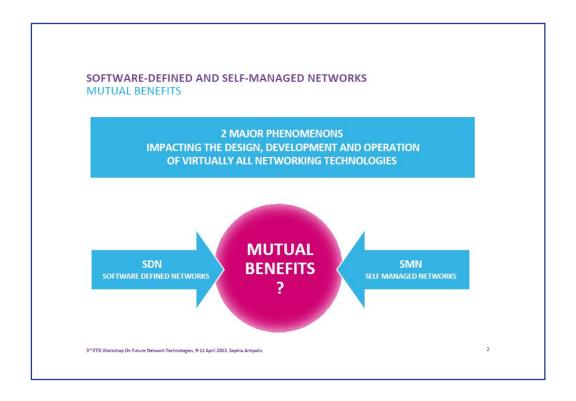
# Thank You Concluding Remark: (Self)Management and Control would represent nearly 100% of the Future SDN functionality !!!



## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

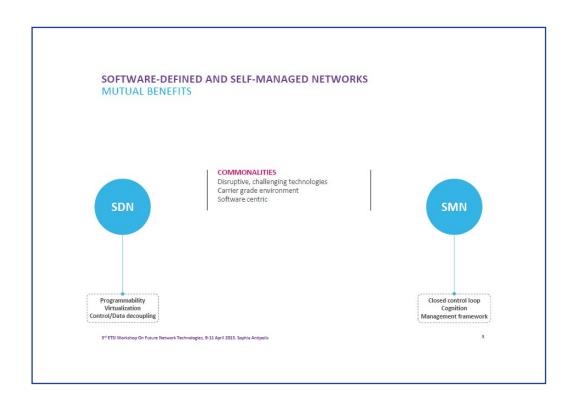
Filling the gap of a SDN management layer with the Unified Management Framework (UMF)

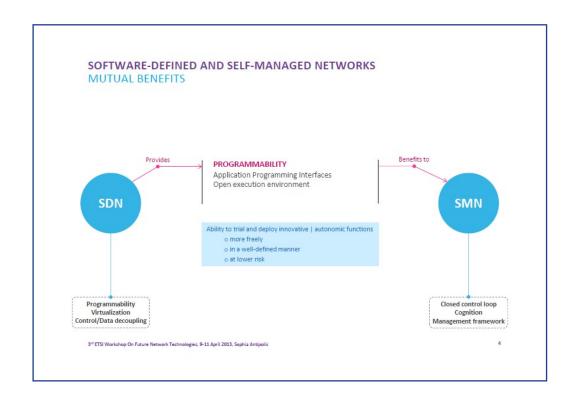






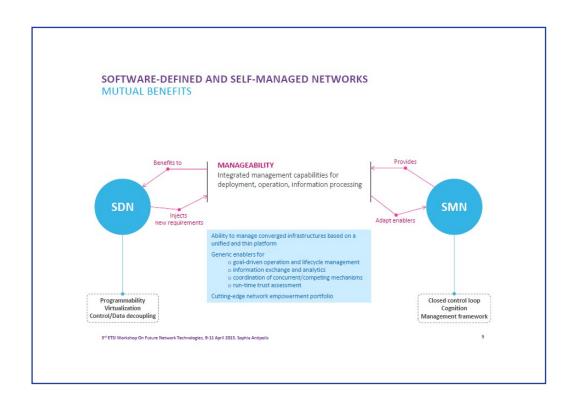
## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

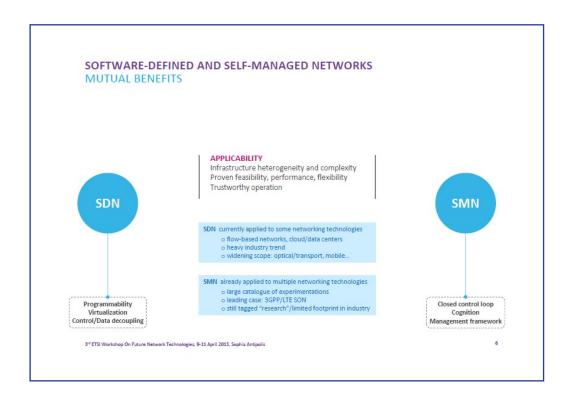






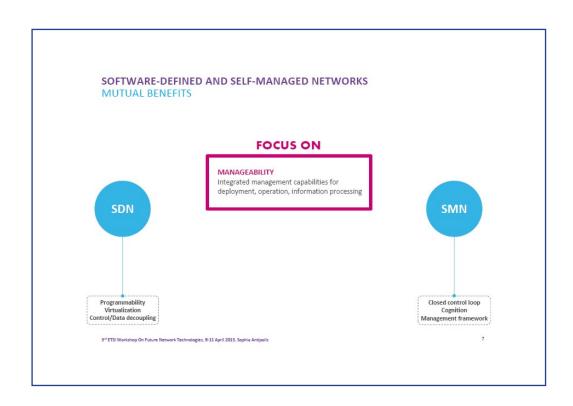
## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)







# SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)



Req. 1	Ability to deploy and operate applications in a seamless, plug-and-play manner
Req. 2	Ability to configure applications using goal-driven, close-to-natural language
Req. 3	Ability to span across multiple technologies (e.g. fixed, mobile, service)
Req. 4	Ability to provide end-to-end, aggregated/service-oriented view(s)
Req. 5	Ability to measure, assess, and report applications performance
Req. 6	Ability to guarantee stable behavior of individual and group(s) of application(s)
Req. 7	On par with existing technologies for scalability, efficiency, reliability, security



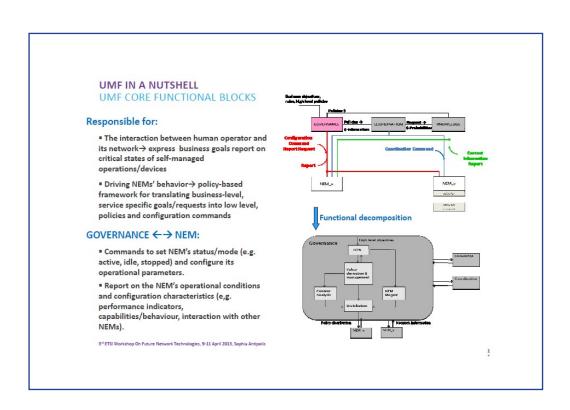
## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

UNIVERSELF VALUE PROPOSITION FRAMEWORK, ENABLERS AND EMPOWERMENT MECHANISMS NEM = use of relevant method to solve a concrete operational problem NETWORK in a specific networking environment **EMPOWERMENT** o e.g. use of genetic algorithm for interference coordination in LTE MECHANISM networks (NEM) NEM = a real autonomic function controlling network resources NEM SKIN = unified abstraction of NEM o common set of objects describing its properties and capabilities e.g. manifest, mandate, instance description o common set of interfaces to connect and interact with the UMF MANAGEMENT FRAMEWORK and other NEMs (UMF) o set of technology-specific adaptors NEM SKIN = vector of unification, re-usable software component, and an accelerator for NEM implementation 3rd ETSI Workshop On Future Network Technologies, 9-11 April 2013, Sophia Antipolis

## UNIVERSELF VALUE PROPOSITION FRAMEWORK, ENABLERS AND EMPOWERMENT MECHANISMS One framework to manage multiple/any types of NEMs NETWORK **EMPOWERMENT** Ability to cope with NEM ecosystem diversity MECHANISM o heterogeneity of NEM function/goal (NEM) o multiple technology domains o multiple roles and interactions among NEMs with same models and interfaces (cf previous slide) Specification of core functions, workflows and NEM lifecycle UNIFIED MANAGEMENT FRAMEWORK 3 core functions: o governance, coordination, knowledge (UMF) o and associated mechanisms e.g. conflict avoidance, data mining... 3rd ETSI Workshop On Future Network Technologies, 9-11 April 2013, Sophia Antipolis



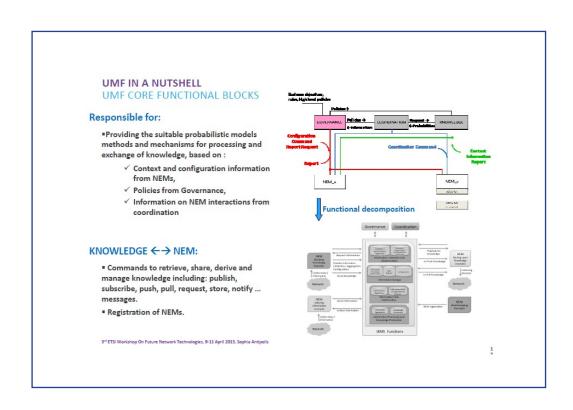
## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)



#### **UMF IN A NUTSHELL UMF CORE FUNCTIONAL BLOCKS** Responsible for: Prevent the network from instabilities and side effects due to the multiple NEMs running in parallel Ensuring the proper sequence in triggering of NEMs, their stable operations, and conditions NEM\_x under which they will be executed taking into account: √ Operator and service requirements, Functional decomposition √ Needs for Conflict avoidance, joint optimization and stability control. COORDINATION ←→ NEM: Commands to drive coordination including: tokens, timing, constraints, status (active/idle), etc. Information on the NEMs operation including: parameters, metrics, scope, utility functions, etc. 3<sup>rd</sup> ETSI Workshop On Future Network Technologies, 9-11 April 2013, Sophia Antipolis



## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)









## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

INT STANDARDIZATION OPPORTUNITIES HAT AND WHERE		
What to do / standardize	Where	-
Collaboration: SDN and SMN are studied in different bodies which may result in different specifications in managing applications/autonomic functions	All involved SDOs/fora	
Definition of a reference set of requirements and design principles for SDN management	Multi-SDOs initiative	
Design and specification of the management framework (functions, objects, states)	ETSI/IETF/ITU-T/ONF	
Extension to information model(s) and techniques	TMF	
Applicability to technology domain(s) and adaptors, feasibility, proof of concepts	ETSIAFI/ONF/IETF/	
Tests specifications, conformance testing, interoperability testing, certification	ETSI AFI, MTS, CTI / 3 <sup>rd</sup> party org.	
LTE SON coordination framework	3GPP / ETSI AFI	
* the list is not exhaustive and open for comments		





## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

## MEET US & OUR LIVE DEMOS AT...

Future Internet Assembly (FIA) Dublin, 8-10 May Integrated Network Management (IM) Ghent, 27-31 May Future Network and Mobile Summit (FUNEMS) Lisbon, 3-5 July









## SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

#### PROJECT ID

- FP7 Call 5 Integrating Project
- Total Cost: ~16M€; EC Contribution: ~10M€
- 16 Partners (3 Vendors, 4 Operators, 4 Research Institutes, 5 Universities)
- Coordinator: Alcatel-Lucent
- Duration: 36 months
- Start date: 01/09/2010
- Website: www.univerself-project.eu

Event, Date, Location

19







# SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

### **Semantic Alarms**

### **Abstract:**

Functions Virtualisation (NFV) and Software Driven Networks (SDN) aggregate resources across multiple domains. This puts requirements on understanding the overall alarm status across these domains and dependencies between them. Current practice of low-quality alarm documentation and confusion around fundamental concepts like alarm states, alarm-types and the underlying protocols like syslog and SNMP traps makes it hard to create one unified alarm interface as part of the SDN API.

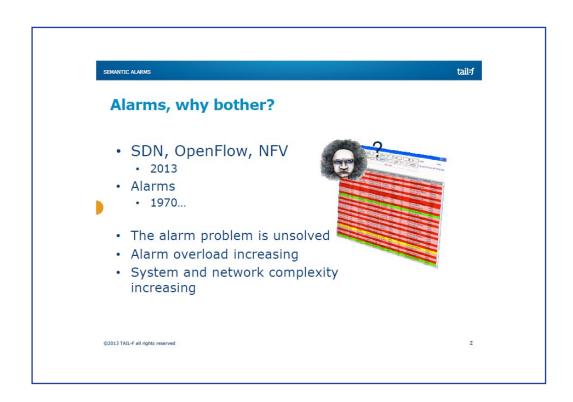
If alarm interfaces for the various components were expressed in a more formal manner including dependencies and propagation between the alarms the NFV/SDN interface could automatically present an integrated alarm API as well as a synthesized alarm state across the virtualized functions.

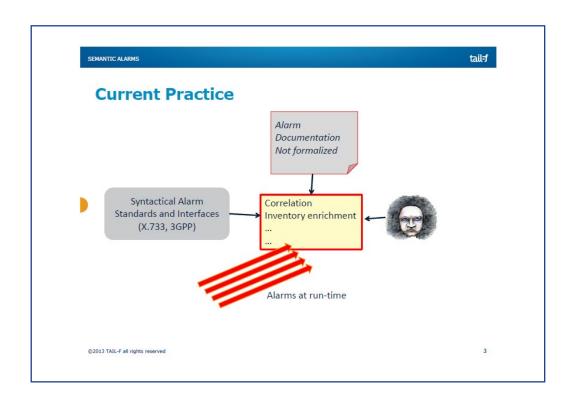
We present a novel approach to alarm interfaces by providing a formal alarm model together with a domain-specific language that allows us to specify both the alarm models and the constraints placed on the alarm models in a consistent manner. This means that we can verify the consistency of an alarm interfaces and automatically generate interfaces, multi-domain correlation and aggregated states.





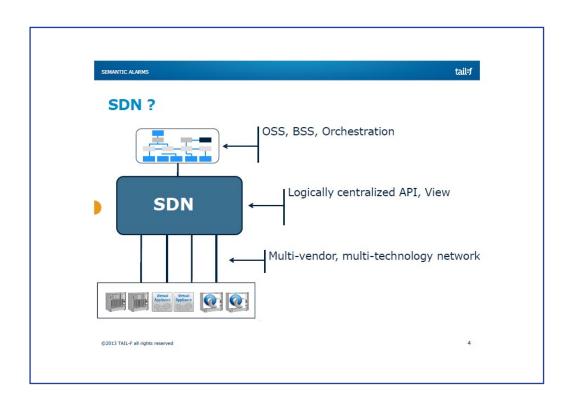
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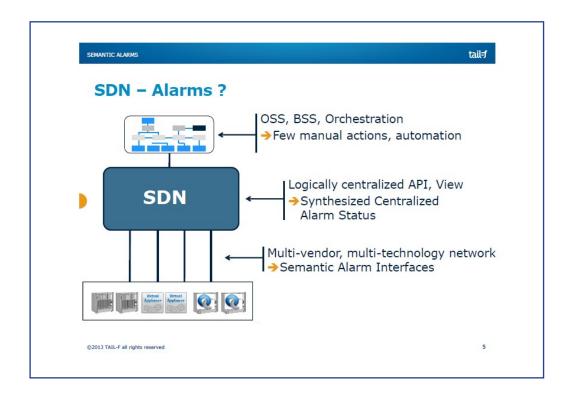






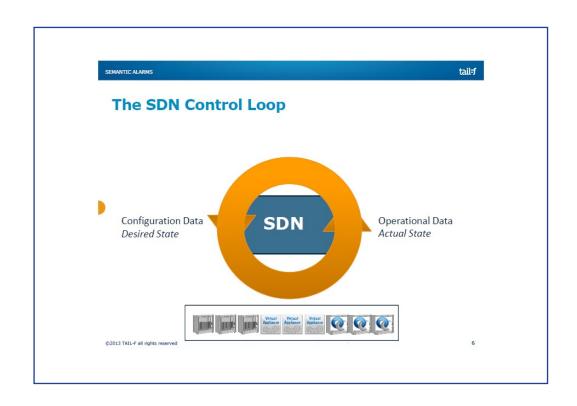
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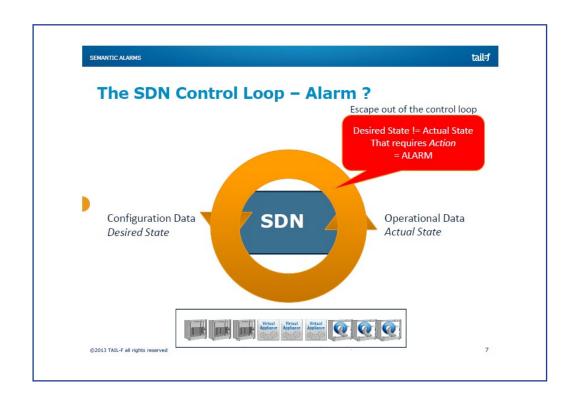






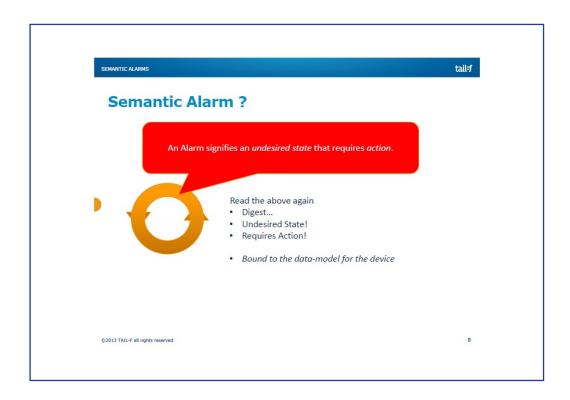
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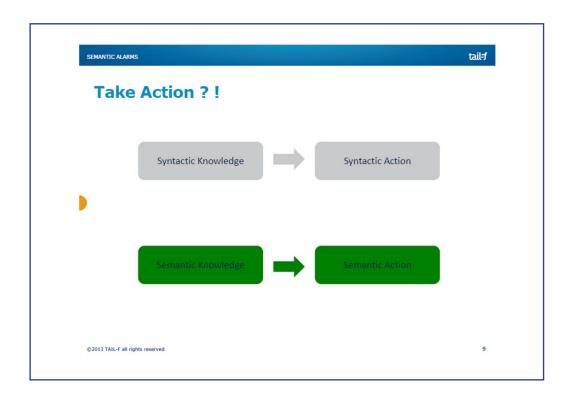






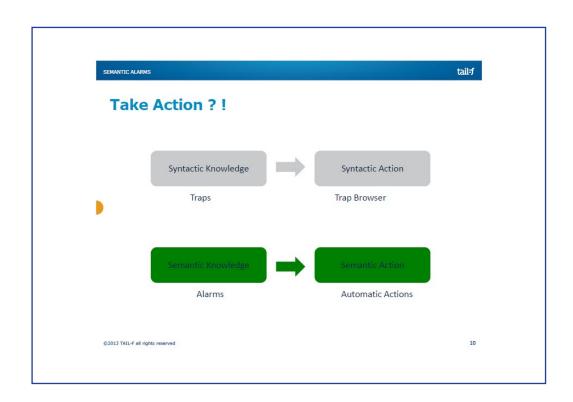
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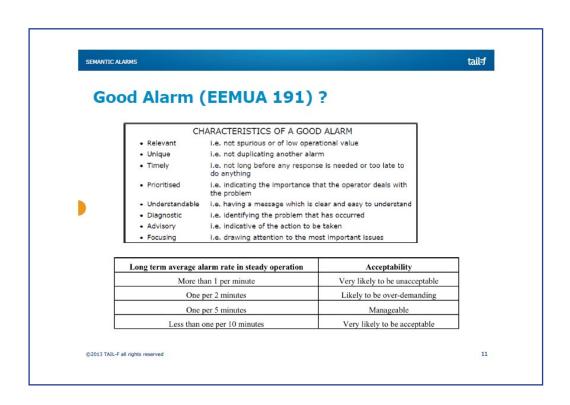






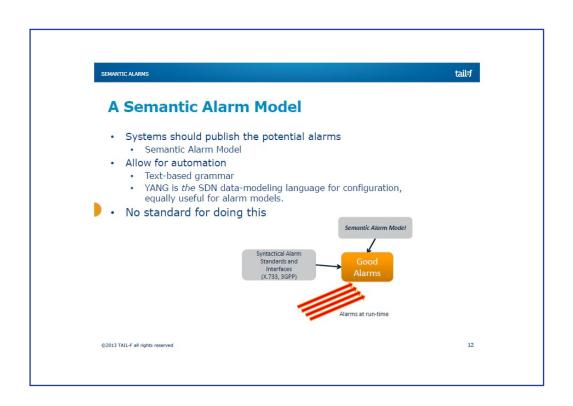
# SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)

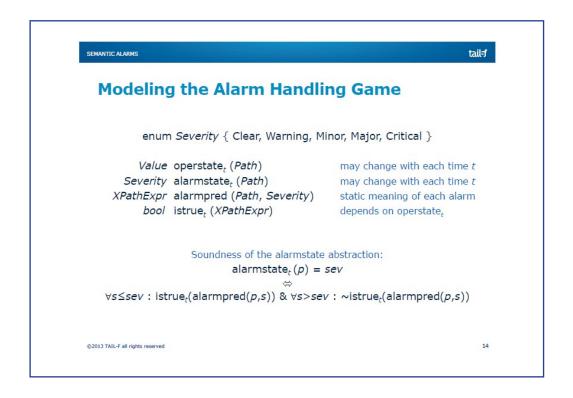






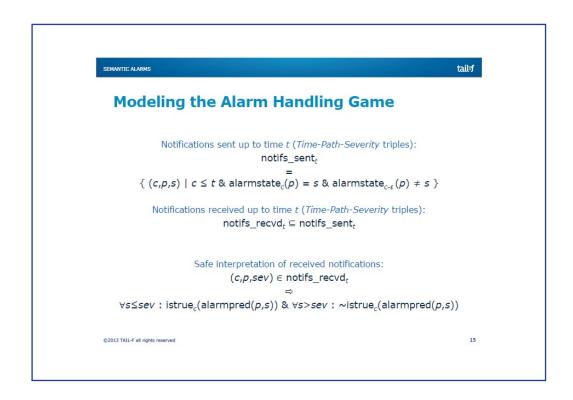
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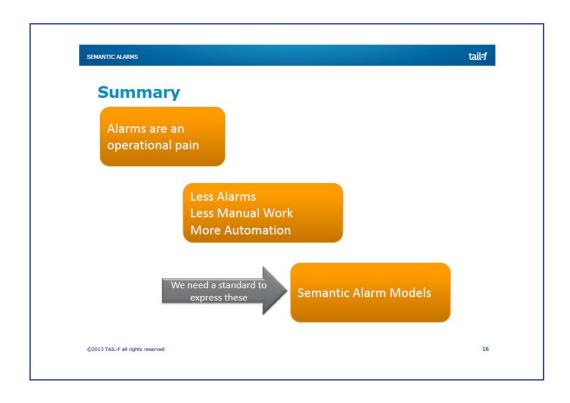






# SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)







# SESSION 4 (SELF-) MANAGEMENT & CONTROL FOR SDN (II)









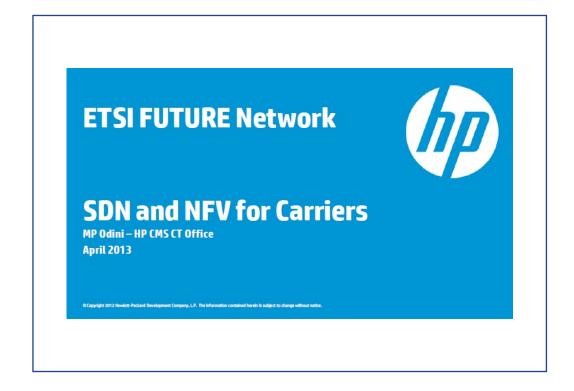
SESSION 5 SDN (I)

### SDN and NFV (Network Function Virtualization) for Carriers (Telecom Service providers)

### **Abstract:**

SDN (Software defined network) and Virtualization are becoming the next big thing for Communication Service Providers (CSP)! Decoupling data forwarding plane from the control plane introduces new functionality and granularity at the flow level. SDN Controllers can now deal with any switch or network equipment vendor and expose networking functions to applications via simple Restful APIs. This virtualization at the network level complements virtualization happening at the application level with virtualized computing and storage capacity, giving CSP the tools they need to cope with growing traffic, unpredictable events and requests, elasticity while keeping control over quality and cost. Management over a more standardized and programmable infrastructure is also simplified and more dynamic. Centralized it can reduce operation costs.

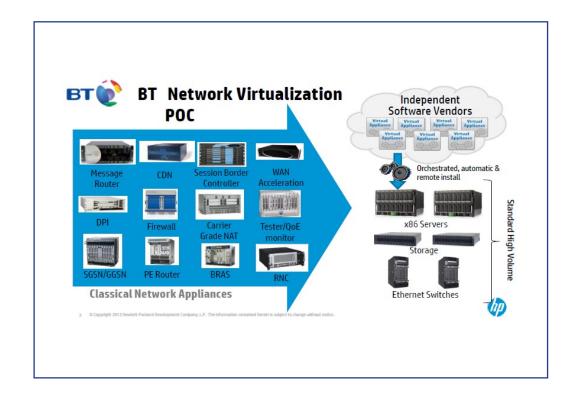
HP is a founding member of Openflow alliance and the 1st vendor to launch SDN Switches. HP is also releasing an SDN Controller mid 2013. This presentation will cover drivers for SDN and then move into specifics for Telecom Carriers, from Data Center to Core and Access Network, and illustrate with a number of concrete examples, specific to carrier networks, use cases describing how telecom functions can leverage SDN and detail benefits for the Carriers but also the enterprise and end users.





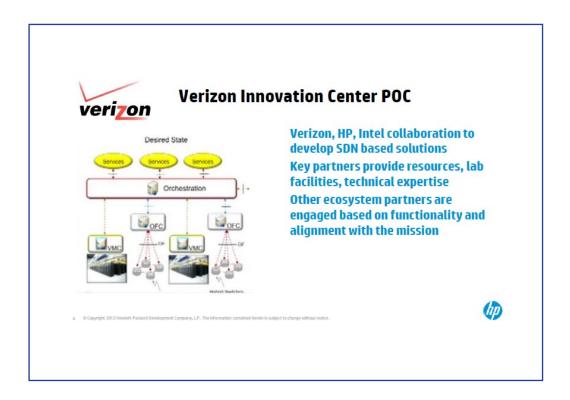
SESSION 5 SDN (I)

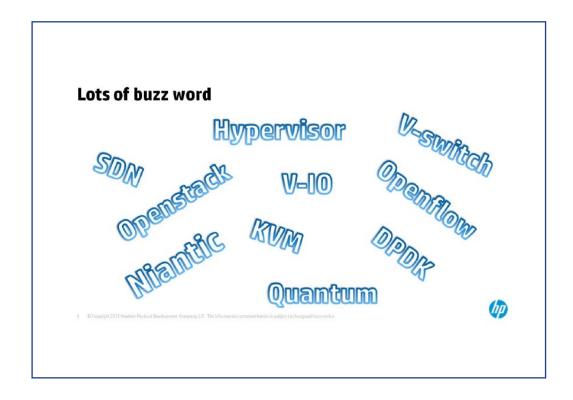






SESSION 5 SDN (I)



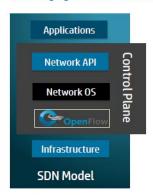




SESSION 5 SDN (I)

### What is SDN

- an emerging software based network architecture



# Abstraction of control plane from forwarding hardware

- Network control plane as a centralized software program
- Centralized intelligence of network topology
- Dynamic and programmable network, interaction with applications
- Implemented via variety of methods including OpenFlow protocol

### **Key Benefits**

- Provides opportunity for rapid innovation in networking
- Use cases for all types of networks including Enterprise Campus, Service Provider, Cloud, Data Center
- Can enable simplified management through network virtualization

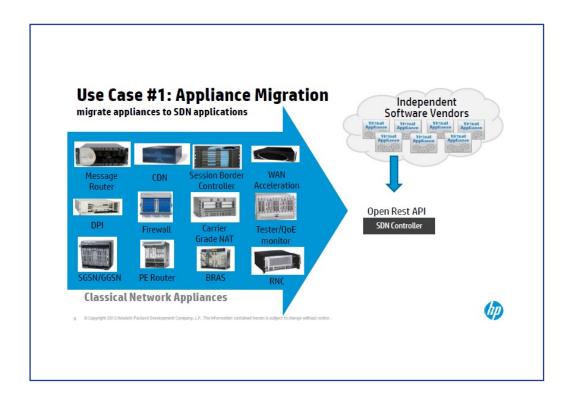


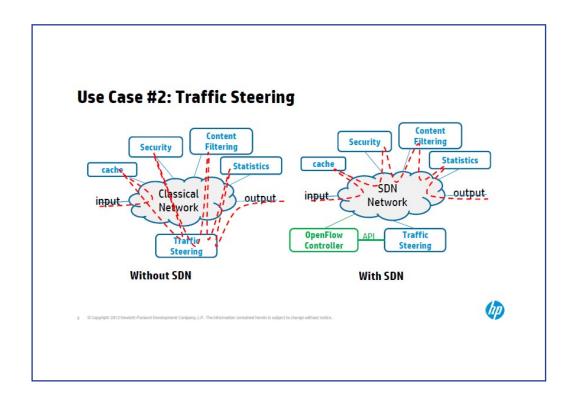
### **Use Case Summary**

Nb	Name	Description
#1	Appliance Migration	Migrate proprietary boxes to COTS servers, decouple Data & control plan, leverage SDN protocols, controllers, centralized controller for multiple data plane components etc
#2	Traffic Steering	Introduce SDN with controller to extract $1^{\sharp}$ packets, tag flow and avoid having to redo this for all packets. Allow dynamic change
#3	Content Delivery Traffic routing	Allow dynamic traffic routing thanks to SDN controller and dynamic view of available NW resources
#4	Virtual Core IMS	Enhance Policy with tight integration with SDN controller to route traffic to virtual core $\ensuremath{IMS}$
#5	Networking as a Service	Extand laaS with dynamic NW resource allocation and allow Telecom operators to offer this as a Service to external customers
#6	Edge policy Enforcement	Have a centralized control but distributed enforcement model for Security policies.
#7	Cloud Bursting	Burst from Private Cloud to Public Cloud and be able to orchestrate the dynamic secure network in the public cloud
#8	Optimal Traffic Engineering Inter-DC WAN	Ability to have a Stateful controller to more dynamically place flows in the network, to best utilize the network resources
#9	Data Center Virtualization	Ability to move workloads around from any server to any other server within a DC without limitations of the network addressing



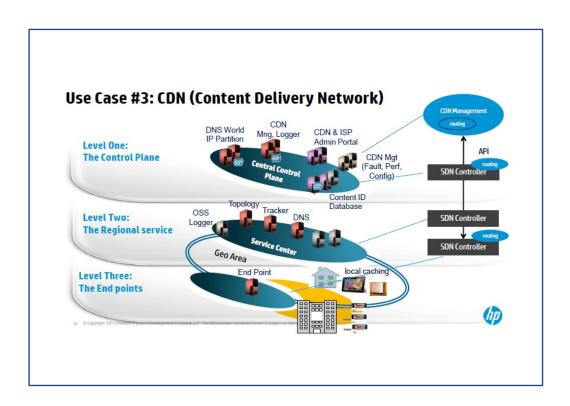
SESSION 5 SDN (I)

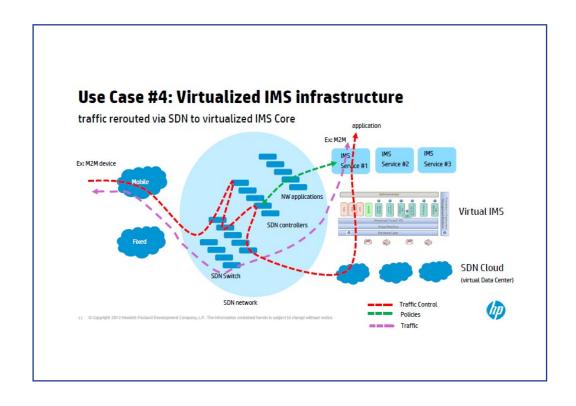






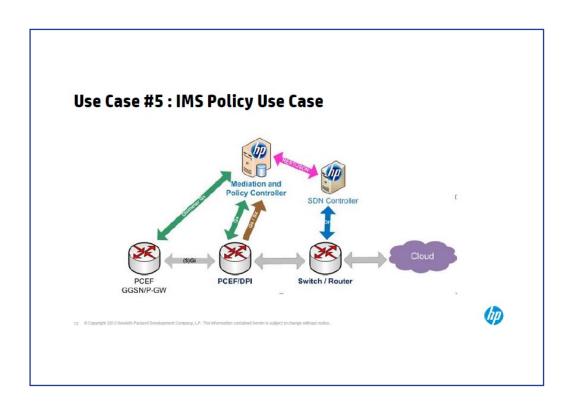
SESSION 5 SDN (I)

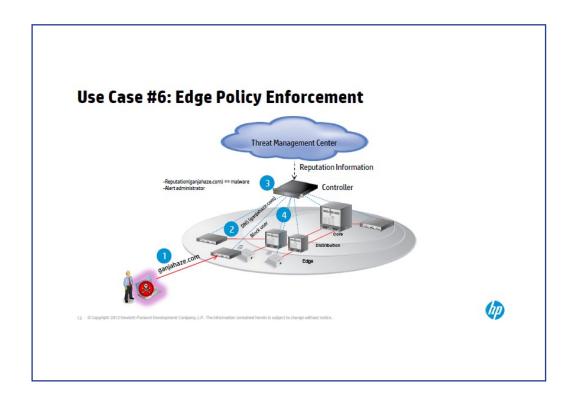






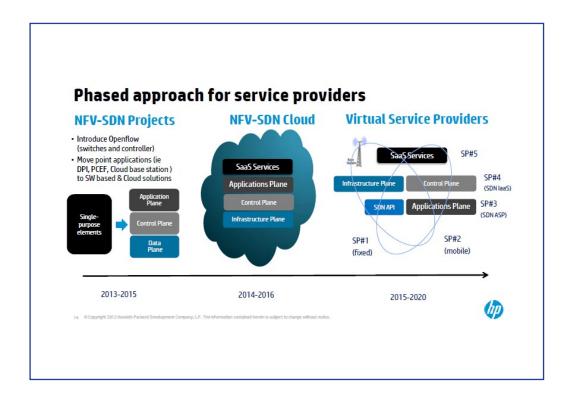
SESSION 5 SDN (I)







SESSION 5 SDN (I)







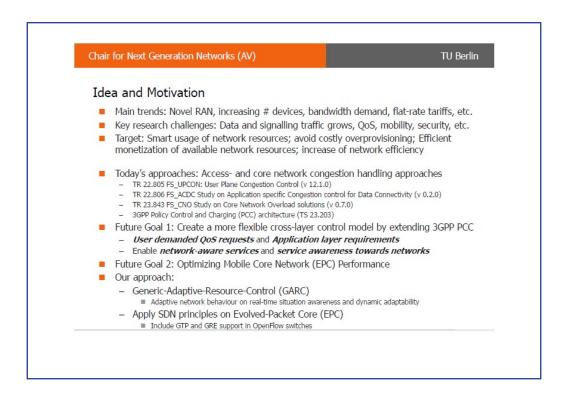
SESSION 5 SDN (I)

### Software Defined Telecommunication Networks

### **Abstract:**

This talk describes our on-going work on extending 3GPP Policy and Charging Control (PCC) through user Quality-of-Service (QoS) demands and application layer QoS requirements into the policy decision process. The major contribution of this work is the model of a flexible Quality-of-Service (QoS) aligned on 3GPP PCC for Next-Generation-Mobile-Broadband-Networks and the Future Internet - namely Generic-Adaptive-Resource-Control (GARC) - together with its prototypical implementation and extensive use-case validation. GARC enables the control of multiple network technologies in parallel. We've prototyped several adapter for 3GPP cellular mobile broadband networks (LTE/EPC), WiFi 802.11e and Software-Defined-Networks (OpenFlow).

GARC is specified to co-exist as an optional network element in the network operator domain and provides a more flexible and adaptive Cross-Layer QoS control functionality. GARC aims in supporting the existing network operator PCC architecture through (1) fine granular per flow prioritization, (2) dynamical real-time network (re-)design enabling elasticity in the network and (3) active service-data-flow-placement or re-routing through graph-theoretical methods. First we describe a conceptual model namely Generic-Adaptive-Resource-Control (GARC) function, which extends the 3GPP Policy and Charging Control (PCC) architecture. We've practically prototyped the described model within a Software-Defined Next-Generation-Mobile-Broadband-Network OpenEPC testbed using OpenFlow exemplary and validated the concept in extensive test scenarios finally.





SESSION 5 SDN (I)

### Chair for Next Generation Networks (AV)

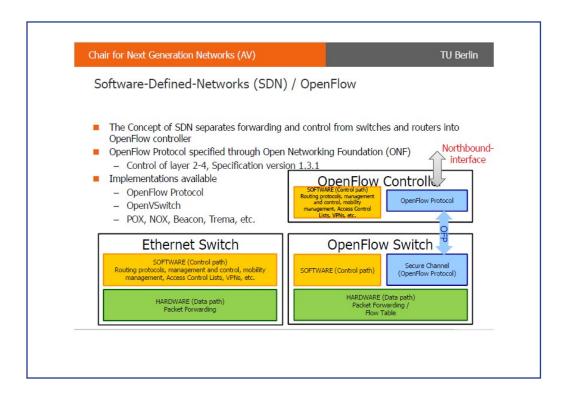
### Agenda for this talk

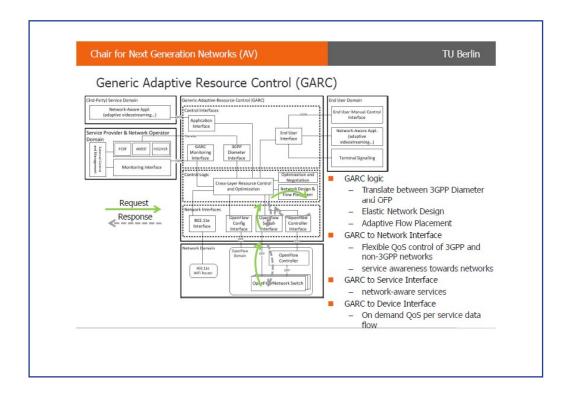
- Idea and Motivation
- SDN Concept and OpenFlow
- Generic Adaptive Resource Control (GARC)
- Openflow Impacts on EPC Evolution
- Summary and Future Work

### Chair for Next Generation Networks (AV) TU Berlin Idea and Motivation Main trends: Novel RAN, increasing # devices, bandwidth demand, flat-rate tariffs, etc. Key research challenges: Data and signalling traffic grows, QoS, mobility, security, etc. Target: Smart usage of network resources; avoid costly overprovisioning; Efficient monetization of available network resources; increase of network efficiency ■ Today's approaches: Access- and core network congestion handling approaches - TR 22.805 FS\_UPCON: User Plane Congestion Control (v 12.1.0) - TR 22.806 FS\_ACDC Study on Application specific Congestion control for Data Connectivity (v 0.2.0) TR 23.843 FS\_CNO Study on Core Network Overload solutions (v 0.7.0) 3GPP Policy Control and Charging (PCC) architecture (TS 23.203) ■ Future Goal 1: Create a more flexible cross-layer control model by extending 3GPP PCC - User demanded QoS requests and Application layer requirements - Enable network-aware services and service awareness towards networks Future Goal 2: Optimizing Mobile Core Network (EPC) Performance Our approach: Generic-Adaptive-Resource-Control (GARC) Adaptive network behaviour on real-time situation awareness and dynamic adaptability - Apply SDN principles on Evolved-Packet Core (EPC) ■ Include GTP and GRE support in OpenFlow switches



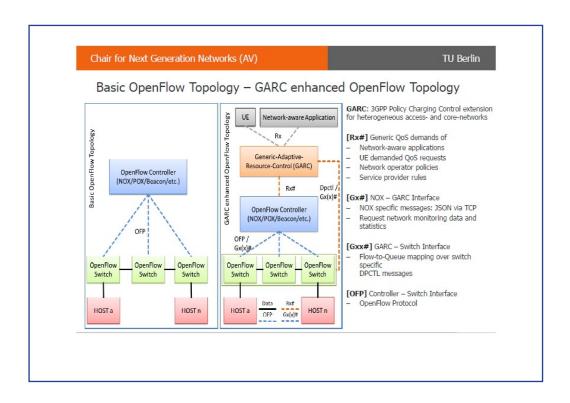
SESSION 5 SDN (I)

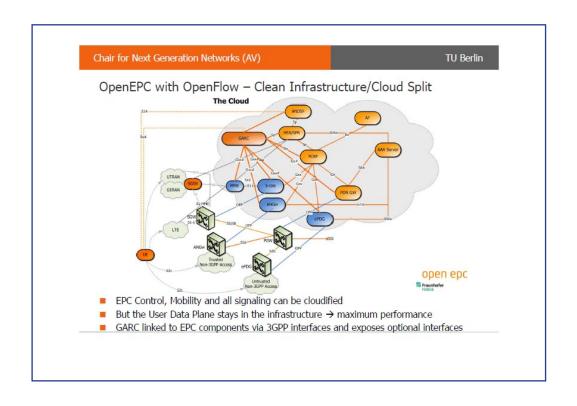






SESSION 5 SDN (I)







SESSION 5 SDN (I)

Chair for Next Generation Networks (AV)

Summary and Future Work

Main trends: Novel RAN, increasing # devices, bandwidth demand, flat-rate tariffs, etc.

Key research challenges: Data and signalling traffic grows, QoS, mobility, security, etc.

Target: Smart usage of network resources; avoid costly overprovisioning; Efficient monetization of available network resources; increase of network efficiency

OpenEPC with OpenFlow — Clean Infrastructure/Cloud Split

Prototypical validation with OpenEPC

GTP and GRE support

Generic Adaptive Resource Control (GARC)

User demanded QoS requests and Application layer requirements

Enable network-aware services and service awareness towards networks

Tanslate between 3GPP Diameter and OFP

Elastic Network Design

Adaptive Flow Placement

### Chair for Next Generation Networks (AV) TU Berlin Abbreviations ADC Application Detection and Control OFCS Offline Charging System AF Application Function OCS Online Charging System ■ BBERF Bearer Binding and Event Reporting PCC Policy and Charging Control Function PCEF Policy and Charging Enforcement BBF Bearer Binding Function Function ■ PCRF Policy and Charging Rules Function CSG Closed Subscriber Group CSG ID Closed Subscriber Group Identity OCI OoS Class Identifier DRA Diameter Routing Agent vSRVCC video Single Radio Voice Call Continuity H-PCEF A PCEF in the HPLMN ■ SPR Subscription Profile Repository H-PCRF A PCRF in the HPLMN ■ TDF Traffic Detection Function HRPD High Rate Packet Data HSGW HRPD Serving Gateway UDC User Data Convergence UDR User Data Repository ■ IP-CAN IP Connectivity Access Network V-PCEF A PCEF in the VPLMN MPS Multimedia Priority Service V-PCRF A PCRF in the VPLMN



**SESSION 5** SDN (I)

### Chair for Next Generation Networks (AV)

TU Berlin

### Related Publications (selected list)



- Mueller J., Magedanz T., Towards a Generic Application Aware Network Resource Control Function for Next-Generation-Networks and Beyond', in the proceedings of IEEE ISCIT 2012, International Symposium on Communications and Information Technologies (ISCIT), Gold Coast, Australia, October 2–5, 2012, <a href="https://www.iscit2012.org">www.iscit2012.org</a>
  Mueller J., Magedanz T., Corici M., Vingarzan D., 'UE & Network Initiated QoS Reservation in NGN and Beyond', IEEE Network of the Future (Norf), 2011 International Conference on the Future Internet, Issue Date: 28-30 Nov. 2011, On page(s): 62 67, Print ISBN: 978-1-4577-1605-8, DOI: 10.1109/NOF.2011.6126684Paris, France, 28-30 Nov. 2011, http://www.network-of-the-future.org/, <a href="https://www.network-of-the-future.org/">https://www.network-of-the-future.org/</a>, <a href=
- J. Mueller, T. Magedanz, 'Der Evolved Packet Core', Handbuch der Telekommunikation, Amold (Hrsg.), 150. Erg. Lfg, Kap. 3.6.0.0, S. 1-52, Wolters Kluwer Deutschland GmbH, April 2012, ISBN: 978-387-156-096-5
- LLange, T.Magedanz, J.Mueller, D.Nehls, D.Vingarzan. 'Evolutionary Future Internet Service Platforms Enabling Seamless Cross Layer Interoperability', Baltic Congress on Future Internet and Communications BCFIC, Riga, Latvia, Feb. 2011, Digital Object Identifier: 10.1109/BCFIC-RIGA.2011.5733228, Publication Year: 2011, Page(s):1-6, Issue Date:16-18 Feb. 2011, Location: Riga, Print ISBN: 978-1-4244-8511-6, INSPEC Accession Number: 11875803, DOI: 10.1109/BCFIC-RIGA.2011.5733228, Date of Current Version: 17 March 2011, <a href="https://ieeexolore.ieee.org/stamo-stamo-s
- http://ieeexolore.ieee.org/stamp/stamp.isp?to=&arnumber=5733228

  J.Mueller, M.Kleis, A.Siddiqui, M.Becke, 'Evaluating a Future Internet Cross-Layer Composition Prototype', 7th
  International ICST Conference on Testbeds and Research Infrastructures for the Development of Networks and
  Communities, TridentCom, Shanghai, China, April 2011, ISBN: 978-1-936968-04-6, Vol. 90, On page(s): 11-27,
  http://www.tridentcom.org/, http://dosace.icsv.det\_2000/dosace/bitstream/123456789/324/1/2010-09Measurements.odf T. Korakis et al. (Eds.): TridentCom 2011, LNICST 90, pp. 11—26. Institute for Computer Sciences,
  Social Informatics and Telecommunications Engineering (2012)
  Corici, Marius; Gouveia, Fabricio; Magedanz, Thomas; Vingairzan, Dragos: OpenEPC: A technical Infrastructure for early
  prototyping of NGMN Testbeds, International Conference on Testbeds and Research Infrastructures for the Development
  of Networks and Communities (Tridentcom '10), 6, 2010, Berlin

### Chair for Next Generation Networks (AV)

TU Berlin

### References

- OpenEPC, <a href="http://www.openepc.net/">http://www.openepc.net/</a>
- OpenIMSCore, <u>www.openimscore.org/</u>
- FOKUS Open SOA Telco Playground,  $\underline{\text{www.opensoaplayground.org}/}$
- NGN to Future Internet Evolution, NGN2FI, www.ngn2fi.org/
- TU-Berlin AV, <a href="http://www.av.tu-berlin.de/">http://www.av.tu-berlin.de/</a>
- Fraunhofer FOKUS NGNI, www.fokus.fraunhofer.de/go/ngni/



SESSION 5 SDN (I)

# Chair for Next Generation Networks (AV) 4th FOKUS "Future Seamless Communication" Forum (FFF) Berlin, Germany, November 28-29, 2013 Theme: "Smart Communications Platforms for Seamless Seamless Communications — Fixed and Mobile Next Generation Networks Evolution towards virtualized network control and service platforms and Seamless Cloud-based H2H and M2M Applications" FUSECO FORUM is the successor of the famous FOKUS IMS Workshop series (2004-09) FFF 2010 attracted 150 experts from 21 nations FFF 2011 was attended by around 200 experts from 30 nations FFF 2012 was attended again by around 200 experts from 30 nations See www.fuseco-forum.org

Chair for Next Generation Networks (AV)

TU Berlin

NGN to Future Internet Evolution
Julius. Mueller@tu-berlin.de

Questions???

4th FOKUS Future Seamless Communication Forum (FFF)
Berlin, Germany, November 28-29, 2013
Visit our Website: www.fuseco-forum.org/



SESSION 5 SDN (I)

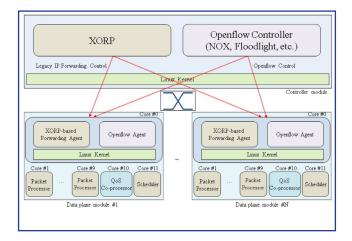
### OpenQFlow: Scalable OpenFlow with Flow-based QoS

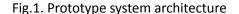
### Abstract:

OpenFlow, originally proposed for campus and enterprise network experimentation, has become a promising SDN architecture that is considered as a widely-deployable production network node recently. It is, however, pointed out that OpenFlow cannot scale and replace today's versatile network devices due to its limited scalability and flexibility. In this research, we propose OpenQFlow, a novel scalable and flexible variant of OpenFlow.

OpenQFlow provides a fine-grained flow tracking while flow classification is decoupled from the tracking by separating the ineffciently coupled flow table to three different tables: flow state table, forwarding rule table, and QoS rule table. We also develop a two-tier flow-based QoS framework, derived from our new packet scheduling algorithm, which provides performance guarantee and fairness on both granularity levels of micro- and aggregate-flow at the same time. OpenQFlow, a novel SDN architecture that is a scalable and flexible variant of OpenFlow. OpenQFlow has a flow state table for flow tracking together with forwarding and QoS tables for flow classification instead of a single unified flow table that hinders both scalable deployment and flexible operation in various network environments. Flow-based QoS that provides performance guarantee and fairness among flows on both micro- and aggregate-flow level runs efficiently by utilizing the newly proposed CETA scheduling algorithm on a dedicated QoS co-processor and software calendar queues.

Performance evaluation of OpenQFlow prototype on an off-the-shelf multicore platform shows that high-performance OpenQFlow data plane implementation is viable on a user friendly programming environment. We also expect that extensions of OpenQFlow that exploits the flexible multi-core processor implementation to provide value-added services or even drive a new networking(NfV's core packet forwarding engine) in high-performance would line up in the near future.





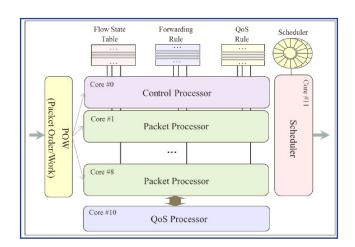


Fig. 2. Prototype data plane architecture



SESSION 5 SDN (I)

ETSI 3<sup>rd</sup> Future Networks Workshop, 9 ~ 11 April 2013



# OpenQFlow: Scalable OpenFlow with Flow-based QoS

April 10, 2013 Nam-Seok Ko (nsko@etri.re.kr)

Net-Computing Convergence Research Section Smart Network Research Department



# **Agenda**

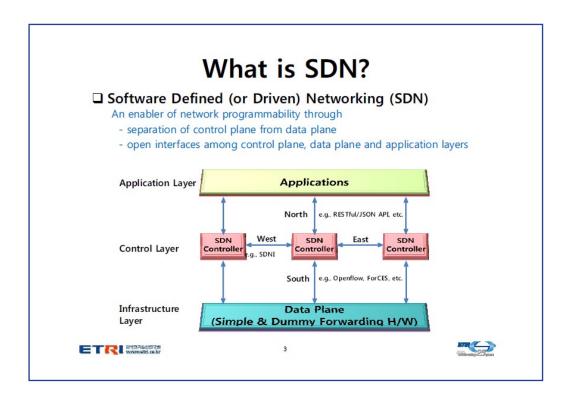
- ☐ SDN (Software Defined/Driven Networking)
  - ❖ What is SDN?
  - Problem Analysis
- □ OpenQFlow
  - Scalability and QoS Enhancement for SDN
  - **\*** Prototype Implementation
- ☐ Standardization Opportunities
- □ Q & A

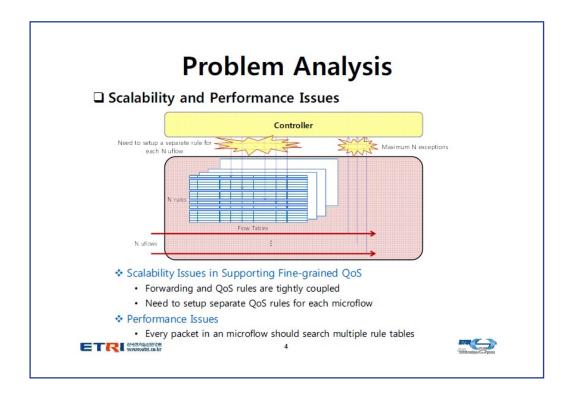






SESSION 5 SDN (I)







SESSION 5 SDN (I)

## **Related Works**

- DevoFlow (Devolved Flow)
  - Minimize the interactions between OpenFlow switches and control led
  - \* Keep flows in the data-plane as much as possible
    - · Provision enough wild-card rules to data-plane
    - · Rule-cloning: microflow-based exact match rules
    - · Determine long-lived flow using statistics sampling or triggering
    - · Controllers get involved in handling long-lived flows
- □ DIFANE (DIstributed Flow Architecture for Networked E nterprises)
  - Distributing the rules across "authority switches"



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# **OpenQflow**

- Objectives
  - To support scalable and stateful SDN which provides microflowbased OoS
- Distinctive Features
  - Clear separation of QoS rules from forwarding rules
  - · Flow learning at microflow level
    - · Learn every information in the first packet processing of a microflow
    - · Simplify forwarding for the subsequent packets in a flow
  - Fine granular flow management regardless of the granularities of forwarding and QoS rules
    - Coarse granular forwarding and QoS rules aggregation of forwarding and QoS rules
    - · QoS profile types of QoS rules
      - E.g., if (DSCP value = 10) then 10Mbps guaranteed bandwidth for each flow





SESSION 5 SDN (I)

# OpenQflow (cont'd)

### □ Distinctive Features (cont'd)

- Complex packet processing in edge node but simpler processing in core node – SDN header
  - Flow label an unique identifier for each microflow in an SDN domain
    - Does not necessarily mean that each and every microflow has its own flow label; flow label is sharable among multiple best-effort flows
    - e.g., best effort traffic share one single flow label to next hop node
    - Short-lived flows may not need to have a separate flow label as well
  - · QoS information
    - QoS type, rate, delay, jitter, etc.



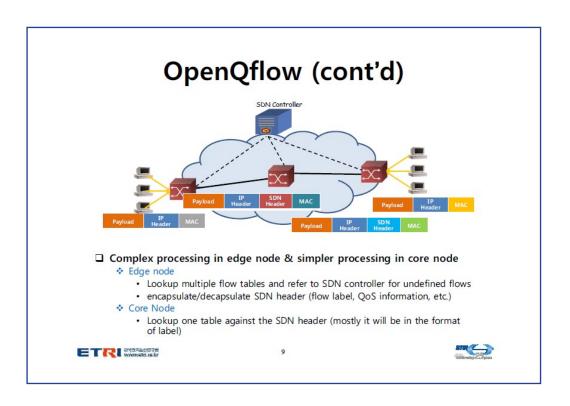
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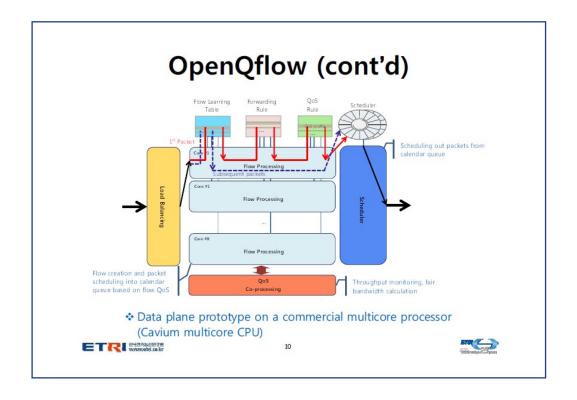


# Controller Separate Rules for Forwarding and QoS Flow Learning Exception is not required Separation of QoS rules from Forwarding rules Multiple micro-flows could share one QoS profile Performance Enhancement Only the first packet goes through all the complex packet processing and then learn the information into flow state table All the subsequent packets are processed according to the flow state table



SESSION 5 SDN (I)







SESSION 5 SDN (I)

## **Standardization Activities**

### □ ONF

- OpenFlow Switch Specification OF 1.4 (08/2012)
  - · open communication protocol between control plane and data plane
- OpenFlow Management and Configuration Protocol OF-Config 1.1
  - · remote configuration of openflow switch

### □ IETF & IRTF

- ForCES
- SDNP BoF, SDNRG

### □ ITU-T

- \* Q.21 of SG13 Future Networks
  - · Y.FNsdn Framework of software-defined networking
  - Y.FNsdn-fm Requirements of formal specification and verification methods for SDN

### □ ETSI

❖ NFV ISG



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# **Standardization Opportunities**

### ☐ Forwarding Architecture

- Separation of QoS rules from forwarding rules
- Flow learning table

### ☐ Scalable Stateful SDN - SDN header

- ❖ Flow label make simpler packet processing in core node
  - · Default flow label for short-term and best-effort flows,
  - · or separate flow label per each flow for enhanced packet processing
- QoS information enhanced QoS processing
  - · Label-inferred packet processing,
  - or separate encoding for explicit QoS treatment (QoS type, rate, delay jitter, etc.)

### ■ Where?

- Study feasibility in ITU-T and/or ETSI in framework level
- Creation or modification of protocols should be done in ONF and/or IETF



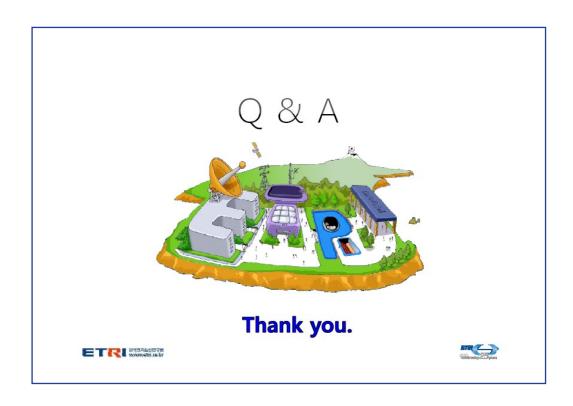
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SESSION 5 SDN (I)







Presentations SESSION 5 SDN (I)

### Service Orientation in Software Defined Networking

### **Abstract**

The entire spectrum of Networking and Communication Services has been evolving towards a programmable model that promises of creating greater values by fabricating a unified serviceable environment. A programmable-serviceable contract needs to be established between stakeholders of such unified environment, essentially leading to phenomena that will enable communication services like Collaboration, Social Media, Rich Media Video, and Internet of Things to attribute to the composition of larger scale business centric services. The key aspect to consider for industrialization is, to integrate the contractual obligations into the Network Centric services layer, having retained the programmable-serviceability characterization.

There are certain environmental inconsistencies that essentially pose challenge to establish the contractual obligations of required scale; some are due to the variants, and some due to the invariants present in the environment. The variants often cause inconsistencies due to diversities associated with the multi-vendor environment, vendor specific programmability support, variations of transport mode, faults & impairments, and cross impacting and propagating nature of the faults. In contrast, the invariants in the environment are largely governed by the fixed Network Architecture, fixed Positioning of Elements and defined Roles & Responsibilities, preset Integration Reference Points and fixed level of adoption for programmability.

This paper analyzes the ways forward and realizes the dimensions that need to be added in existing SDN programmability model, to help construct the unified serviceable environment with required amount of control, agility and stability. These are:

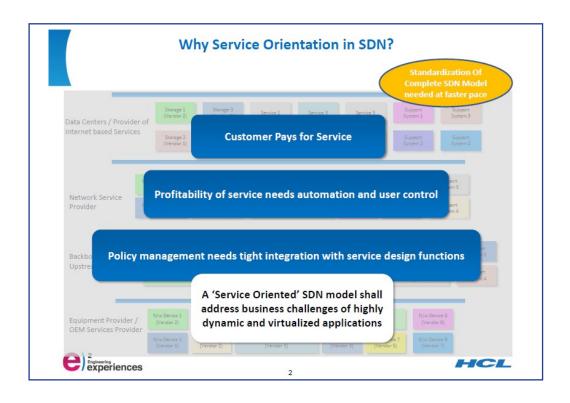
- Establishment of meta-information-model for complete service creation, as will be required to introduce service agility in a predetermined network architecture
- Structural Abstractions to gain control over defined roles and responsibilities of key network positioning, as will be essential for Service Creation & Orchestration
- Behavioural Abstraction over dynamic capabilities will help monitoring real-time change in environment and help augment the Service Orchestration
- Accelerated and Systematic adoption of programmability will streamline and create definitive Service Delivery

Adoption of the proposed means can potentially help aligning the environment fabric to identify the models to attain gradual consistency, for both varying and non-varying factors discussed. And while this can assure the controllability and scale, this in turn shall help the environment to organize for a converged service orchestration capability. The present silos of orchestration for each service shall be overridden as each element present in the chain of responsibilities become collectively responsible for constructing the unified serviceable environment. Further, during the process of concluding, the paper recommends few areas that can be considered as subject of Technical Research and Specification development.



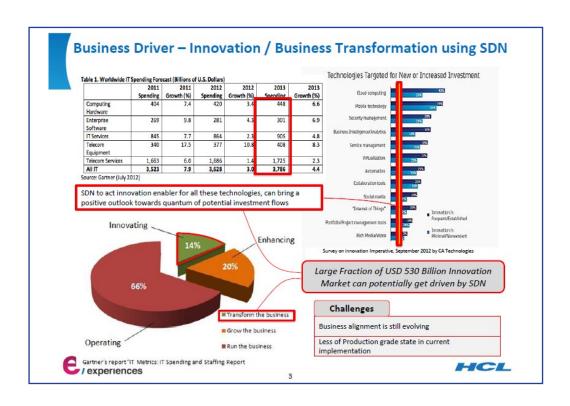
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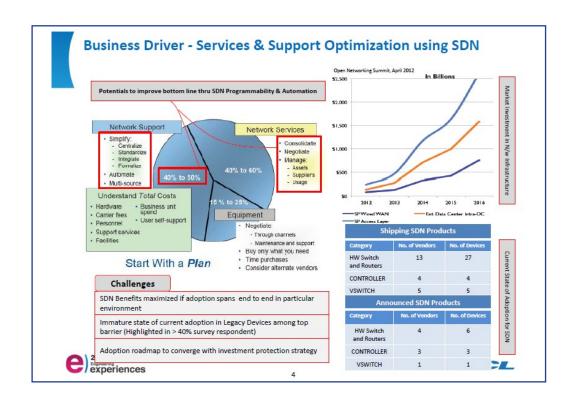






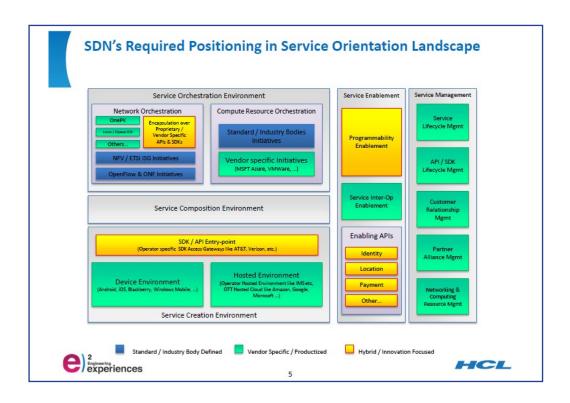
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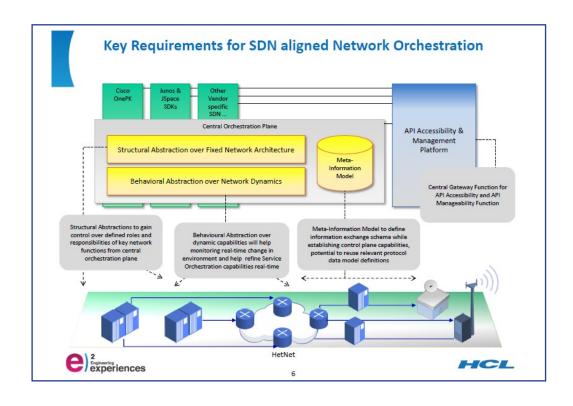






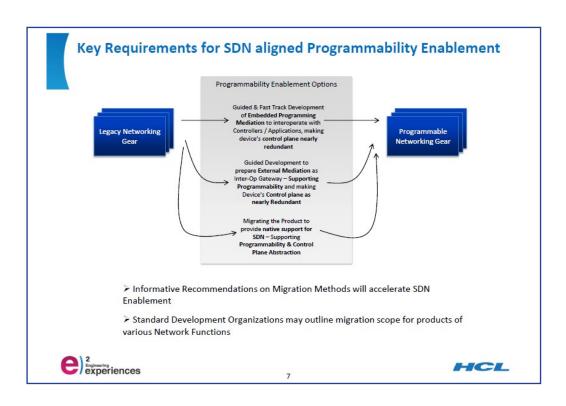
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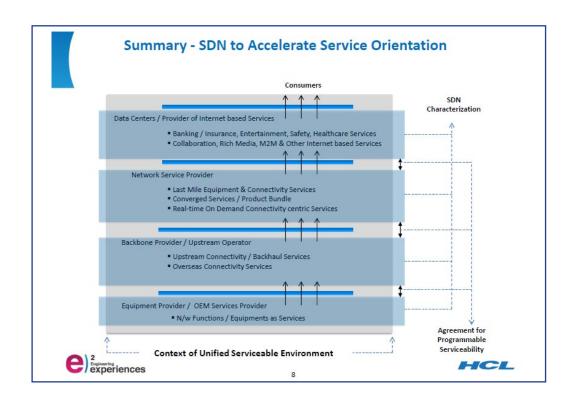






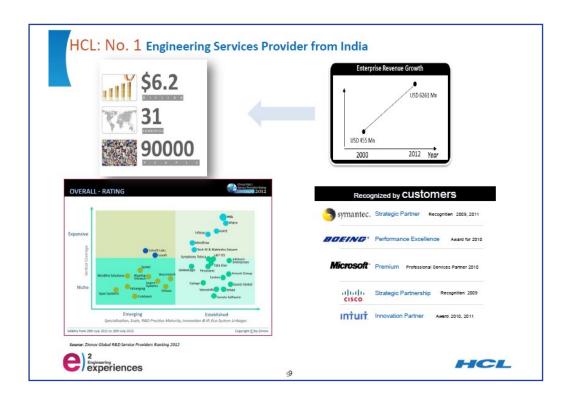
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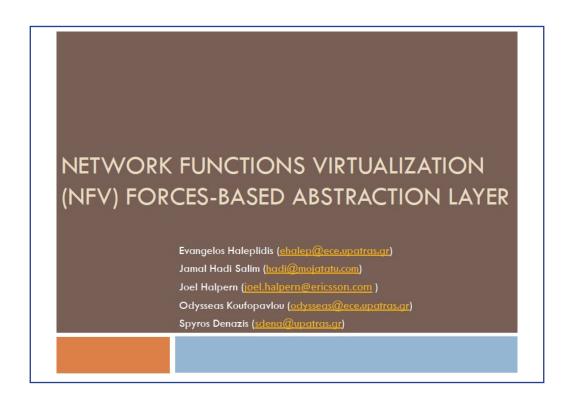


SESSION 6 SDN (II)

#### NFV ForCES-based abstraction layer

#### **Abstract**

Network Functions Virtualization is expected to play a key role in the future of networking. One key element for the success of NFV is the definition of an abstraction layer based upon which NFV can be realized. Such a layer must be accompanied with an abstraction model that defines function building blocks that aggregated in a specific graph will deliver one specific Network Function. Such an abstraction layer/model provides the ability to virtualize and isolate functions between users, ensure interoperability between different physical infrastructure as well as apply a common API for management. Additionally it will need to provide forward-compatibility as new network functions are realized and deployed. The ForCES model (RFC5812) provides an adequate level of granularity and abstraction to achieve this goal. The model can be used in all layers, from description of the forwarding plane to the definition of service parameters in the service plane. Accompanied with the ForCES protocol (RFC5810) for managing model entities, ForCES provides a powerful and extensible architecture for the empowerement of NFV with the additional benefit of being part of the SDN concept of programmability. The presentation will focus on how ForCES is suitable/applicable for NFV along the concepts described above.



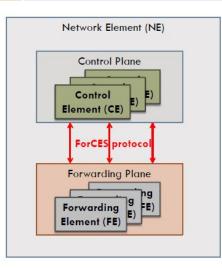


SESSION 6 SDN (II)

### Goal

- Define and Deploy Network Functions (NFs) (NFV-related)
  - White paper clearly defines problem statement
  - □ NF Abstraction model to enable common handling of NFs
- □ Integrate deployed NFs into datapath (SDN-related)
  - Required for faster and reliable deployment of NFs
  - Requires separation of control/forwarding plane
- □ Can we do both with the same framework?

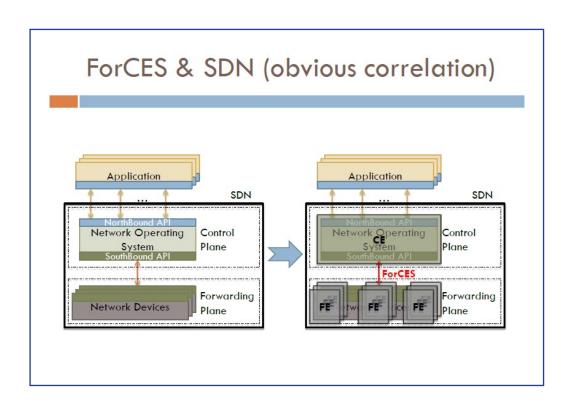
# (Enter) ForCES Framework

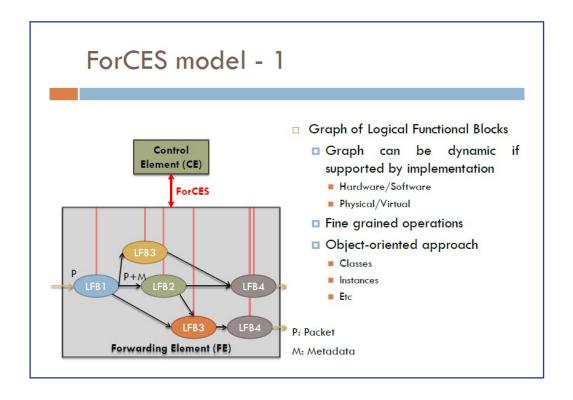


- Network Element (NE)
  - Packet Processing Entity
  - Constitutes of CEs & FEs
  - Multiple CEs to FEs for HA
  - CEs/FEs Physical or Virtual
- NE components distributed
  - Local (within one box)
  - Geographical distributed (LAN/WAN/Internet)



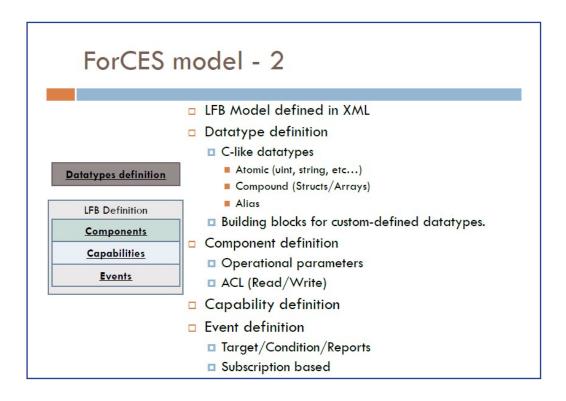
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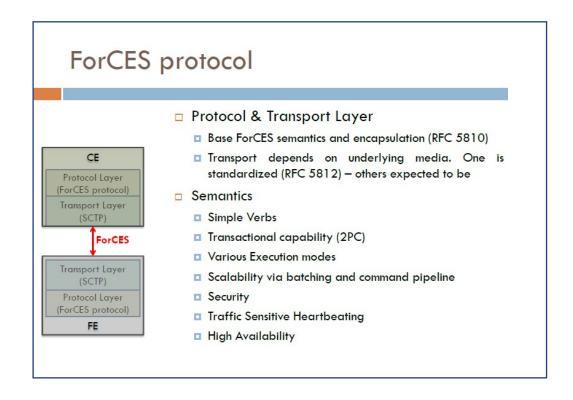






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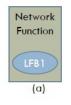
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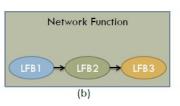
# So? Why ForCES for NFV?

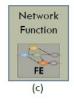
- Initial ForCES design for controlling forwarding engines
- BUT!
- Model is:
  - Extensible/Powerful/Descriptive
  - Unrelated to physical/virtual implementation
- Protocol is:
  - Rich in features
  - Agnostic to the model
- Conclusion:
  - ForCES defines a base abstraction layer for any separation
  - Can be applied where operational parameters are defined

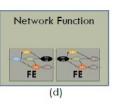
# ForCES & NFV - ForCES NF definition

- Define a Network Function (NF) as either:
  - An LFB (a) or a series of LFBs (b) (LFB chain)
    - An LFB chain may go across FEs (new charter work)
  - An FE (c) or a series of FEs (d) (FE chain)
- Immediate gain: Manage operational parameters of NF







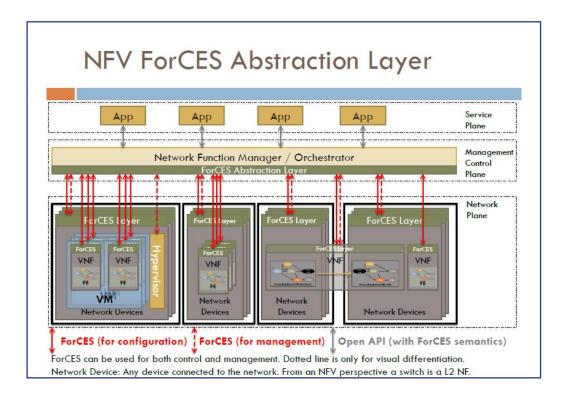




SESSION 6 SDN (II)

## ForCES & NFV - Overview

- □ ForCES model:
  - Does not care if NF is virtualized or not
  - Components are the operational parameters of the NF
- □ ForCES protocol (one for all):
  - Instantiate/Destroy NFs (Define Hypervisor as an FE)
  - Connect LFBs within same FE (current proposed standard) or interconnect with other FEs (new charter work) NFs
  - One protocol for both network device management & NF deployment and configuration





SESSION 6 SDN (II)

# ForCES & NFV – Use Cases (1)

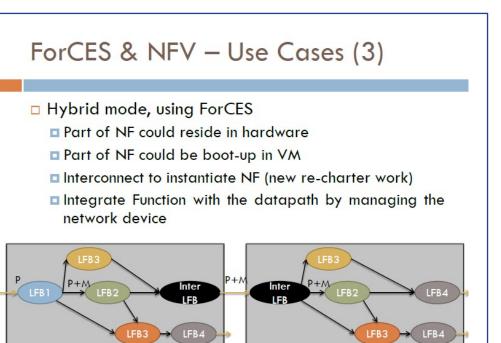
- On existing hardware, using ForCES
  - Locate Network Devices that support the NF
  - Instantiate and configure the operational parameters of the NF
  - Integrate NF with the datapath by managing the network device

# ForCES & NFV - Use Cases (2)

- On virtual machines, using ForCES
  - Boot-up required VMs with required NF based on profile
    - FE Manager LFB (hypervisor)
  - Initial configuration of NF
  - Integrate Function with the datapath by managing the network device



SESSION 6 SDN (II)



Forwarding Element (FE) (VM)

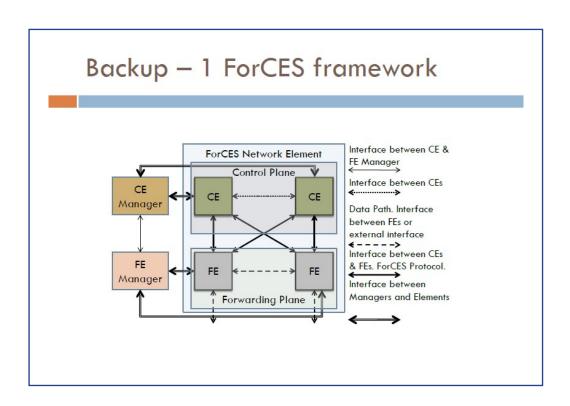
### IETF ForCES & ETSI NFV ISG Activities

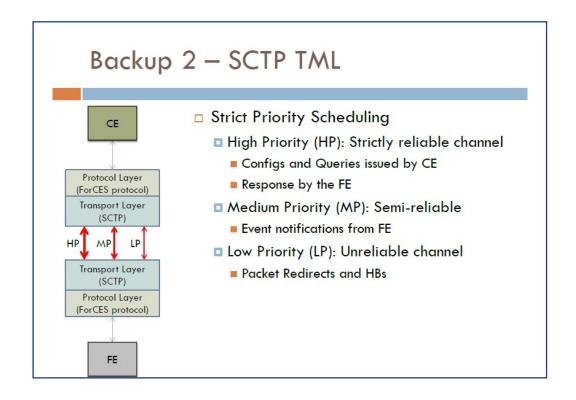
Forwarding Element (FE) (Hardware)

- Standardize the operating parameters & a base LFB of Network Functions
- Coordination between with IETF ForCES working group and ETSI NFV ISG
- □ ForCES can be used for the northbound interface (orchestrator to apps) (not in recharter)
  - Requires minor changes to ForCES protocol (for clean solution)
- □ Service chaining ForCES FEs & LFBs for VNFs
- Bootstrapping & dynamic element insertion interfaces



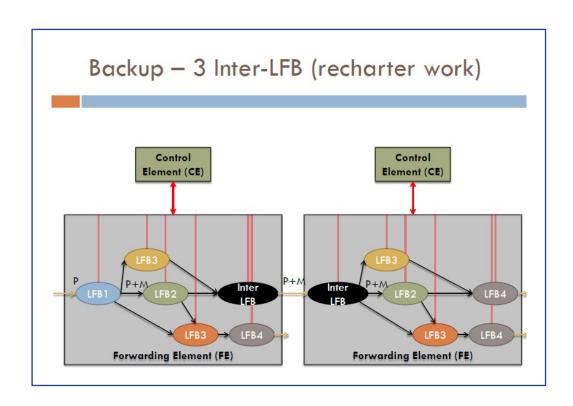
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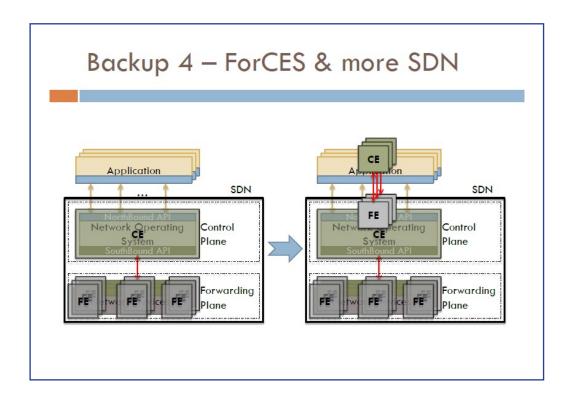






SESSION 6 SDN (II)







SESSION 6 SDN (II)

# Backup 5 - Boot up profiled VM

- On virtual machines, using ForCES
  - Boot-up required VMs with required NF based on profile
    - FE Manager LFB (hypervisor-style)
    - Array of FE and LFB instances that will be instantiated per Function and the connection graph
    - Array of "Locations" for instantiation
    - Array of instantiated Functions (Array of {Function, Location}). (Set the array == instantiate FE)
  - Initial configuration of NF
  - Integrate Function with the datapath by managing the network device

# Backup 6 - Define a new NF

- □ Model LFB(s) (e.g. using UPatras ForCES DSL)
- Parse model and generate code (e.g. with Mojatatu SDK)
- Write specific hardware code (if missing)
- Instantiate/Deploy with FE Manager LFB



Presentations SESSION 6 SDN (II)

#### NfV and SDN in Future Carrier Networks

#### 1. Abstract

Facing declining revenues, the telecom industry focuses on, firstly, reducing costs by consolidating network infrastructure and, secondly, generating new sources of revenue by opening network capabilities via virtualized cloud infrastructures. Virtualization, in turn, is promoting a mind shift that has focus on core competences as its defining characteristic. This mind shift is about to change the current business ecosystem to the one, in which physical infrastructure resources (computing, network, storage, sensors...) are pooled together by brokers and delivered to specialized service providers, who then implement their own network functions on these resources.

Among enabling technologies supporting this change, Cloud Computing technologies and Software Defined Networking (SDN) are the most important ones. In an environment, in which any required functions can be dynamically allocated to physical nodes, resource orchestration and "virtual to physical" embedding mechanisms will become key topics. They will be followed by the need to define and standardize interfaces for resource publication, discovery and monitoring and methods for service level agreement (SLA) automation. Such an environment would be an efficient instantiation of ETSI's current vision for Network Function Virtualization (NFV).

This paper describes details on our research on these topics, along with our vision of future network architecture, in which many functions are delivered as a service by possibly different players. Besides, we identify requirements for the functional blocks involved in the interaction between Physical Infrastructure Providers (PIPs) and brokers. These blocks are logically responsible for resource management, orchestration, negotiation and monitoring. Finally, we show the roles of Cloud Computing technologies and SDN in realizing this architecture

#### 2. Introduction

Declining revenues and increasing operational costs are forcing network operators to rethink the ways they operate their networks and provide their services. Technologies such as Cloud Computing, Software Defined Networking [1]-[2] and Network Virtualization [3] are clearly pointing to the main directions to be taken by the network operators. Wherever possible (e.g. allowed by strict performance requirements) both end user services and network functions are provided on top of common hardware and software platforms in order to reduce their operational costs. The latter is for example the primary scope of the ETSI ISG on Network function virtualization (NFV). At the same time, physical resources are pooled together and sliced when and as needed, in order to deliver a service, leading to their higher utilization and further OPEX reduction.

Yet, we wonder what is beyond this change, i.e. what next change we can expect to see once the mentioned technologies and solutions are adopted fully by the networking industry? This document provides our answer to this question. In short, we believe that this next big change, i.e. the future network, will be characterized by the further adoption of the principle of focusing on core competences, already introduced to some degree by the ongoing change. We believe that the mentioned technologies will evolve in such a way to enable a horizontal market division in which distinct market players will be responsible for operating physical infrastructure, brokering the infrastructure and providing end user services.

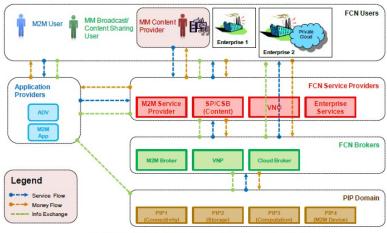


Figure 1: Future Carrier Networks Ecosystem



SESSION 6 SDN (II)

As shown in Figure 1, the future business ecosystem will comprise the following four key actors: the User, the Service Provider (SP), the FCN Broker, and the Physical Infrastructure Provider (PIP). The main roles they play in the ecosystem are as follows. Physical Infrastructure Providers consolidate physical resources, pool them together and expose them as service to service providers or any other entity that can add value and resell them further. For what concerns Service Providers, it is unrealistic to expect that they will focus on both interfacing the user (i.e. understand the semantics and any details of the service they deliver) and supervising the PIPs that provide the physical infrastructure to host the services. This role will, in our opinion, be taken on by another player that we call FCN broker. The presence of FCN broker represents a strong discontinuity with respect to current telco ecosystem. Its role is to provide the service provider with a tailored virtual telco infrastructure, efficiently exploiting all available infrastructures, regardless of their location and/or ownership.

Assuming the ecosystem described above is in place, the key challenges addressed in the paper are:

- Defining an architecture (comprising logical functions and logical interfaces) allowing the proper interactions among key players, enabling the dynamic instantiation of virtual infrastructures required by SPs to provide services to users;
- Specifying a methodology, within the devised architecture, allowing:
  - The PIPs to publish the inventory of the available physical infrastructure;

The FCN Broker to interpret service requests issued by SPs, and to instantiate efficiently the required virtual infrastructure, according to combined economic and technical constraints and to the negotiated Service Level Agreements (SLAs);

The SP to operate the virtual infrastructure, while providing the service to the users;

The Broker and the PIPs to manage and monitor the virtual infrastructure, ensuring fulfillment of SLAs.

The focus of this paper is on a particular aspect of the lower part of the picture, i.e., the interaction between PIPs and an FCN broker, although we touch upon certain aspects of operation of service providers as well.

The rest of the paper is organized as follows:

- Section 3 examines prior art.
- Section 4 describes the proposed architecture and its functional blocks.
- Section 5 provides details about the functional phases involved in the resource orchestration process.
- Section 6 describes the relation between NFV and the proposed orchestration framework.
- Section 7 draws the conclusions.

#### 3. Related work

A network virtualization architecture is proposed in [4], including both technical and business details. The paper identifies the four following roles: Physical Infrastructure Provider (PIP), Virtual Network Provider (VNP), Virtual Network Operator (VNO), and Service provider (SP). Even if the role names are to some degree biased by a specific service to be delivered, namely network connectivity, the proposed ecosystem is very similar to what we described in Figure 1. However, beyond the ecosystem roles, our paper develops in more technical details how PIP and broker should interact.

A new business model for virtual networking environment is proposed in [5]. The business model, used as basis for the definition of service-oriented network virtualization architecture, is inspired by two existing models: the TINA-C model [6] (from the classical telecommunications sector) and the web service composition model [7]-[8]-[9] (stemming from the Internet). The paper proposes a Service Oriented Hierarchical model, which includes 5 business roles: the Physical Infrastructure Provider, the Service Provider, the Virtual Infrastructure Provider, the Consumer and the Service and Resource Registry (SRR). Although apparently the high level description of both business model and architecture are quite compliant with the subject of the current paper, the paper lacks details necessary to understand a eventual match between the two architectures going beyond names and definitions.



SESSION 6 SDN (II)

In [10] the authors present their Network Configuration Platform (NCP) for creating virtualized mobile operator networks. While their work focuses on technical and geographic classification, our focus is on the business classification that is required to realise a complete virtualization solution. Contrary to our architecture, theirs is a flat NCP with interfaces to the different technical domains that need to be combined to create a mobile operator network. Although similar ideas can be found in our paper, we tried to generalize these ideas to the environment of Future Networks and integrate concepts such as Negotiation and Monitoring.

Several papers like [11]-[15] disclose a number of algorithms to embed requests for virtual networks into the underlying physical substrate. As such they specify details on internal operation of one of the modules we find important for internal operation of the PIP. Yet, our focus here is on defining the architecture of the PIP and broker and interactions between their functional blocks.

#### 4. Future Carrier Network: Reference Scenario and Architecture

In future, a plurality of physical infrastructure providers will coexist to enable provisioning of various services to end users. Services are not directly provisioned by the PIPs. Instead, service providers rent infrastructure from appropriate PIPs. Therefore, the appropriate model in this case is NaaS (Network as a Service), where NaaS is understood as a generalization of the concept of IaaS from the Cloud Computing area, explicitly involving network device modeling and dynamically provisioning the latter owing to SDN. Another fundamental difference to existing IaaS offerings is that service providers may rent resources from multiple PIPs, rather than from one. This is depicted in Figure 2: brokers specialise on maintaining information on available infrastructure at various PIPs and on interacting with PIPs in order to distribute service providers' request onto the selected infrastructure in a most cost efficient way.

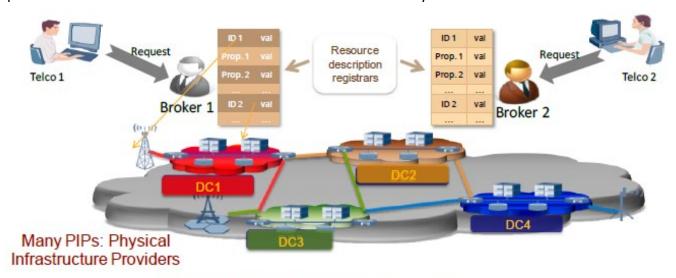


Figure 2: Future Reference Scenario

To realize such a scenario, the key is to understand the required interactions between the brokers and the PIPs, as well as between service providers and brokers.



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#### 4.1 Architecture Overview

Figure 3 shows how the controllable and programmable resources (the block denoted as SDN-C at the left) are made available to the Service Providers (respective block at the right) through PIP and Broker orchestration. It identifies the typical interactions between the four major blocks SDN-C, multiple PIPs, Brokers and Service Providers. Additionally, for the newly introduced entities it identifies the internal functional blocks and the interactions between the later. Note that the service provider is out of the scope of this paper. As depicted in Figure 3, both Broker and PIP entities have the following internal functional blocks:

- Orchestrator
- Negotiator
- Resource manager
- Monitoring manager
- Database

However, the logic built into these modules, the information maintained in the databases and the algorithms executed in them are slightly different for PIPs and brokers. We will make this clear in the remainder of this section. The main scenario depicted in Figure 3 is as follows:

- A broker receives a service request from a Service provider. The requested service is presented as a
  Virtual Network (VN) graph, essentially providing information about what resources the provider needs
  and what their properties should be (SLA). More details are provided in Section 4.2.
- The broker's goal is to divide this VN graph into a number of VN subgraphs and to distribute these to the most appropriate PIPs. The broker has to find the most cost-effective yet SLA fulfilling distribution of the original graph.
- On the side of PIPs, whatever request is accepted to be hosted at the PIP's infrastructure, a PIP-internal
  orchestrator makes sure that the request is mapped onto the physical infrastructure in a way that fulfils
  the internal goals of the PIP, e.g. optimizes the resource utilization ratio.

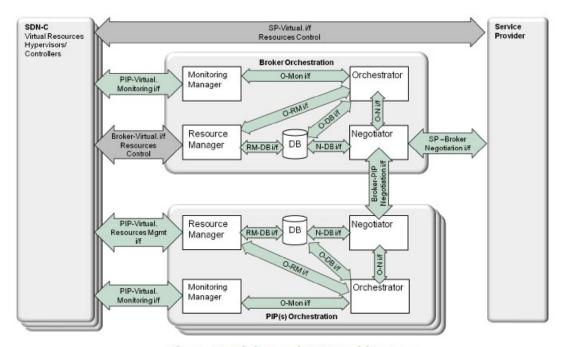
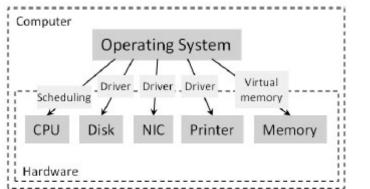


Figure 3: High Level FCN Architecture



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The development of techniques to embed network appliances into virtualized substrates is a fundamental enabler for this architecture to become reality. Figure 4 compares the concepts of Operating System for a computer and Orchestrator for a network; all physical resources are programmable and expose suitable APIs (openness) by means of interfaces enabling automation and seamless integration of the cloud infrastructure. From now on we will refer to SDN controller as a broader entity than it is often understood today: SDN controller is any platform that leverages on virtualization techniques to integrate physical resources (compute, memory, network) in a cloud infrastructure.



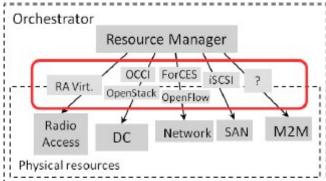


Figure 4 - SDN enablers and Resource Management

We identify the following functional blocks within the broker and the PIPs and describe them briefly as follows:

#### PIP:

- Orchestrator is responsible for finding an optimal mapping (assignment) of brokers' requests to the
  underlying physical infrastructure. A typical example of optimization performed by the orchestrator is
  maximizing the number of successfully embedded service requests from various brokers in the physical
  infrastructure of the PIP.
- Negotiator should maintain logic to assess if a request from a broker will be accepted or not. It can contact
  the orchestrator to calculate if it is possible to embed the request into the current infrastructure and, if
  possible, to calculate the state of physical infrastructure when the request is realised. We believe that
  negotiator should implement a complex mapping from a number of input variables to a (set of) price(s) to
  be exposed to brokers, i.e. made public. The input variables should be: state of own individual resources,
  histories of request (translating into beliefs about future requests) and, optionally, prices of other PIPs.
- Resource Manager: the Resource Manager (RM) at PIP is the functional block responsible for the direct
  management of the underlying infrastructure. The PIP RM interacts with SDN Controllers, exploiting their
  virtualization capabilities. In a sense, the RM serves as a driver, mapping high level requests from other
  functional blocks into low level commands specific to virtualization environments.
- Monitoring Manager: Each virtual resource hosting a service graph's component is monitored to verify
  the fulfilment of the offered SLA. This is the main task of the monitoring manager. The PIP orchestrators
  may consider the reports as an input to re-calculate the embedding of the service graphs.

#### Broker:

Orchestrator is responsible for splitting the service request (coming in form of a graph) into pieces and
distributing them to the PIPs. For instance, the orchestrator could try to find the service splitting with



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the minimum price. The service requirements (SLA) are taken as constraints that have to be satisfied. The prices published by the PIPs are used to estimate the service price.

- Negotiator is responsible for making a price offer to the service provider. Similarly to the negotiator of
  a PIP, a broker's negotiator collects a number of inputs and maps them into a price to be offered to the
  service provider. The inputs can be (but are not limited to): the price estimate from the PIPs, possibly
  estimates of what other brokers might offer for the same request, history of deals made with the service
  provider in question and so on.
- Resource manager: A broker's resource manager maintains the broker's management access to the
  relevant virtual resources. Unlike the PIP's RM, it is only responsible for maintaining and managing the
  access info for the management of the virtual infrastructure at brokers and SPs.
- Monitoring Manager: the Monitoring Manager at the Broker is responsible for the management of the
  global monitoring of the whole instantiated virtual infrastructure. For each Service Request instantiated,
  the Monitoring Manager collects monitoring data from all concerned PIPs, assesses performance for the
  instantiated infrastructure, verifies compliance to established SLAs, and triggers countermeasures in case
  SLAs are not fulfilled.

#### 4.2 Service graphs

As anticipated in Section 4.1, the service provider submits the service requests in the form of a VN graph. The broker splits the request in VN sub-graphs to embed them into virtualized substrates possibly belonging to different PIPs. The abstract description of the VN requests is a fundamental enabler for employing embedding algorithms in the orchestrators. The resource and appliance description formats can be derived from IaaS and virtual appliances description languages like OCCI [18], VXDL [19] and OVF [20]. A detailed description of VN graph structure is not in the scope of this paper, we will just introduce some basic requirements. Each node and link of the graph (component, in short) is characterized by the requested capacity and Service Level attributes.

The components of the VN graph correspond to:

- Processing elements: characterized by capacity requirements such as number of CPUs and amount of memory (RAM) and, optionally, the geographical location;
- Storage elements: amount of storage and, optionally, the geographical location;
- Forwarding elements: characterized by switching capacity requirements, latency and, optionally, the geographical location;
- Connectivity requirements requirements: links between the components that have data dependencies; the graph specifies the bandwidth and latency requirements of the connections.

Each service graph component may be also characterized by Service Level (SL) attributes, organized in two groups according to [16]:

- Data policies: defining constraints related to resources availability, redundancy, data location, preservation and privacy;
- Business policies: guarantees, payment and penalty models.

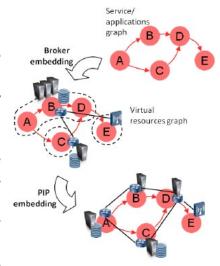


Figure 5 - VN graph embedding in PIP and Broker



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The embedding is performed at different levels by Brokers and PIPs (see Figure 5). Examples of embedding algorithms can be found in [11]-[15] and graph scheduling in [17]. The embedding consists in translating service requirements into resources allocation, dynamically re-evaluating the allocation as a consequence of:

- new incoming requests
- changes in the costs of the infrastructure
- evolution of the offered infrastructure
- monitoring reports about SLA fulfillment

For this purpose, the information model must support:

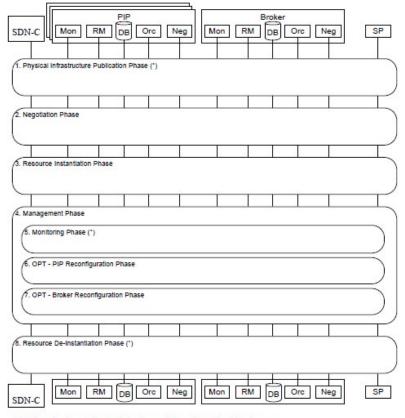
- Different levels of abstraction (physical -> virtual -> service graph);
- Resource elasticity, to offer short term expansion capabilities;
- Resource granularity, to ensure efficient allocation.

#### 5. Method for Dispatching Service Requests to Multiple PIPs

We now provide operational details of the above architecture. We specify what each of the involved components is supposed to do and how they contribute to realizing the final goal of the architecture, pooling physical resources together and delivering customer services from a set of physical resources that may belong to different physical infrastructure providers.

#### 5.1 Method Overview

Figure 6 shows an overview of the method, where key phases are highlighted



(\*): Triggering Events for Optimization and Reconfiguration Algorithms

Figure 6: Service Request Dispatching Method Overview



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- 1. Physical Infrastructure Publication phase: this phase is triggered, whenever a change in the status of any Physical Infrastructure (PIs) relating to any PIP occurs. This phase allows both PIP DBs and Broker DBs to be updated at any time, according to the latest status of available PIs.
- 2. Negotiation Phase: this phase is triggered when a SP issues a Service Request to the Broker. During this phase, the Broker determines the optimal embedding solution (according to economic and technical criteria) for the Service Request, identifying the optimal partitioning among available PIPs, reserving the required resources at the involved PIPs, and negotiating SLA and price with the SP.
- 3. Resource Instantiation Phase: this phase is triggered whenever a Negotiation Phase is successfully concluded. During this phase, the Broker commands the instantiation of the defined embedded solution to the involved PIPs. The PIPs leverage on SDN controllers (identified in Figure 6 as SDN-C) to instantiate the physical resources; after the virtual infrastructure is instantiated, Access Information is distributed to Broker and SP, and the monitoring of virtual infrastructure is initialized.
- 4. Management Phase: after the instantiation has been successfully completed, the instantiated infrastructure is managed by the involved parties;
  - a. Monitoring Phase: during the Management Phase, the Monitoring Phase also continuously takes place. The purpose of this phase is to monitor the status of all involved resources in order to assess system performance, verify SLAs fulfilment, and eventually trigger infrastructure reconfiguration.
  - b. PIP reconfiguration Phase: this phase is triggered whenever at a given PIP some conditions occur, making an embedded solution not anymore optimal. During this phase, the concerned PIP devises and instantiates a new embedding solution. This phase is transparent to both Broker and SP.
  - c. Broker Reconfiguration Phase: this phase is triggered whenever some conditions, making an embedded solution not anymore optimal from Broker perspective, occur. During this phase, the Broker evaluates the opportunity to redefine the partition for the Service Request, renegotiates and reserves resources with the concerned PIPs, and triggers the instantiation procedure.
- 5. Resource De-instantiation Phase: this phase is triggered by de-instantiation requests originated by the Broker or the PIP.

In this paper, we will not provide detailed explanation of all phases. As an example, we will just describe the Resource Instantiation Phase in the following paragraph.

#### 5.2 Resource instantiation phase

The instantiation phase starts as a result of the negotiation phase when a PIP receives a request for instantiating a service graph.

- 1. The PIP negotiator receives an instantiation request for embedding the service graph onto the SDN infrastructure he owns. The service graph specifies the service that needs to be installed and any other supporting info that may be required, such as, the access and monitoring details.
- 2. The negotiator verifies that the request and the price offered are in compliance with what was agreed during the negotiation phase and forwards the service graph request to the PIP orchestrator.
- 3. The orchestrator then executes the embedding algorithm optimizing the placement of the virtualized components over the SDN infrastructure. This optimization may be based on service provider requested parameters (SLA policies in the requested Service Graph, introduced in Section 4.2) or the PIPs own parameters in accordance with the contract set in the negotiation phase.
- 4. This virtual resource to physical resource mapping is saved in the DB.
- 5. The Orchestrator triggers the RM to instantiate these virtual machines in the SDN resources.



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- 6. The RM instantiates the virtual infrastructure over the SDN infrastructure using the virtualization control infrastructure exposed by them.
- 7. Once the instantiation succeeds the RM provides the access credentials and other supporting information to the broker RM. These credentials are important for managing the service by the SP. The broker RM saves this access info to the broker DB and also forwards it to the SP.
- 8. Parallel to step 7 the monitoring infrastructure for monitoring the performance of the service and reporting it to the broker as well as the SP is also set up.
- 9. -10. The SP or the broker may then directly access the virtual infrastructure for network/service configuration and other management issues.

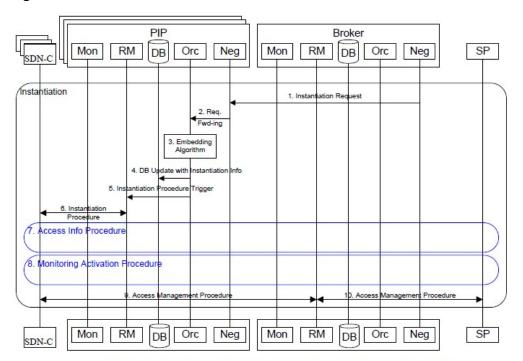


Figure 7: Resource Instantiation Phase Sequence Diagram

#### 6. A Use Case: Network Functions Virtualization

Embedding Carrier grade network functions over Cloud Computing technologies is a significant field of application for the architecture proposed in this paper. NFV Industry Specification Group (ISG) at ETSI has invited "IT and Telecom industries to combine their complementary expertise and resources in a joint collaborative effort, to reach broad agreement on standardised approaches and common architectures, and which are interoperable and have economies of scale" [3]. Network Elements such as switching elements (routers, BNG) and mobile network nodes (HLR/HSS, MME, SGSN, GGSN/PDN-GW...) could be hosted in Commercial-off-the-Shelf IT-platforms. Each Network Element can be formally described by a Service Graph as a structure of elementary functional blocks and connectivity requirements among them. A service graph may also describe a portion of a network.

As an example, Figure 8 shows an hypothetical service graph of a portion of EPS network derived from 3GPP specifications [21]-[22]-[23]. In accordance to the method introduced in Section 4.2, the service request is issued in the form of a Virtual Network graph. The VN graph splits the service in processing elements, forwarding elements, storage elements and connections. At the periphery of the VN graph, the connections



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may end up to empty components, characterized only by their location.

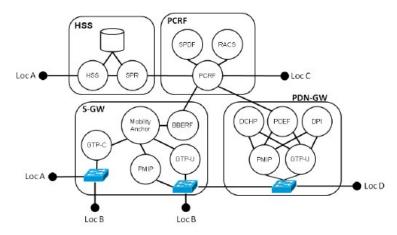


Figure 8: Service Graph of a Portion of Evolved Packet System (EPS)

The PIP and Broker Orchestrators may be implemented as OSS/BSS functional blocks in charge of embedding network functions in the infrastructure offered by one or more PIPs. In this case the service graphs might convey the dimensioning requirements issued by a network planning department of a Telco operator. The PIPs operate physical infrastructures and translate them into virtual resources by means of virtualization controllers, such as:

- Network controllers, for instance OpenFlow [1] controllers such as Nox, Beacon or FloodLight or recent integrated network management controllers such as OpenDaylight [24], managing virtual infrastructures built from general purpose switching gear;
- IT middleware controllers, e.g. OpenStack [25] components, exposing data center resources like compute, storage and communication nodes;
- Radio access controllers managing wireless access points, for instance OpenRAN [26].

Each PIP publishes the virtual resources to one or more Brokers. Each Broker splits network graphs into subgraph by means of embedding algorithms. The PIPs embed virtual network sub-graph into virtual resources; the PIP Resource Manager translates the virtual resource requirements for the underlying virtualization controller.

Running network functions on top of general purpose hardware and sharing wireless access points could allow significant cost reduction for Telco operators. The Orchestration of network functions would enable re-allocating slices of infrastructure to different Network Elements according to evolving dimensioning requirements, replacing networking technologies by re-using existing infrastructures or re-arranging the geographical distribution of the network functions according to the location of the connected devices.

#### 7. Conclusion

In this paper, we describe a future network architecture that we expect to emerge as a result of the recently initiated integration of SDN and Cloud Computing concepts in the telecommunications networks. The new probable ecosystem defines 4 roles (PIPs, brokers, service providers, users) and poses key requirements:

- a) assessing wide ranges/types of service requests issued by SPs;
- b) consolidating physical resources and using them efficiently;
- c) embedding service requests in the most convenient way, both on tech and economical perspective;
- d) monitoring of resource utilisation and performance.

We propose an architecture that slightly redefines the current business ecosystem by introducing business

# Future Networks Workshop



#### **Presentations**

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boundaries between various work items, where they more naturally fit with the currently popular concept of "cloudization". Based on that, we proceed to define logical functions and interfaces between main business players satisfying all requirements above. The proposed architecture also highlights Resource Orchestration to be the key technology to be developed.

We discussed some operational details and propose solution to a concrete use case (NFV).

We find that efficient orchestration is one of the key challenges to be addressed in order to enable flexible architectures like the one we propose here. Unlike most of the previous work, we believe that the properties and underlying concepts of such architectures such as versatility, flexibility and resource usage efficiency will be of paramount importance not only for physical infrastructure providers but also for service providers and users. Besides, the proposed architecture has the potential to create new sustainable business models and roles, as we explain at the example of brokers. The key insight here is that, unlike in previous attempts on brokerage in telecoms, in our architecture brokers have a role going beyond a purely economic perspective: managing low-level resources spanning multiple tenants, brokers have an important technological contribution to the overall ecosystem, on the one hand providing a solid raison d'être for themselves and, on the other hand, breaking the locality and limited reach problems intrinsic to physical infrastructure providers. Similarly to current OTTs, brokers will be able to act on a global scale, reducing service provider's involvement with technical subjects. Owing to brokers, SPs can concentrate on the higher level service properties, ultimately yielding a better overall quality of experience for users.

#### 8. References

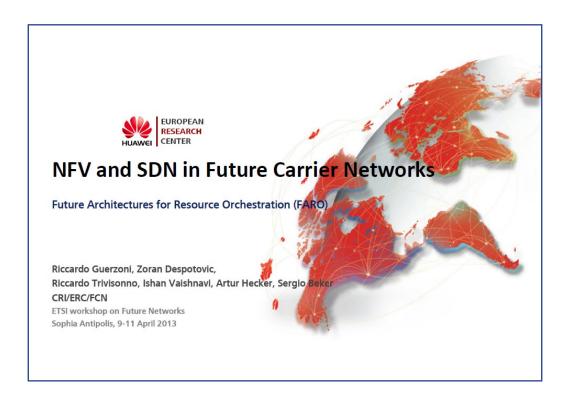
- [1]. McKeown, Nick, et al. "OpenFlow: enabling innovation in campus networks." ACM SIGCOMM Computer Communication Review 38.2 (2008): 69-74.
- [2]. "Software-Defined Networking: The New Norm for Networks." ONF White Paper, https://www.opennetworking.org/
- [3]. "Network functions virtualisation: An introduction, benefits, enablers, challenges & call for action, 2012." White paper, NFV ISG in ETSI, http://portal.etsi.org/NFV/NFV White Paper.pdf.
- [4]. Schaffrath, Gregor, et al. "Network virtualization architecture: proposal and initial prototype." Proceedings of the 1st ACM workshop on Virtualized infrastructure systems and architectures. ACM, 2009.
- [5]. El Barachi, May, Nadjia Kara, and Rachida Dssouli. "Towards a service-oriented network virtualization architecture." Kaleidoscope: Beyond the Internet?-Innovations for Future Networks and Services, 2010 ITU-T. IEEE, 2010.
- [6]. TINA Business Model and Reference Points, v.4.0, May 1997, http://www.tinac.com/specifications/documents/bm\_rp.pdf, accessed 7 June 2009;
- [7]. Web Services Architecture Specification, W3C Working Group Note, Feb. 2004, http://www.w3.org/TR/ws-arch/, accessed 28 July 2009;
- [8]. Papazoglou, Michael P. "Extending the service oriented architecture." Business integration journal 7.1 (2005): 18-21.
- [9]. Karunamurthy, Rajesh, Ferhat Khendek, and Roch H. Glitho. "A business model for dynamic composition of telecommunication web services." Communications Magazine, IEEE 45.7 (2007): 36-43.
- [10]. Khan, Ashiq, et al. "Network sharing in the next mobile network: TCO reduction, management flexibility, and operational independence." Communications Magazine, IEEE 49.10 (2011): 134-142.
- [11]. Chowdhury, NM Mosharaf Kabir, Muntasir Raihan Rahman, and Raouf Boutaba. "Virtual network embedding with coordinated node and link mapping." INFOCOM 2009, IEEE.
- [12]. Lu, Jing, and Jonathan Turner. "Efficient mapping of virtual networks onto a shared substrate." Washington University in St. Louis, Tech. Rep (2006).
- [13]. Zhu, Yong, and Mostafa H. Ammar. "Algorithms for Assigning Substrate Network Resources to Virtual Network Components." INFOCOM. 2006.



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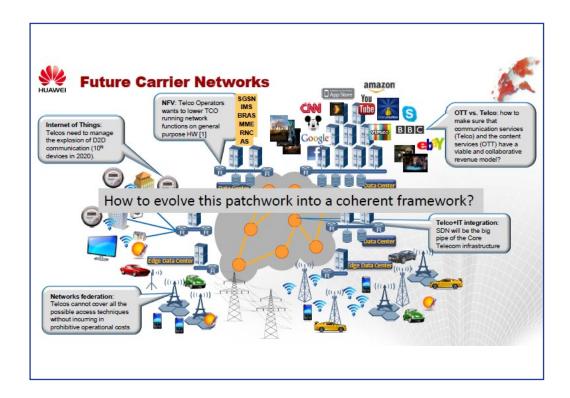
- [14]. Yu, Minlan, et al. "Rethinking virtual network embedding: substrate support for path splitting and migration." ACM SIGCOMM Computer Communication Review 38.2 (2008): 17-29.
- [15]. Houidi, Ines, et al. "Virtual network provisioning across multiple substrate networks." Computer Networks 55.4 (2011): 1011-1023.
- [16]. Practical Guide to Cloud SLA, Version 1.0. Cloud Standards Customer Council (CCSC), April 2012
- [17]. Bittencourt, Luiz F., Edmundo RM Madeira, and Nelson LS Da Fonseca. "Scheduling in hybrid clouds." Communications Magazine, IEEE 50.9 (2012): 42-47
- [18]. Metsch, Thijs, and Andy Edmonds. "Open Cloud Computing Interface—Infrastructure." Standards Track, no. GFD-R in The Open Grid Forum Document Series, Open Cloud Computing Interface (OCCI) Working Group, Muncie (IN). 2010.
- [19]. Koslovski, Guilherme Piegas, Pascale Vicat-Blanc Primet, and Andrea Schwertner Charao. "VXDL: Virtual resources and interconnection networks description language." Networks for Grid Applications (2009): 138-154.
- [20]. Open virtualization format specification v2.0.0, 2011. DMTF Standard, http://www.dmtf.org/standards/ovf.
- [21]. 3GPP TS 23.002, http://www.3gpp.org/ftp/Specs/html-info/23002.htm
- [22]. 3GPP TS 23.401, http://www.3gpp.org/ftp/Specs/html-info/23401.htm
- [23]. 3GPP TS 23.402, http://www.3gpp.org/ftp/Specs/html-info/23402.htm
- [24]. OpenDaylight An Open Source Community and Meritocracy for Software-Defined Networking, OpenDaylight White Paper http://www.opendaylight.org/
- [25]. OpenStack: An Overview, http://www.openstack.org
- [26]. Kempf, James, and Parviz Yegani. "Openran: A new architecture for mobile wireless internet radio access networks." Communications Magazine, IEEE 40.5 (2002): 118-123.

#### **Presentation**





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# Orchestrate all these various services and fit optimally onto the available infrastructure

Good news:

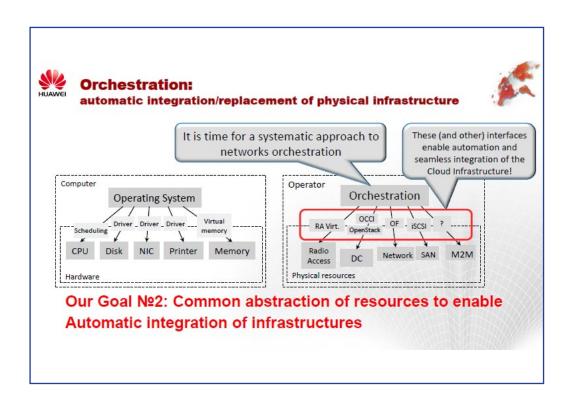
All physical resources are programmable and expose suitable APIs (openness), which make the orchestration possible!

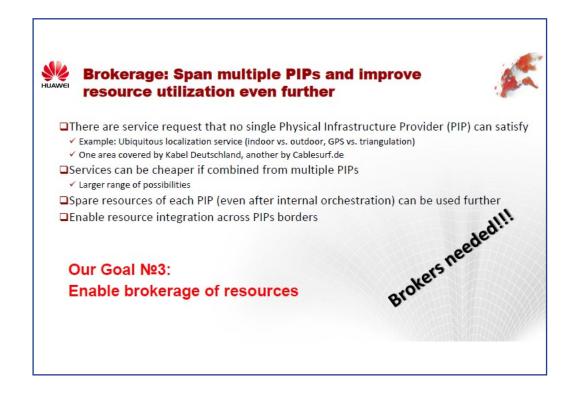
Our Goal №1:

Increase Utilization Ratio of Physical Resources in Each Operator Network



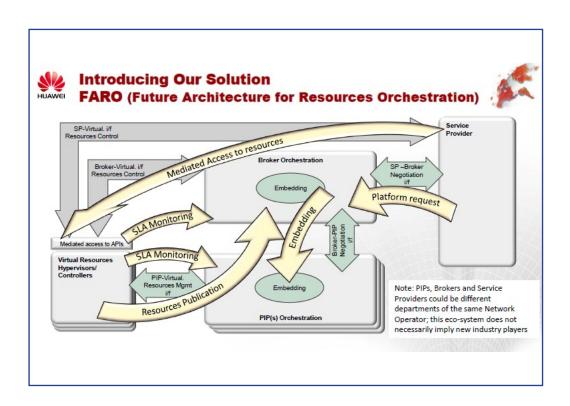
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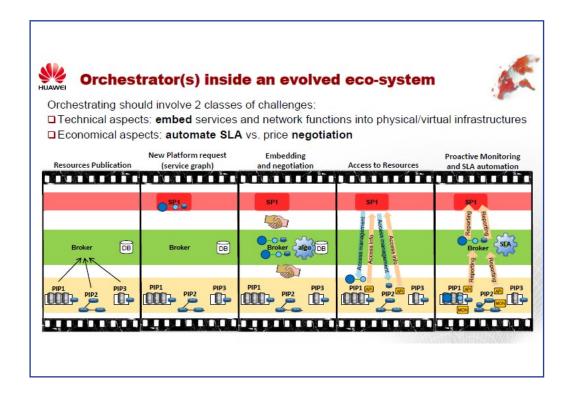






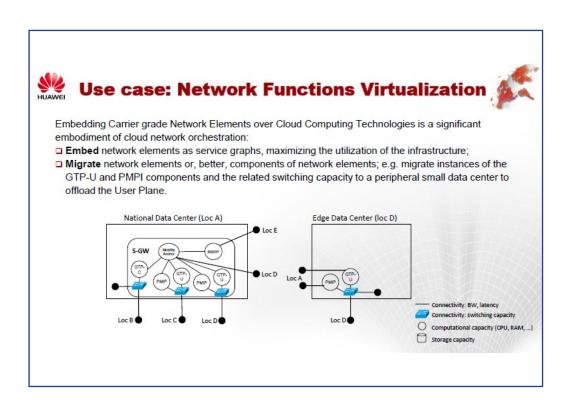
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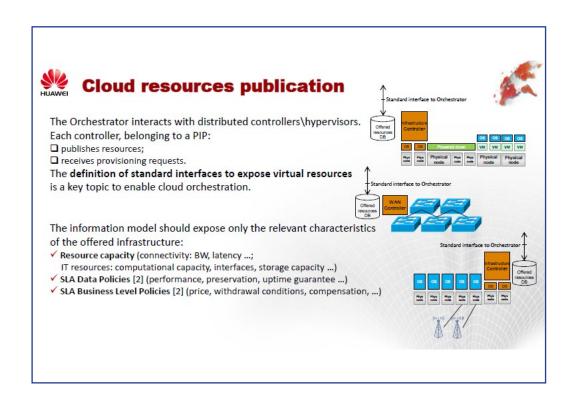






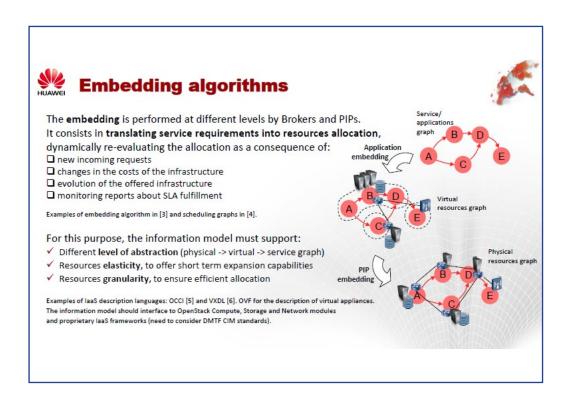
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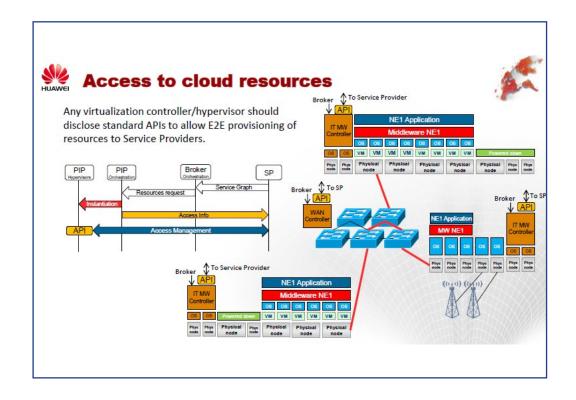






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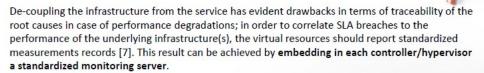




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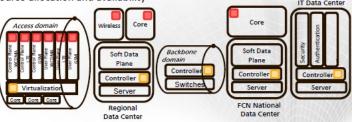
#### **Monitoring**



The figure shows a possible distribution of monitoring servers:

■ Telco Protocols performance over IaaS

Physical/Virtual resource allocation and availability





#### **Conclusions**



Approaching NFV challenges from FARO perspective establishes concrete requirements for the Orchestration platform.

The requirements can be grouped in the following areas of work:

- ☐ Interfaces standardization: resource publication, resources access, resources monitoring;
- □ Embedding algorithms: map service graphs issued by Service Providers and Brokers into virtual infrastructures offered by multiple parties (PIPs);
- Definition of a multi-layer resources and service graphs description framework, enabling SLA automation;
- □ Technology evolution: development of inter-operable virtualization techniques, enabling migration of services/functions through WANs [8].



SESSION 6 SDN (II)



#### References



[1] "Network Functions Virtualisation - An Introduction, Benefits, Enablers, Challenges & Call for Action", NFV Industry Specification Group (ISG) in ETSI, October 22-24, 2012 at the "SDN and OpenFlow World Congress", Darmstadt-Germany

[2] Practical Guide to Cloud Service Level Agreements, CSCC (Cloud Standards Customer Council), April 2012
[3] Chowdhury, M.; Rahman, M.R.; Boutaba, R., "ViNEYard: Virtual Network Embedding Algorithms With
Coordinated Node and Link Mapping," Networking, IEEE/ACM Transactions on , vol.20, no.1, pp.206,219, Feb. 2012
[4] Bittencourt, Luiz F., Edmundo RM Madeira, and Nelson LS Da Fonseca. "Scheduling in hybrid clouds."
Communications Magazine, IEEE 50.9 (2012): 42-47.

[5] Metsch, Thijs, and Andy Edmonds. "Open Cloud Computing Interface–Infrastructure,"." Standards Track, no. GFD-R in The Open Grid Forum Document Series, Open Cloud Computing Interface (OCCI) Working Group, Muncie (IN). 2010.

[6] Koslovski, Guilherme Piegas, Pascale Vicat-Blanc Primet, and Andrea Schwertner Charao. "VXDL: Virtual resources and interconnection networks description language." *Networks for Grid Applications* (2009): 138-154. [7] Guerzoni, Fontana, Beker, Soldani, "A User Centric Troubleshooting Framework for Current and Future Networks", Wireless World Research Forum Meeting 30, April 2013, Oulu-Finland [8] Wood, Timothy, et al. "Cloudnet: A platform for optimized wan migration of virtual machines." *University of* 

# Thank you

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Massachusetts Technical Report TR-2010-002 (2010).

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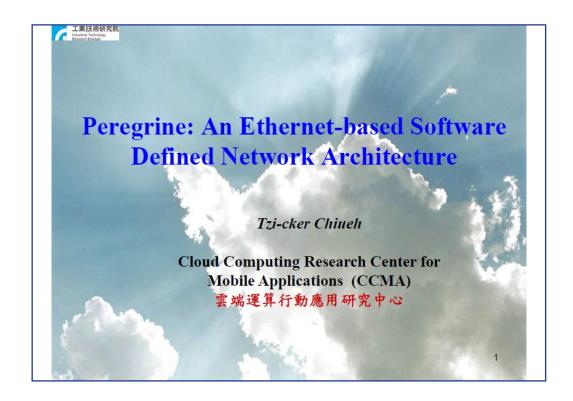
SESSION 6 SDN (II)

#### Peregrine: An Ethernet Switch-based Software-Defined Network Architecture for laaS

#### **Abstract**

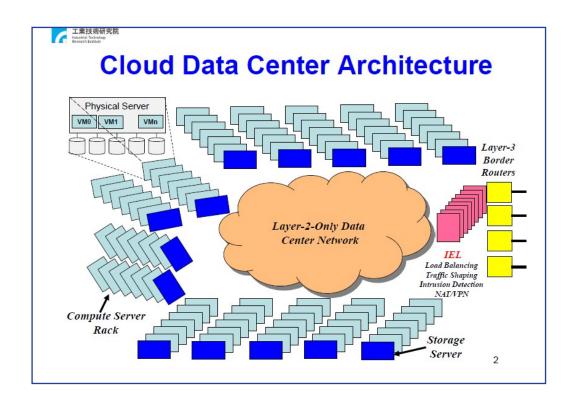
Peregrine is a software-defined network architecture designed to run on commercially available Ethernet switches and support the kind of network virtualization as required by AWS-like laaS.

Rather than using a traditional data center network architecture, which is typically based on a combination of Layer 2 switches and Layer 3 routers, Peregrine is built on layer-2 switches and specifically architected to meet the scalability, fast fail-over and multi-tenancy requirements of cloud data centers. Leveraging a centralized control plane architecture, Peregrine provides fast fail-over from any single network link/device failure, and dynamic policy-driven routing to enable network-wide load balancing and make the best of all available physical network links. In addition, Peregrine multiplexes a large number of virtual networks on a single physical network, offering each virtual network its own private IP address space, logical network topology, firewalling rules, traffic shaping policies, etc.





SESSION 6 SDN (II)





## **Cloud Data Center Network**

- Cloud data centers are Big and Shared
  - Data center virtualization: multiple virtual data centers (VDC) on a single physical data center
- Scalable and available data center fabrics
  - Use of all physical links in a load-balancing way
  - Fail-over latency is small (< 100 msec)
- Network virtualization: Each virtual data center (VDC) gets to define its own virtual network
  - Private IP address reuse
  - VDC-aware VPN and NAT
  - Cross-site global load balancing

3



SESSION 6 SDN (II)



#### Weaknesses of Ethernet's Control Plane

- · Spanning tree-based
  - Not all physical links are used
  - No load-sensitive dynamic routing
  - Fail-over latency is high ( > 5 seconds)
- Cannot scale to a large number of VMs (> 1M)
  - Forwarding table is too small: 16K to 64K
- Does not support VM migration and visibility
- Does not support network virtualization, e.g., private IP address reuse (PIAR)
- Does not support inter-VDC isolation: VMs in one VDC cannot ping VMs in another VDC

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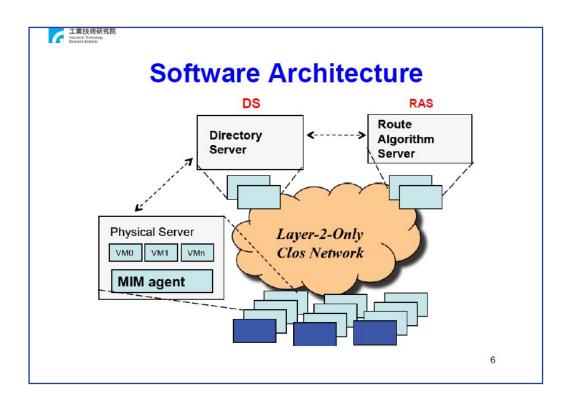
# **Peregrine: Ethernet-based SDN**

- A unified Layer-2-only network for LAN and SAN using centralized control plane and distributed data plane
- A software defined network using commodity Ethernet switches
  - SDN ≠ OpenFlow
  - All Ethernet control plane functionalities are turned off: spanning tree, source learning, unknown DST flooding, source MAC check, etc.
- Centralized load-balancing and QoS-aware routing using real-time traffic matrix, traffic volume between each node pair
- Fast fail-over using pre-computed primary/back routes
- Centralized ARP server to control IP → MAC address mapping
  - Minimum-route-change VM migration
  - Fast fail-over
  - Private IP address reuse

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SESSION 6 SDN (II)





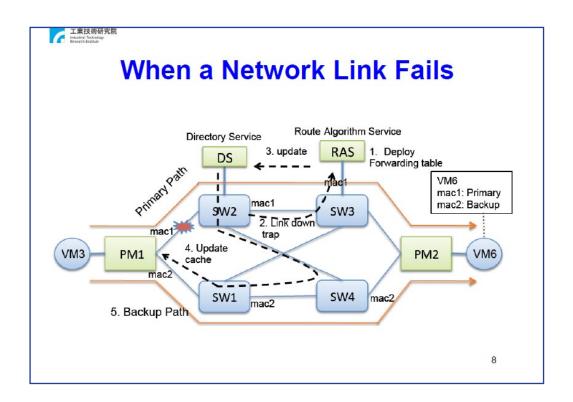
# **Load Balancing Routing**

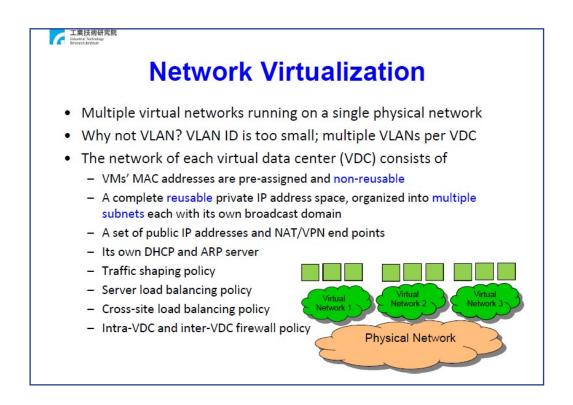
- · Collection of real-time traffic matrix
  - Traffic volume between each pair of VMs
  - Traffic volume between each pair of PMs
- Load balancing routing algorithm
  - Loads on the physical links
  - Number of hops
  - Forwarding table entries
  - Prioritization: QoS considerations
- Computed routes are programmatically installed on switches

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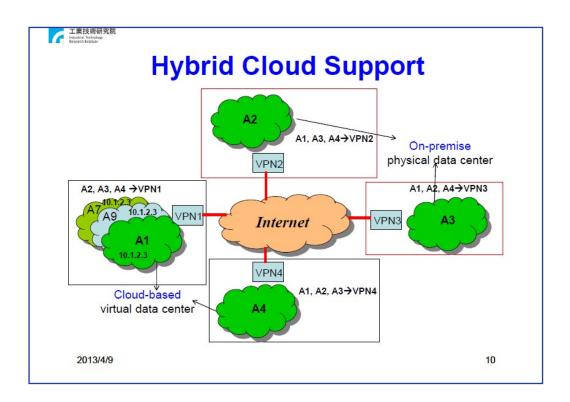
SESSION 6 SDN (II)







SESSION 6 SDN (II)





# **Private IP Address Space Reuse**

- Requirement: Every VDC has a VDC ID and its own full 24-bit private IP address space (10.x.x.x), even though multiple VDCs run on top of the same data center network; works across VPN connections
- Two approaches:
  - Ethernet over TCP/UDP:
    - Every Ethernet packet is encapsulated inside an TCP/UDP packet or TCP/UDP connection as an Ethernet link
    - Needs to implement in software such Ethernet switch functions as source learning, flooding, VLAN, etc.
    - · Can work with arbitrary IP networks
  - Multi-tenancy-aware IP-MAC mapping: our approach
    - VDC ID + private IP address → MAC address
    - MAC address → VDC ID
    - · Destination MAC address enforcement
    - · Runs directly on L2 networks, no need for Ethernet switch emulation

2013/4/9



SESSION 6 SDN (II)



# **Peregrine in SDN Framework**

- Data plane: Ethernet switches vs. OpenFlow switches
- Southbound API or control protocol: SNMP/CLI vs. OpenFlow protocol
- Controller:
  - RAS for SNMP trap processing and switch configuration vs.
     OpenFlow controller
- · Applications:
  - Dynamic load balancing routing
  - Fast fail-over
  - Network virtualization
- Northbound API: Quantum from OpenStack

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# **Peregrine Summary**

- Peregrine is a <u>network system</u> technology, not a network device technology, and consists of
  - A hypervisor agent running on every compute node
    - L7/Web application firewall and out-going traffic NAT and shaping
  - A centralized route server and ARP server
  - A VDC-aware Internet Edge Logic cluster
    - · Server load balancing, VPN, NAT, L4 firewall, and incoming traffic NAT and shaping
- Current Status: A fully operational Peregrine prototype that works on a 10-switch and 100-server test-bed
- Network virtualization technology that does not require tunneling
- A software defined network (SDN) architecture that runs on commodity Ethernet switches, and is able to manage both legacy Ethernet and OpenFlow switches

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SESSION 6 SDN (II)



# SDN ≠ OpenFlow

#### Thank You!

#### **Questions and Comments?**

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# **SDN Problems and Functions**

- · Three impactful SDN functions
  - Dynamic load-balancing routing
  - Fast fail-over
  - Private IP address reuse
- Three important SDN problems
  - Applying SDN to COTS Ethernet switches
  - Having unified control over Ethernet and OpenFlow switches
  - In-band vs. out-of-band control network

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SESSION 6 SDN (II)



# **Standardization Opportunities**

- SDN-friendly Ethernet switches
- · Removal of unwanted functionalities
  - Disables flooding of packets with unknown destination MAC address > prevents loop storms
  - Disables source MAC address check → enables asymmetric routing
- · Addition of desirable functionalities
  - Interrupt-based rather than polling-based link/switch failure detection > reduces failure detection time
  - Bulk forwarding table updates → speeds up forwarding table programming
  - Multiple notification targets for each SNMP trap → allows fail-over of control plane
  - MAC address aliasing → gives multiple MAC addresses to each NIC

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SESSION 6 SDN (II)

#### Opportunistic Networks and Cognitive Management Systems: Towards an SDN approach

#### **Abstract**

This presentation introduces an SDN approach for the control and management of operator-governed Opportunistic Networks (ONs). ONs are temporary coordinated extensions of the infrastructure and are dynamically managed and controlled through Cognitive Management Systems (CMS) with the use of proper operator policies. They capitalize on traffic offloading (e.g., from cellular to Wi-Fi and other wireless short range), and on Device-to-Device (D2D) communications concept in the sense that communication among user equipments (UEs) is possible, through Control Channels for the Cooperation of CMSs (C4MS) which convey information and knowledge, in order to provide coverage or capacity extension to the infrastructure. In the former case an ON is created in order to resolve outage situations; in the latter case ONs are created in order to route traffic from a congested to a non-congested area. The exploitation of ONs leads to benefits in the energy consumption of the infrastructure and the UEs that switch to ON, as well as communication benefits in terms of load and delay. In an SDN approach the CMSs can be seen as SDN applications that communicate with an SDN controller. CMSs collaborate in order to determine the suitability of the ON approach, create ONs, reconfigure existing ONs, as well as terminate ONs that are no longer needed. On the other hand, the C4MS can be seen as an SDN communication technology which can be implemented for instance in OpenFlow. The utilization of SDN can reduce the control overhead. To sum up, the presentation will discuss about the SDN approach for the control and management of ONs and the derived benefits, both for the network operator and the end users.

From Opportunistic Networks and Cognitive Management Systems to SDN-based Edge Networks

Prof. P. Demestichas, Dr. K. Tsagkaris, D. Karvounas, **M. Logothetis** 

> 3rd ETSI Future Networks Workshop April 10th, Sophia Antipolis, France





SESSION 6 SDN (II)

#### Overview

#### Legacy

- o Opportunistic Networks
- o Control Channels for the Cooperation of Cognitive Management Systems
- o Algorithmic Solutions
- o Prototyping

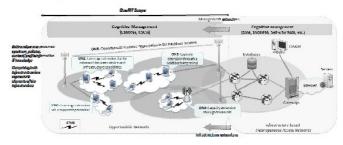
#### Edge Networks

- o Concept
- o Functionality
- SDN-based Architecture for Edge Networks

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#### Legacy: Opportunistic Networks

- Opportunistic networks are operator governed (through resources, policies, and information/knowledge) and can be coordinated extensions of the infrastructure for a particular time interval (OneFIT definition)
- Cognitive management systems required: (i) Cognitive system for the Management of the Opportunistic Network (CMONs); (ii) Cognitive System for Coordination with the Infrastructure (CSCIs);
- Control Channels for the Cooperation of Cognitive Management Systems (C4MS) required: information definition, signaling flows, protocols (packet structures, exchange)
- Challenges: Suitability determination (candidate node discovery, spectrum opportunity identification and generation); opportunistic network creation, maintenance and release

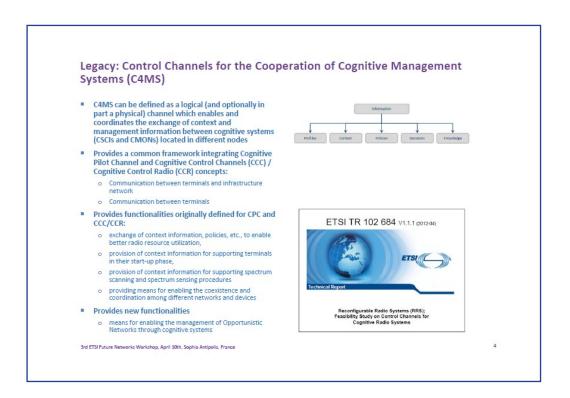


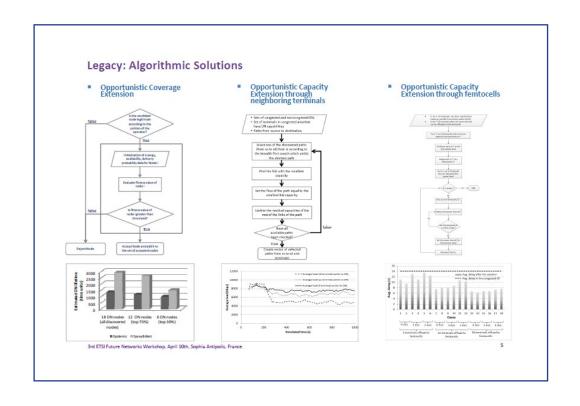
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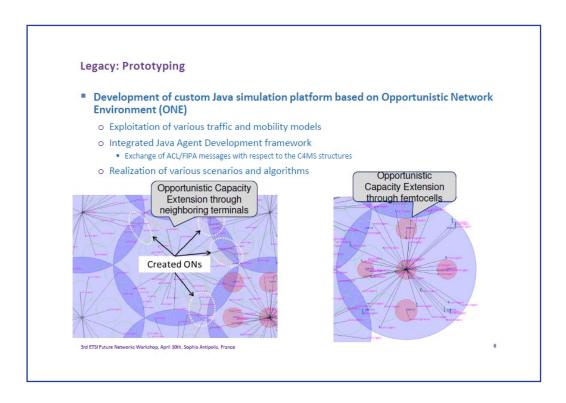
SESSION 6 SDN (II)







**SESSION 6** SDN (II)



#### **Edge Networks: Concept**

- Node of Edge Network
  - o Is a node interconnecting an edge network with the core network (e.g. future evolution of an edge router)

    One or more Virtual Machine per Users are allocated.

    - Responsible for processing service requests from Users of the associated edge network
      Has local intelligence (e.g. based on unsupervised learning), APIs and interfaces of orchestration enforcements
  - Is a class of standard-hardware nodes which will contribute in creating a continuum (indoors/outdoors) of connectivity
     High capacity nodes can be deployed outdoors in kiosks, medium capacity nodes in lamp streets, cars and also in the indoors environments

    - Users can be provided with low cost nodes, capable of wireless device-to-device communications, sharing network connectivity and conducting packets forwarding

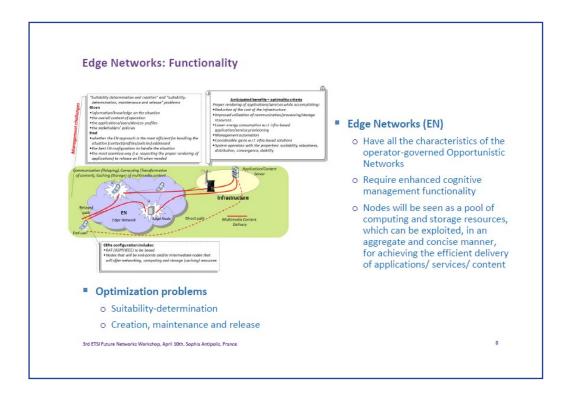
      Equipped with cognitive capabilities to ease Users experience and to exploit self-organization

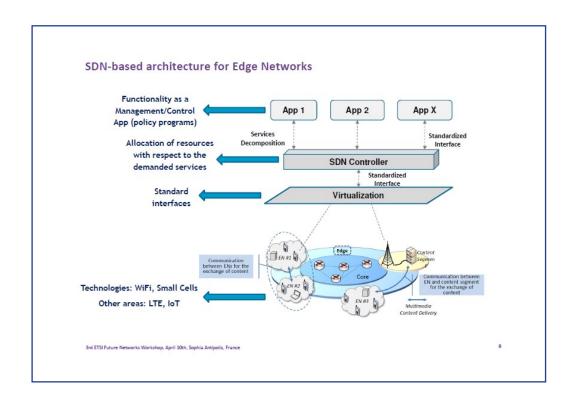


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#### Acknowledgement

Parts of this work are performed in the framework of the European-Union FP7 funded integrated project UniverSelf (<a href="www.univerself-project.eu">www.univerself-project.eu</a>) under EC Grant agreement 257513 and the EU-FP7 OneFIT (<a href="www.ict-onefit.eu">www.ict-onefit.eu</a>) project under EC Grant agreement 257385. The views expressed in this document do not necessarily represent the views of the complete consortia. The Community is not liable for any use that may be made of the information contained herein.

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Presentations SESSION 7
NFV

#### The Scope and Objectives of the ETSI ISG – Network Functions Virtualisation (NFV)

#### Abstract:

ETSI hosted the first meeting of a new ISG on Network Functions Virtualisation (NFV) following a 'call for action' white paper from thirteen of the world major telecoms carriers. This initiative is distinctive in its origins and continuing strong drive from the telecoms carriers who bring a holistic view of the full complexity of overall operational system of telecoms. The scope and objectives of this ISG are also distinctive.

The scope is the recasting of network functionality currently supplied as bespoke equipment into the form of virtual machines which can be deployed and run on the cloud technologies of generic servers and hypervisors. Candidate network functions include LTE mobile networks functions including base station gateways, border gateways, as well as LTE control functions; fixed and core gateway functions such firewalls, BRAS, edge routers, carrier grade NAT; as well as CDN caching servers, DPI, message routing, test access and monitoring, etc.

The objective is to produce 'white papers' rather than to write new detailed interface specifications. These will concentrate on the requirements needed to make the end to end carrier system work including issues associated with management and orchestration, performance, reliability, and scalability. The ISG will work with existing bodies on any detailed interfaces specifications. With this objective, the intention is that the ISG only has a life of around two years.

The presentation will also go through the organisation and planned deliverables of the ISG.





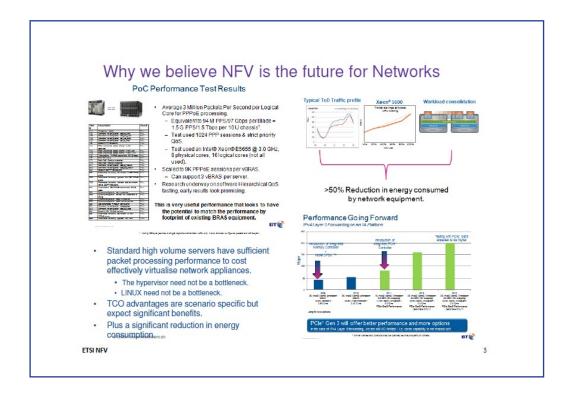
SESSION 7

#### Background to ETSI NFV ISG



- · Many carriers independently progressing research on NFV technology
  - independently concluded that technology is ready but would not be commercialised quickly for scale deployment without industry cooperation and support
- Cooperation amongst the carriers began with informal discussions in April 2012
- With wide carrier support, started informal discussions on convening an industry forum
- A meeting in Sept 2012 decided after consideration of several options to parent under ETSI as an "Industry Specification Group"
- The joint white paper on Network Functions Virtualisation was published to coincide with presentations at the OpenFlow/SDN World Congress, Darmstadt (Oct 2012), and the ETSI Board approved creation of the NFV ISG (Nov 2012)
- · Founding members:
  - AT&T, BT, Deutsche Telekom, Orange, Telecom Italia, Telefonica, Verizon
- First formal meeting in ETSI HQ, Sophia Antipolis, Jan 2013

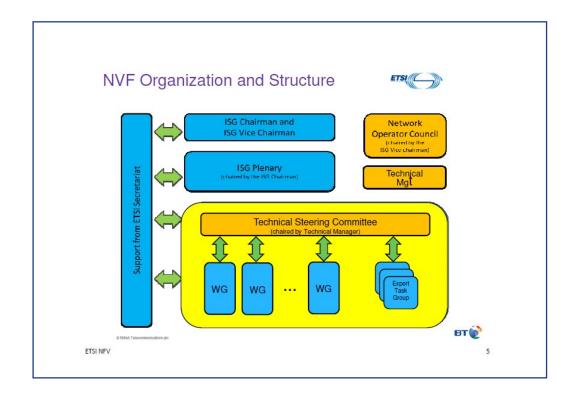






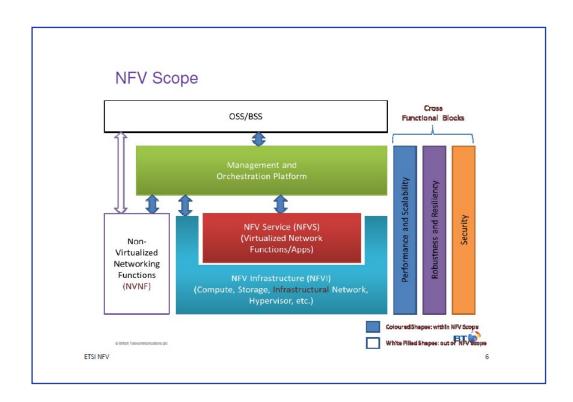
SESSION 7 NFV

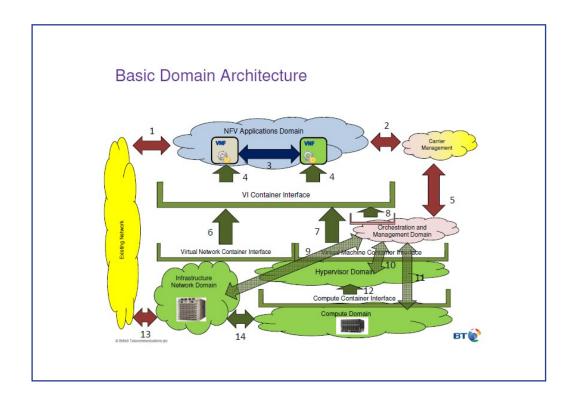






SESSION 7 NFV







SESSION 7

#### **Example Use Cases**

- · Mobile networks:
  - HLR/HSS, MME, SGSN, GGSN/PDN-GW, Base Station, vEPC
- NGN signalling:
  - SBCs, IMS
- · Switching elements:
  - BNG, CG-NAT, routers
- Home environment:
- home router, set top box
- · Application-level optimisation:
  - CDNs, Cache Servers, Load Balancers, Application Accelerators

- Security functions:
  - Firewalls, virus scanners, intrusion detection systems, spam protection
- · Tunnelling gateway elements:
  - IPSec/SSL VPN gateways
- Converged and network-wide functions:
  - AAA servers, policy control and charging platforms
- · Traffic analysis/forensics:
  - DPI, QoE measurement
- · Traffic Monitoring,
  - Service Assurance, SLA monitoring, Test and Diagnostics

BT

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#### Benefits

- Reduced equipment costs (CapEx) through equipment consolidation equipment and due to economies of scale
- · Reduced operational costs (OpEx): labor, power, space
- Increased speed of Time to Market by minimising the typical network operator cycle of innovation.
- Availability of network appliance multi-version and multi-tenancy, which allows use of a single platform for different applications, users and tenants.
- Flexibility to easily, rapidly dynamically provision and instantiate new services in various locations (no need for new equipment install)
- Improved operational efficiency by taking advantage of the higher uniformity of the physical network platform and its homogeneity to other support platforms.
- Encouraging innovation to bring new services and generate new revenue streams
- · Mobility of skillset and talent (easy to move around, on need basis)





SESSION 7

#### **ETSI NFV ISG**

- Carrier-led Industry Specification Group (ISG) under the auspices of ETSI (20 carriers and mobile operators). Wide industry support (more than 50 vendors).
- Open membership to everyone

  - Non-ETSI members sign the "Participant Agreement"
- Operates by consensus (formal voting only when required)
- Deliverables: White papers addressing challenges and operator requirements, as input to standardisation bodies
- Face-to-face meetings quarterly
- Currently four (4) WGs and two (2) expert groups (EG)
  - WG1: Infrastructure Architecture

  - WG4: Reliability & Availability
- Network Operators Council (NOC)
- governing and technical advisory body
- Technical Steering Committee:

  - Technical Manager
     WG Chairs, EG Leaders

Do join and contribute







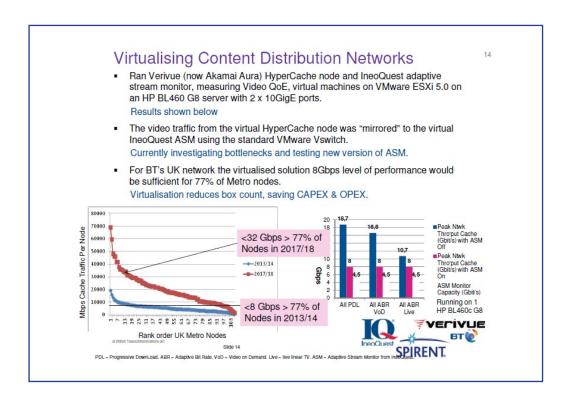
SESSION 7



# Implementing Hierarchical-QoS in Software Proclimately 2012 vbrasses test implemented Priority QoS and implementing Hierarchical-QoS in software was seen as a barrier. BT & Intel ® initiated a project to implement high performance H-QoS in software. Currently implemented a Hierarchical scheduler with: 5 levels, 64K queues, traffic shaping, strict priority and weighted round robin. Preliminary performance per CPU core is close to line rate for hierarchical scheduling and packet transmission for one 10GbE port at 64 byte packet size i.e. 13.3 Mpps Hardware: 2x Intel Xeon E5-2680 CPUs @2.7GHz, 8 cores, 20MB L3 cache, 8GT/s QPI, 4x DDR3 memory, 32 GB DDR3 memory; 2x 2GB DIMMs per each of the 4x memory channels of each CPU, 1x Intel X520-5R2 Dual Port 10Gbps Ethernet Controller connected to CPU0 through one PCI-Express Gen2 x8 slot. Software: Fedora release 16 (Verne) with Linux kernel 3.1.0-7.1c/16/388\*/8s\*/hight-965f time configuration: 16x 1GB huge memory pages reserved (8 pager for each CPP) is solation enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 1.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants enabled to restrict kernel scheduler to CPU0 core 0; Intel DPDK 1.4 Early Acgess Figure 2.5 constants en



SESSION 7



#### Where Virtualisation Improves Performance Widely accepted that virtualisation reduces performance compared to running on "bear metal" but here's a real application where it improves performance: Scalable IPsec solutions are required for FONera roaming WiFi and LTE Investigated lowest cost IPsec solution for BT's FON WiFi service. Requirements: Null encryption, 3DES IKE, ~80Kbps/tunnel, millions tunnels, high tunnel set-up rate. Tested the KAME solution bundled in the Linux kernel (Ubuntu With Virtualisation achieved 7K tunnels. Tunnel set-up Bottleneck was a single core being Psec tunnels per 30000 used to terminate all IPsec tunnels. = 100/sec 25000 How to use more CPU cores? 20000 Rewrite the code ® 15000 Without Virtualisation DL360 Or use KVM and run multiple 0000 virtual Linux kernels to load share server the IPsec tunnels across multiple cores © Number of E5-2667 Cores Used KVM (redhat 6.3) with Ubuntu 10.04 LTS virtual machines



SESSION 7 NFV

#### Towards the Standardization of Transparency and Isolation Metrics for Virtual Network Elements

#### **Abstract**

Network Virtualization (NV) has become a major design paradigm of future networks. It provides significant advantages over the concept of dedicated networks in terms of flexibility and (re-)use of network infrastructure.

The major assumptions of Network Virtualization are a) the isolation of multiple virtual networks in a physical infrastructure element against influences from each other and b) the transparency of the virtual infrastructure for the data flows transmitted by it.

In this contribution, we investigate how to characterize the features of isolation and transparency in quantitative terms. The characterization is done with respect to transmission performance for data flows, i.e. by the strength a virtualized element changes the characteristic of a data stream flowing through it. A virtual element might be in this context a virtual links or a virtual routers. The proposed metrics will consider the impact on the flows as seem from individual streams and from the outside across all flows. The impacts will be demonstrated by measurements in a well-define testbed.

We expect that the methodology, which we aim to develop, can be used a) to describe the suitability and performance of specific NV techniques and b) to compare different hardware and software in virtualized systems. In this way, our concepts might impact the definition and standardization of performance metrics for Network Virtualization as well as for Network Functions Virtualization.

# Towards the Standardization of Transparency and Isolation Metrics for Virtual Network Elements in SDN

K. Tutschku (kurt.tutschku@bth.se)

In collaboration with

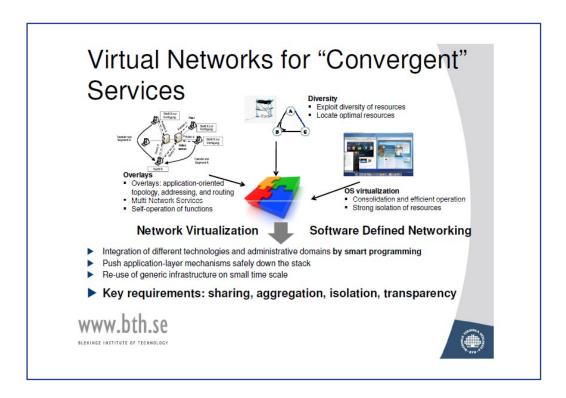
- D. Stezenbach (david.stezenbach@univie.ac.at)
- O. Nawaz (<u>omer.nawaz@bth.se</u>)
- M. Fiedler (markus.fiedler@bth.se)







SESSION 7 NFV



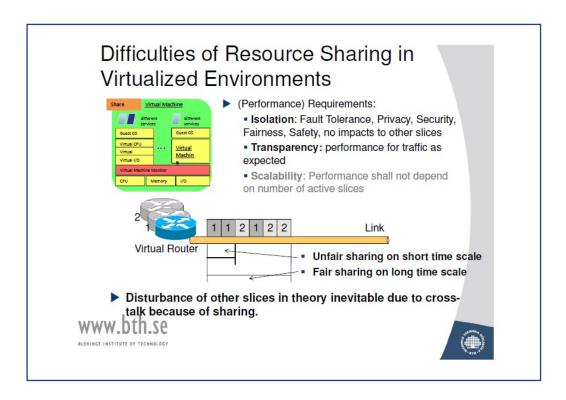
What are the performance requirements of virtual network elements in SDN?

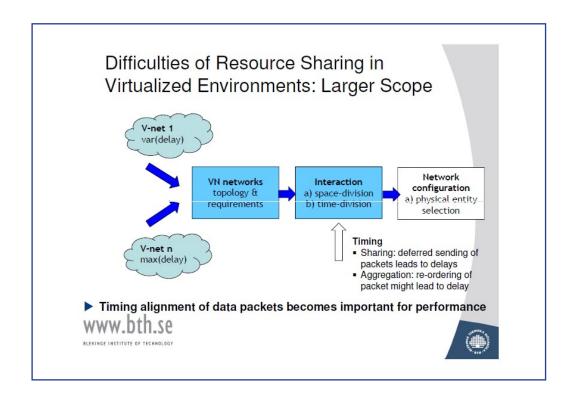
www.bth.se





SESSION 7 NFV







SESSION 7

# What is Isolation and Transparency?



Language terms:

 Isolation: is the feature that no virtual entity may impact the behavior of any other similar virtual entity on the same

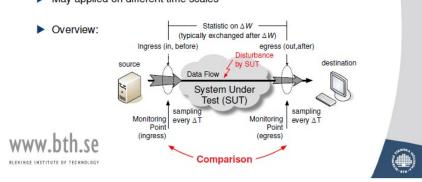
physical element.

- **-Transparency:** is the feature of a virtual system that a user is not able to recognize that the system, he or she is using, runs in a virtual environment. Transparency is related to *fidelity*.
- •Fidelity: is the feature that a software running in virtualized environment should provide identical results as running on the real machine, barring from timing effects [Adam et al. 2006].
- These feature can either be fulfilled or not fulfilled!
- Is there a quantitative evaluation available? For example, for judging the quality of a (virtual) network element?



# Evaluation Concept: Comparative Analysis

- General concept for the numerical analysis of the impacts of networks/network elements on traffic streams (developed by Fiedler und Tutschku since 2003)
- Compares the statistical characteristics of traffic stream at the In and Out of a (network) element.
- May applied on different time scales



**SESSION 7 NFV** 

# Basic Metric for Isolation and Transparency



▶ Aim on the influence of virtualization on single packets:

 $t_{p}^{out} - t_{p}^{in} = 0, \forall p$   $t_{p_{i}}^{in} - t_{p_{i-1}}^{in} = t_{p_{i}}^{out} - t_{p_{i-1}}^{out}, \forall p$   $p_{i}^{in} = p_{j}^{out}, i = j, \forall p$ (3) Additional delay:

Inter packet time:

Packet order:





### Advanced Metrics for Isolation and Transparency



- Multi-timescale metrics: a second class of metrics evaluates the performance based on multiple timescales.
- Considers timing alignment between packet on multiple timescales.
- Throughput statistic (for given ΔT)

$$\begin{split} X^{in/out}(t) &= \sum_{p:t_p \leq t} x_p^{out/in} \\ R_{i,\Delta T}^{in/out} &= \frac{X(i\Delta T) - X((i-1)\Delta T)}{\Delta T} \end{split}$$

Mean value and variance (for given ΔT)

$$\begin{split} E\left[\left\{R_{i,\Delta T}^{in}\right\}\right] &= E\left[\left\{R_{i,\Delta T}^{out}\right\}\right], \forall i, \forall \Delta T \\ \sigma\left[\left\{R_{i,\Delta T}^{in}\right\}\right] &= \sigma\left[\left\{R_{i,\Delta T}^{out}\right\}\right], \forall i, \forall \Delta T \end{split}$$

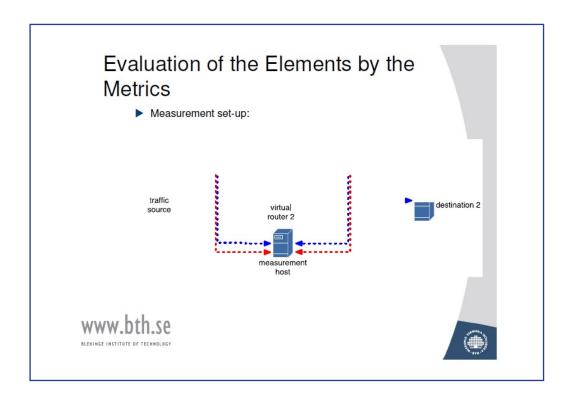
ΔT = time interval on which statistical value is computed = time

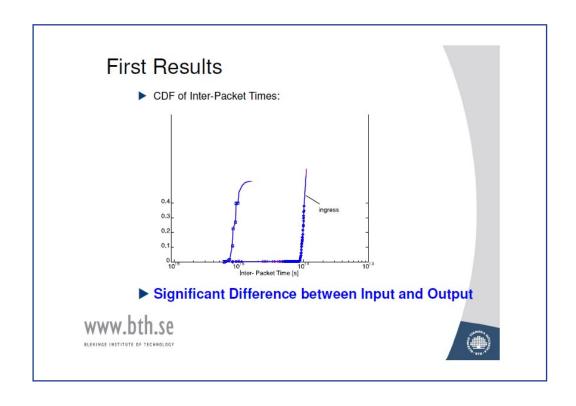






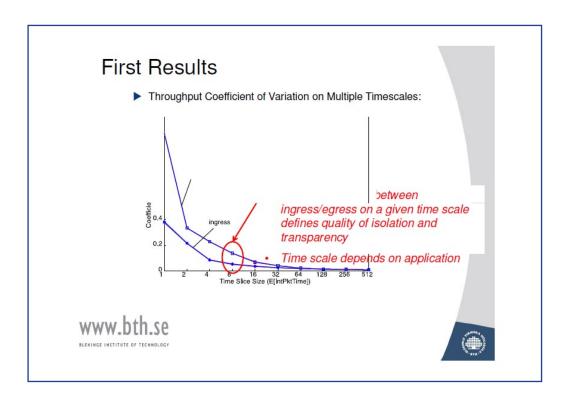
SESSION 7







SESSION 7 NEV



# Summary and Outlook

- ➤ SDN and Network Virtualization will have specific performance requirements resulting from the needs of
  - Sharing, Isolation and Transparency
- ➤ The understanding of the changes in the inter-packet timing alignment is the key towards metrics for the quality of virtualization technology
- Future research will involve
  - the improvements of the metrics (incl. their accuracy)
  - how to implement control of virtual network based on the deviation of the performance







SESSION 7 NEV





Presentations SESSION 7
NFV

#### Principles and Attributes of NFV Orchestration and Automation Platforms

#### **Abstract**

Network functions virtualization is a new approach to designing network and application infrastructures. This new approach promises significantly lower CAPEX and OPEX as well as a new level of agility in deploying and managing services and applications based on virtual network functions. But these promises can only be realized with NFV platforms that orchestrate and automate the lifecycle of virtual applications.

In this contribution we present key requirements and design principles for NFV platforms such as these:

- Enable an open market place of applications supporting servers, hypervisors, data centers, and networks from multiple vendors.
- Manage a distributed set of data centers interconnected with wide-area networks as one single pool of resources.
- Provide mechanisms to simplify and automate the application lifecycle including onboarding, testing, deployment, monitoring, scaling, repair, and maintenance.

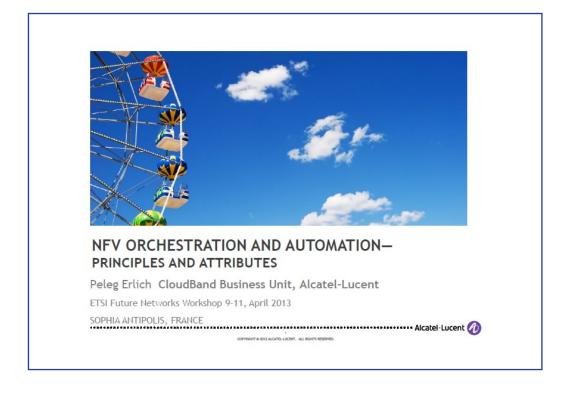
To simplify the NFV platform architecture, we argue that the platform should separate different concerns within the orchestration layer:

- Network orchestration (network driver)
- Server orchestration (cloud driver)
- Application lifecycle orchestration (onboarding, deployment, ...)
- Application function orchestration (composition of applications from functional blocks)

With this approach a DevOps methodology can be realized that fosters a closer integration of development and operation to achieve the faster deployment cycles demanded for NFV.

We support this approach with proof points from an implementation and a use case.

(A demonstration of the implementation is possible, if desired.)





**SESSION 7 NFV** 

#### **AGENDA**

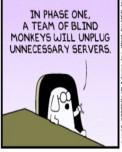
- 1. THE CARRIER CHALLENGE
- 2. NFV ORCHESTRATOR CHALLENGE
- 3. NFV ORCHESTRATOR EXPECTATIONS
- 4. NFV ARCHITECTURE
- 5. CHALLENGES OF AUTOMATING THE VNF LIFECYCLE
- 6. NETWORK FUNCTIONS VIRTUALIZATION PRINCIPLES

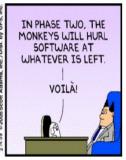
AT THE SPEED OF IDEAS"

Alcatel-Lucent

#### VIRTUALIZATION: A (CYNICAL) ENGINEER'S VIEW







VIRTUALIZATION IS ANSWER BUT WE NEED TO BE MORE THAN BLIND MONKEYS!



**SESSION 7** 





Static and OPEX-heavy, with multiple management systems and slow time to market.

Increased agility and decreased OPEX, with unified orchestration and faster to market.

Alcatel·Lucent



#### NFV ORCHESTRATOR CHALLENGES



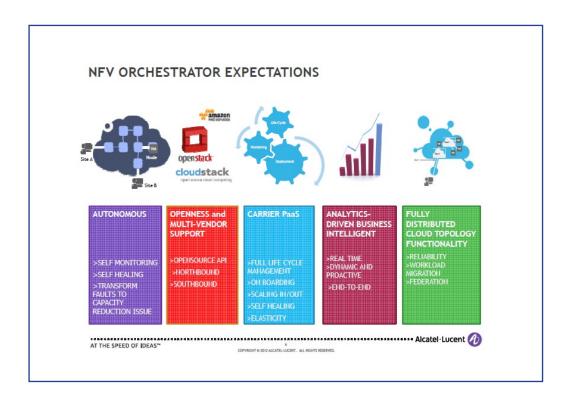
- · How to select tools and techniques for the instantiation, activation, resource allocation and programming of Virtual Network Function (VNF)?
- · How to ensure that actions are performed in consistent way across all physical resources? and distributed environment?
- How to ensure that VNF consumes resources effectively across distributed infrastructure?
- · How to monitor all available data about cloud nodes, allocated resources, network and
- How to display the data and alerts to user and make them available over open APIs? And how to apply analytics, trending and prediction and feeding it back into optimization.
- How to trigger events when metrics cross defined threshold?
- How to identify security mechanisms?
- What are the best practices to improve O&M functionality?

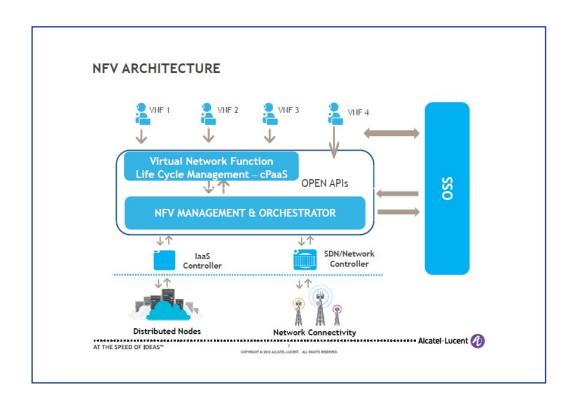
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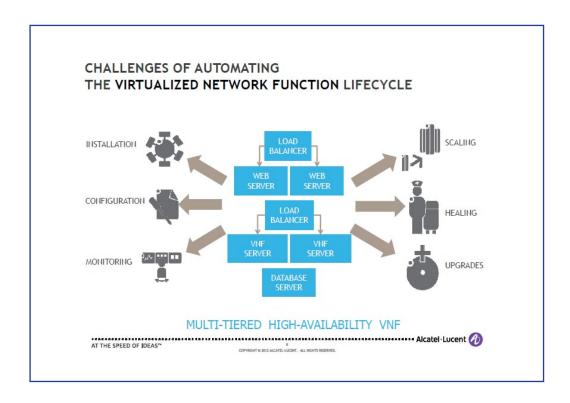
SESSION 7 NFV

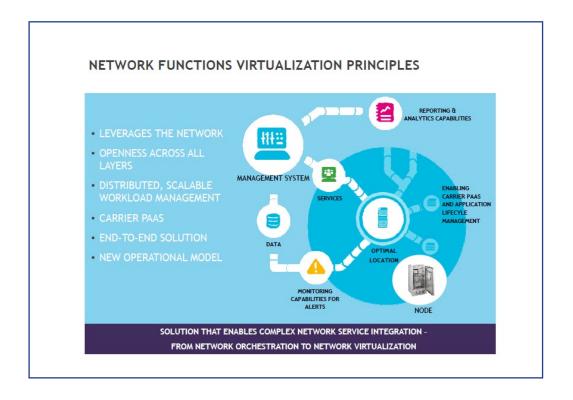






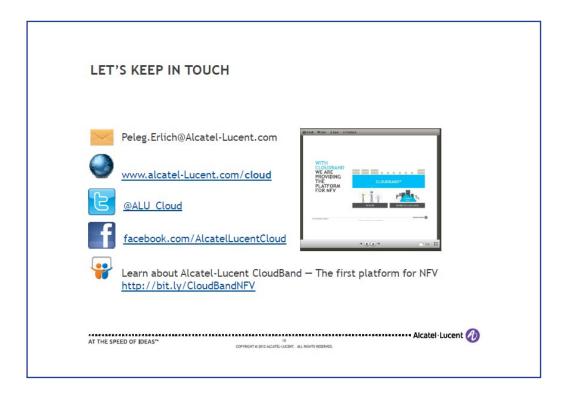
SESSION 7 NFV







SESSION 7 NFV







Presentations SESSION 7
NFV

Unleashing the potential of virtualization by the right toolkits and open testbeds: Lessons learned from implementing a virtualized 3GPP EPC toolkit

#### **Abstract**

Virtualization comes with the promise of cost reduction of both the equipment and of the operations in a core network, through running the core network functions as software on common hardware platforms. Initiated in 2008, Fraunhofer FOKUS OpenEPC (www.openepc.net) is a practical software implementation addressing testbeds and research projects of the 3GPP Evolved Packet Core (EPC), the state of the art mobile core network.

This presentation reports on the lessons learned, issues, limitations, and the solutions found while realizing the OpenEPC toolkit, as well as on the flexibility decisions taken in order to realize easily customizable virtual network research infrastructures for more than 25 R&D institutions.

Following, based on this experience, the presentation will try to give initial estimates whether virtualization is the brave new world of network operators by considering the massive mobile broadband requirements on the core network against the costs of deploying and running it.

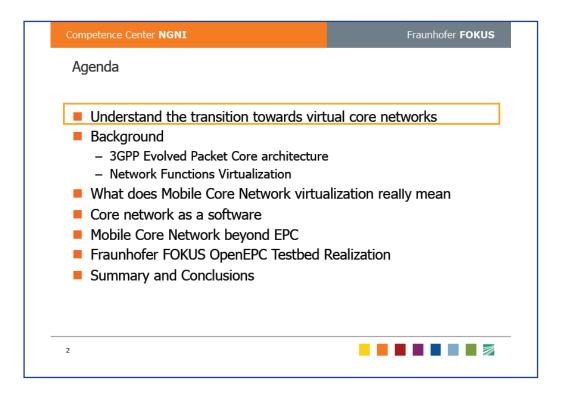
Following, the presentation will include a pragmatic evaluation of virtualization technology as well as the description of the directions in which the mobile core network architecture can evolve when using a single underlying hardware architecture as to further reduce the signaling within the core network and the data path stretch between mobile devices and applications.

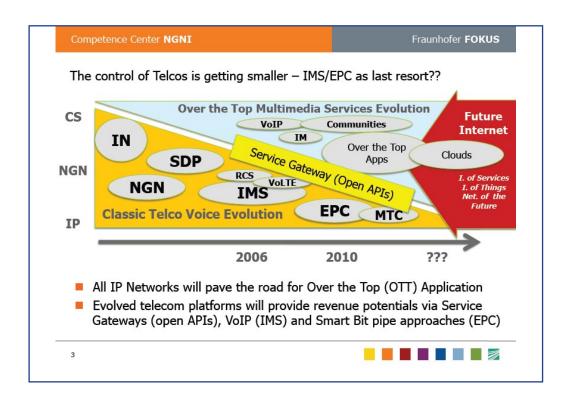
The presentation concludes with a roadmap of virtualization technology seen from the perspective of an industry oriented independent research institution.





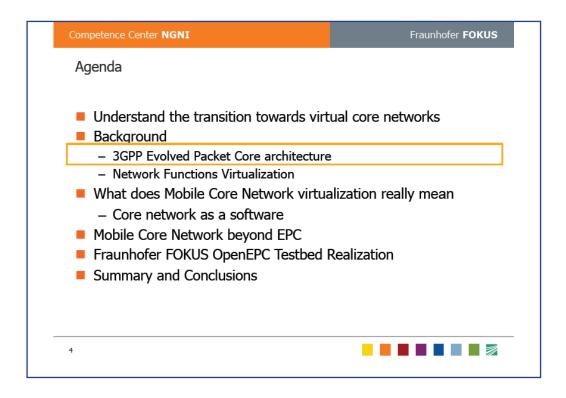
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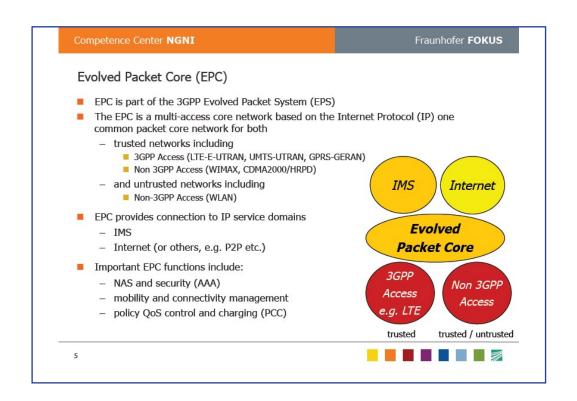






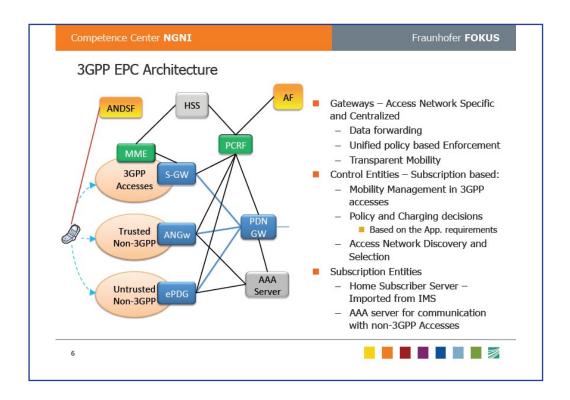
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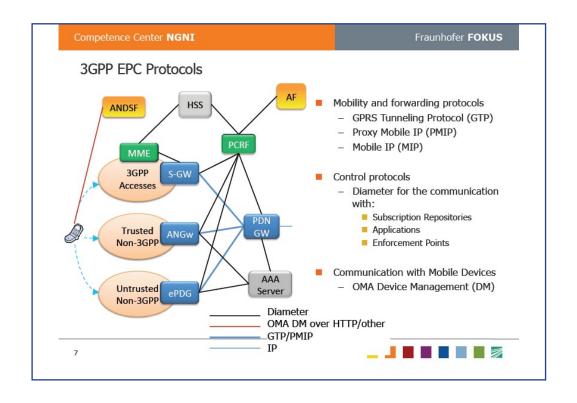






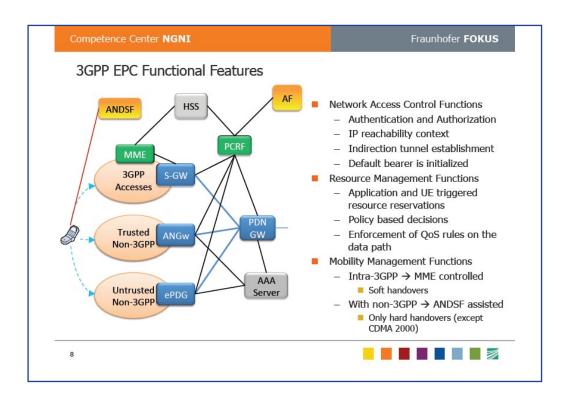
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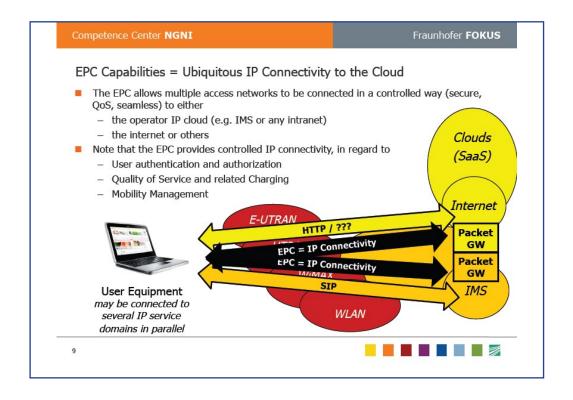






SESSION 7 NFV







SESSION 7

### Competence Center NGNI

Fraunhofer FOKUS

Network Functions Virtualization vs. current network architectures

### Definition:

- Network Functions Virtualization aims to transform the way that network operators architect networks by evolving standard IT virtualization technology to consolidate many network equipment types onto industry standard high volume servers, switches and storage, which could be located in Data Centres, Network Nodes and in the end user premises, as illustrated in Figure 1.
- It involves the implementation of network functions in software that can run on a range of industry standard server hardware, and that can be moved to, or instantiated in, various locations in the network as required, without the need for installation of new equipment.
- Network Functions Virtualization (NFV) presumes that network functions are:
  - Software implementations (software programs) of the current network components
    - Software technologies brought the success of Internet by separating hardware life-cycle from application life-cycle - i.e. all IP services use this paradigm
  - Running on top of standard server hardware architectures
    - No dedicated hardware gives a high liberty on program placement, merging, etc.

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### Competence Center **NGNI**

Fraunhofer FOKUS

### Agenda

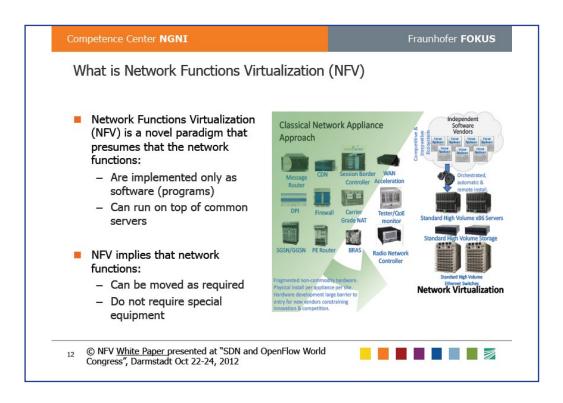
- Understand the transition towards virtual core networks
- Background
  - 3GPP Evolved Packet Core architecture
  - Network Functions Virtualization
- What does Mobile Core Network virtualization really mean
  - Core network as a software
- Mobile Core Network beyond EPC
- Fraunhofer FOKUS OpenEPC Testbed Realization
- Summary and Conclusions

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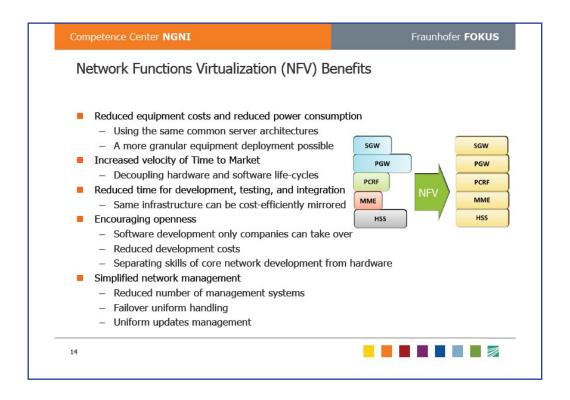
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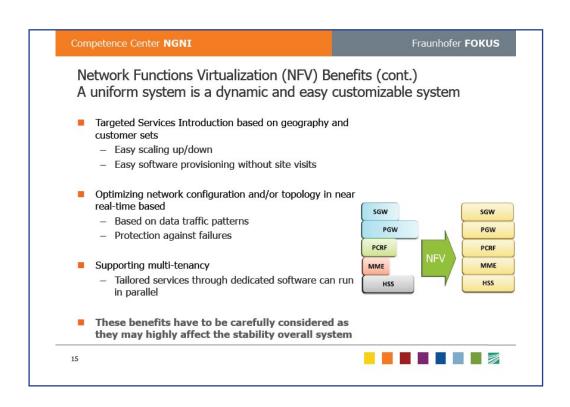


# Agenda Understand the transition towards virtual core networks Background - 3GPP Evolved Packet Core architecture - Network Functions Virtualization What does Mobile Core Network virtualization really mean - Core network as a software Mobile Core Network beyond EPC Fraunhofer FOKUS OpenEPC Testbed Realization Summary and Conclusions



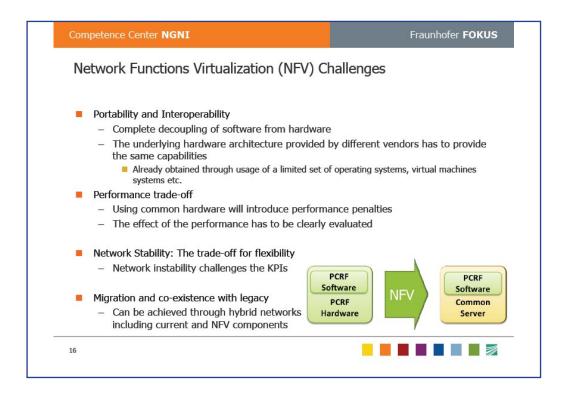
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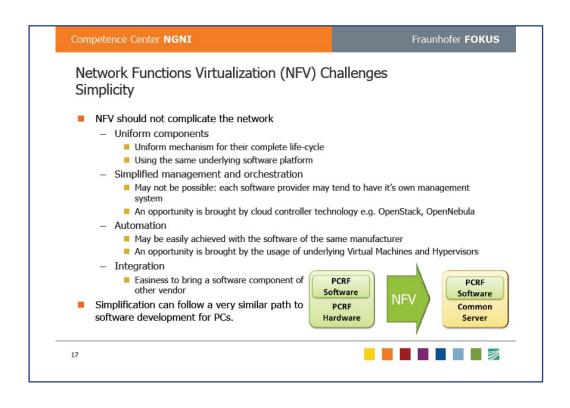






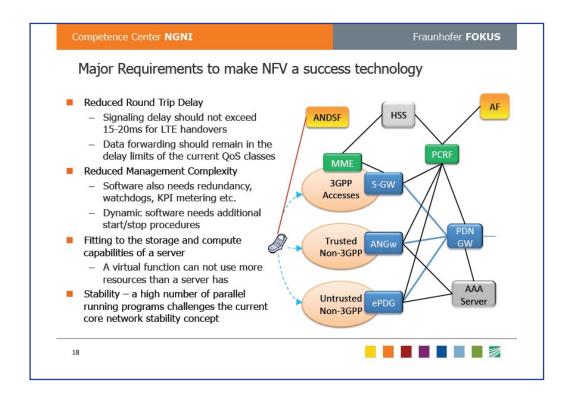
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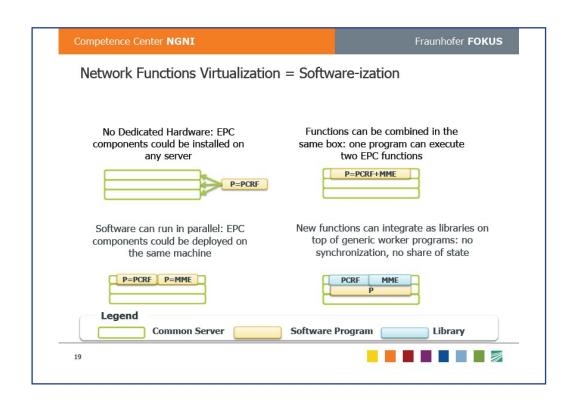






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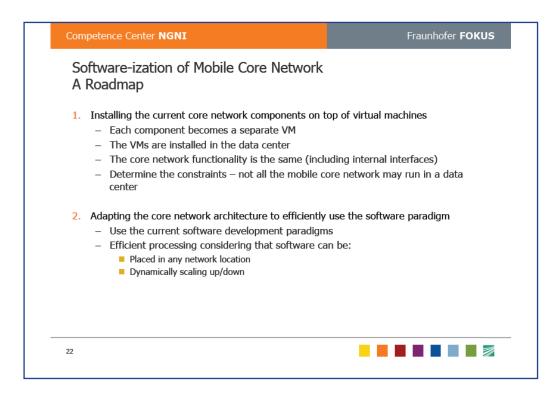
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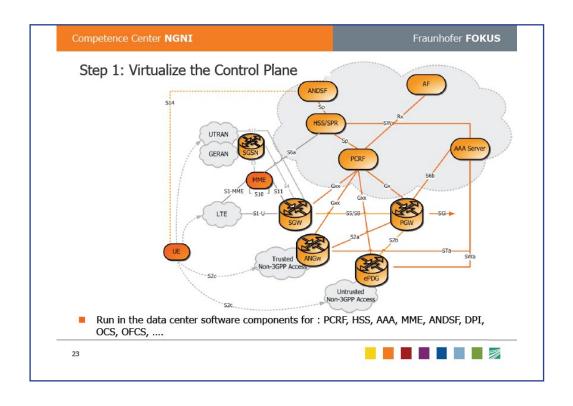
### Competence Center NGNI Fraunhofer FOKUS NFV ≠ Cloud Technologies Cloud technologies presume usage of specific data center tools for automated instantiation of virtual machines e.g. OpenStack, OpenNebula, etc. Cloud technologies automation includes: The dynamic creation of Virtual Machines (empty or based on templates) Allocating dynamically storage and compute resources to VMs Allocating virtual networks between Virtual Machines Contextualization of the Virtual Machines (IP addresses, transfer of other specific information) Network Functions Virtualization (NFV) is the starting point for applying Cloud technologies in the networking area Provides a new service for cloud based data centers Provides the underlying software to be run in the virtual machines Provides a new set of customers for public and private data centers Mobile Virtual Network providers - Specialized Core Network Providers e.g. eHealth, SmartGrid, Transportation ... 20

# Agenda Understand the transition towards virtual core networks Background - 3GPP Evolved Packet Core architecture - Network Functions Virtualization What does Mobile Core Network virtualization really mean - Core network as a software Mobile Core Network beyond EPC Fraunhofer FOKUS OpenEPC Testbed Realization Summary and Conclusions



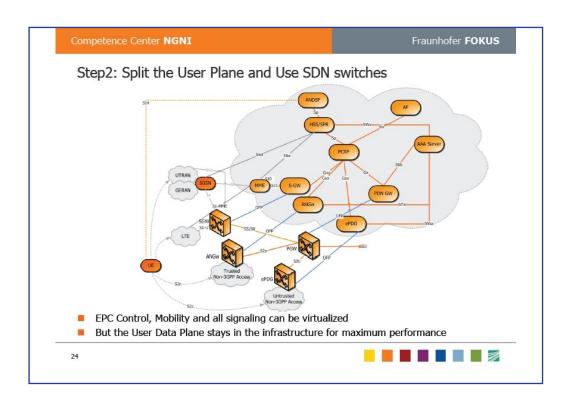
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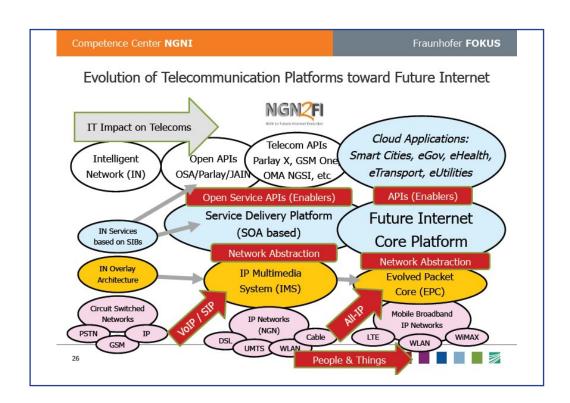
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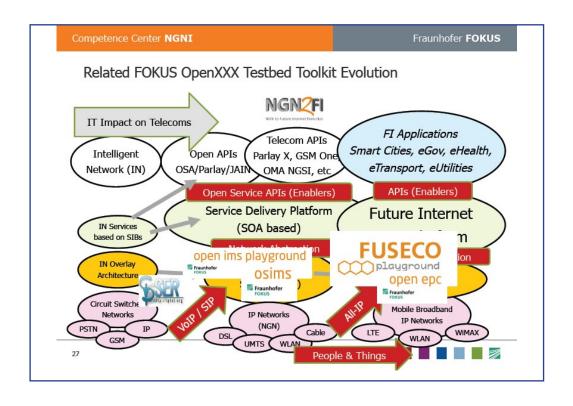


# Agenda Understand the transition towards virtual core networks Background - 3GPP Evolved Packet Core architecture - Network Functions Virtualization What does Mobile Core Network virtualization really mean - Core network as a software Mobile Core Network beyond EPC Fraunhofer FOKUS OpenEPC Testbed Realization Summary and Conclusions



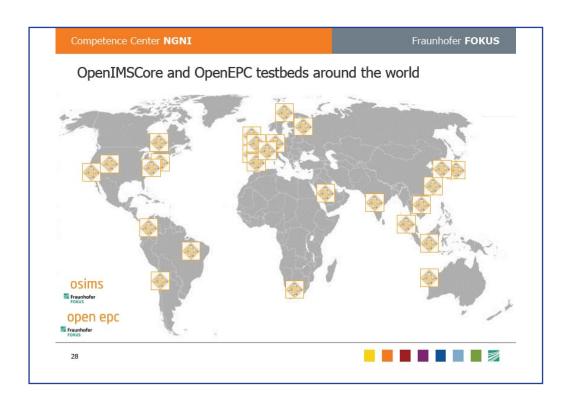
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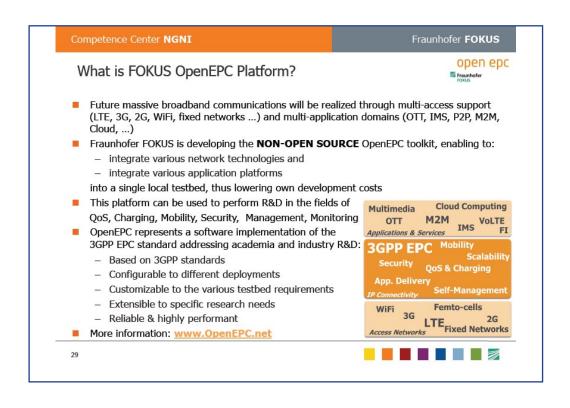






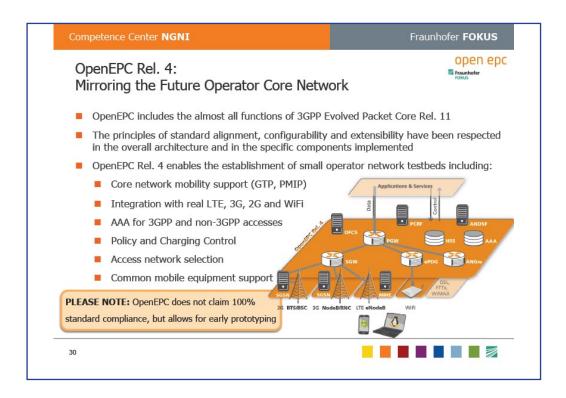
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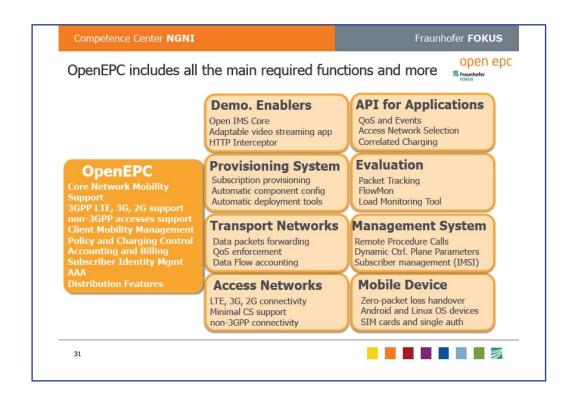






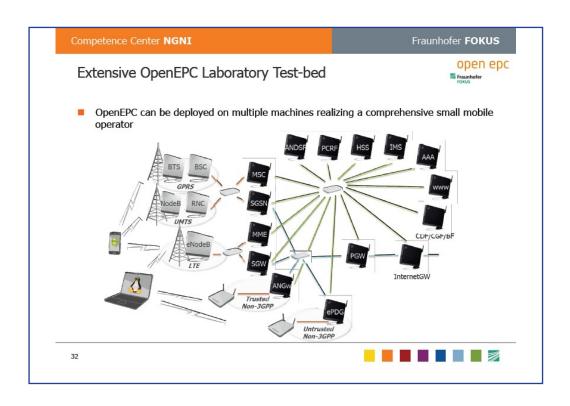
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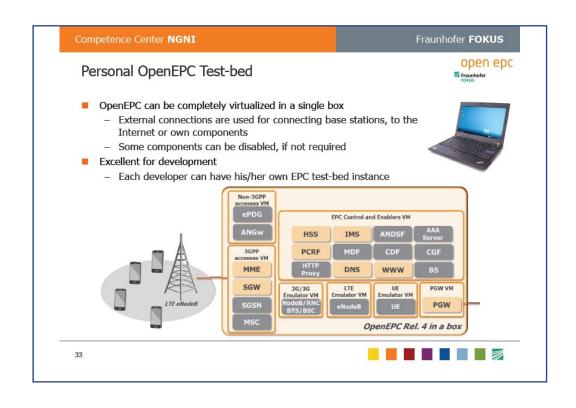






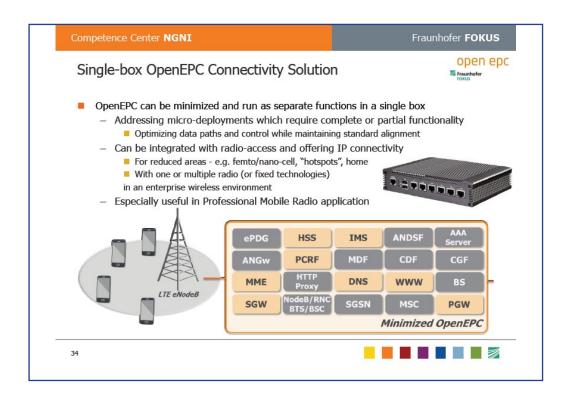
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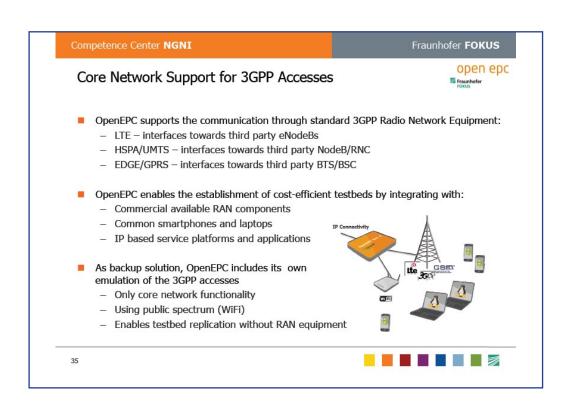






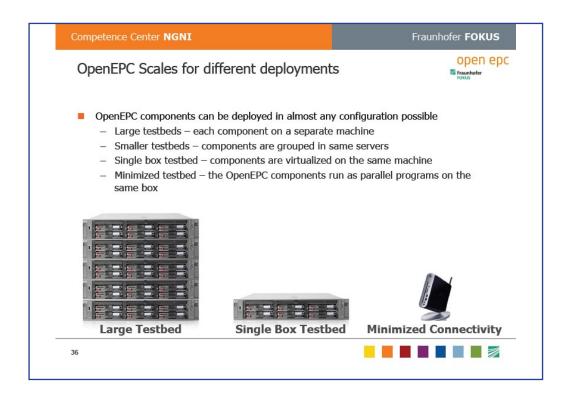
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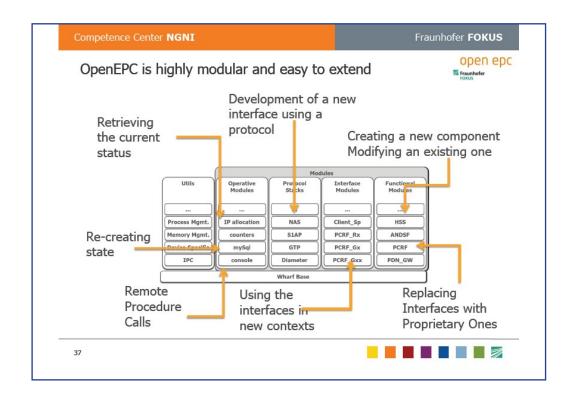






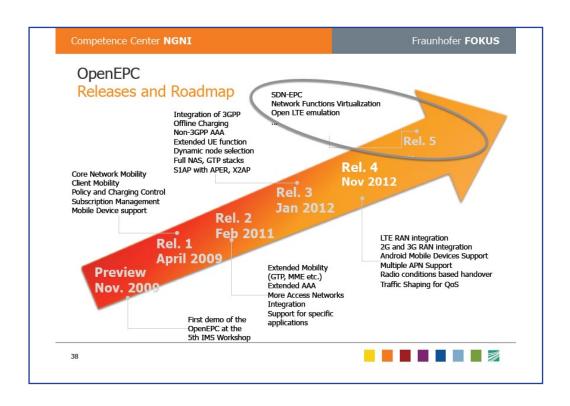
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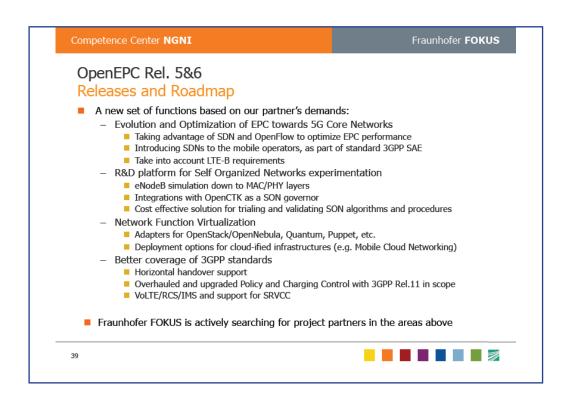






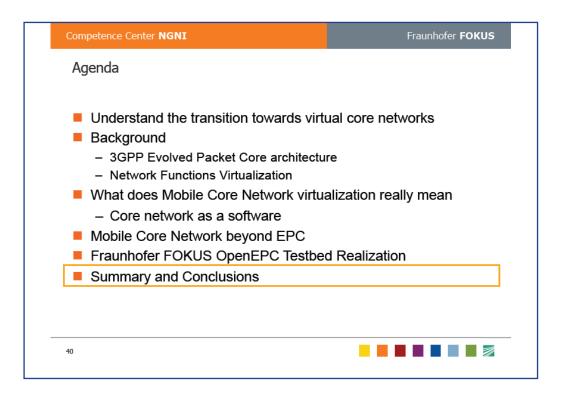
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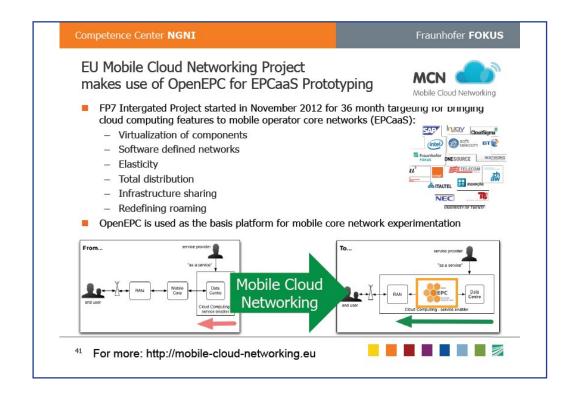






SESSION 7 NFV







SESSION 7 NFV

### Competence Center NGNI

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### Summary and Conclusions

- Virtualization comes with the promise of cost reduction of both the equipment and of the operations in the core network, through running the core network functions as software on common hardware platforms
- Network Functions Virtualization (NFV) = (Core) Network Software programs on common hardware platforms
  - Any addition to this definition should be carefully considered
- In order to be accepted by community NFV has to provide the same functionality as current core network at acceptable delays, with reduced management and scalability issues
- Software-ization comes with its specific development features currently well understood by web application developers
- Fraunhofer FOKUS OpenEPC represents the first complete R&D toolkit for evaluation of novel concepts in the area virtualization of carrier grade mobile operator networks
  - Provides a comprehensive set of EPC + other carrier grade operator functionality
  - Running on cost-efficient off-the-shelf hardware
  - Supports deployments customized to the testbed requirements
  - Based on a single highly efficient C based platform

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### Competence Center NGNI

Fraunhofer **FOKUS** 

4th FOKUS "Future Seamless Communication" Forum (FFF) Berlin, Germany, November 28-29, 2013



- Theme: "Smart Communications Platforms for Seamless Smart City Applications – Fixed and Mobile Next Generation Networks Evolution towards virtualized network control and service platforms and Seamless Cloud-based H2H and M2M Applications"
- FUSECO FORUM is the successor of the famous FOKUS IMS Workshop series (2004-09)
  - FFF 2010 attracted 150 experts from 21 nations
  - FFF 2011 was attended by around 200 experts from 30 nations
  - FFF 2012 was attended again by around 200 experts from 30 nations

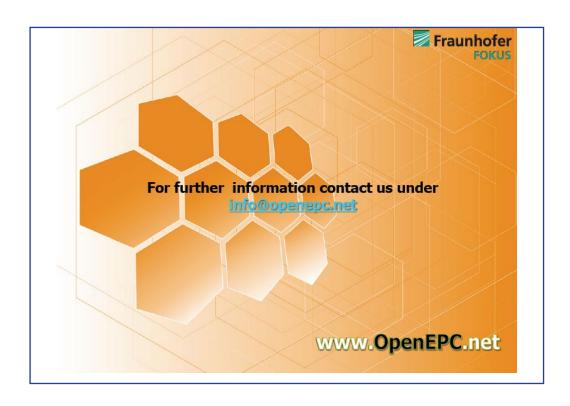
See www.fuseco-forum.org



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SESSION 7 NFV





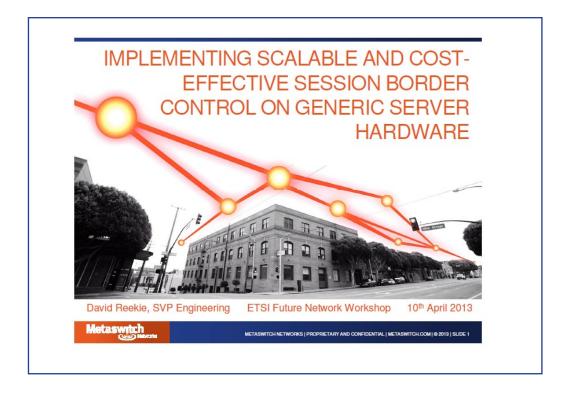
SESSION 7 NFV

### Implementing scalable and cost-effective Session Border Control on generic server hardware

### **Abstract:**

Session Border Control is one of the network functions that has been explicitly identified in materials published by the NFV initiative as a candidate for deployment as a Virtualised Network Function. Session Border Control is a particularly interesting case study for NFV because SBCs have traditionally used specialised hardware for a number of essential functions including discarding packets from blacklisted IP addresses, relaying large numbers of media flows, performing interworking between secured and unsecured media flows, and transcoding media.

In this session, Metaswitch will describe the lessons learned in successfully implementing scalable and cost-effective Session Border Control on generic server hardware – firstly on bare metal, and subsequently in a fully virtualised environment. Metaswitch will also compare and contrast virtualised SBCs with those built on proprietary hardware in terms of cost, density and power consumption, and will identify some of the key challenges that need to be overcome to achieve the full potential of Session Border Control in an NFV environment.





SESSION 7 NFV

### **AGENDA**

- Why is this an interesting case study?
  - The route to virtualisation
  - How most people build SBCs today
- Aspects of performance
  - Packet throughput
  - Media transcoding
- Remaining challenges

Metaswitch

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### THE ROUTE TO COTS HARDWARE AND VIRTUALISATION

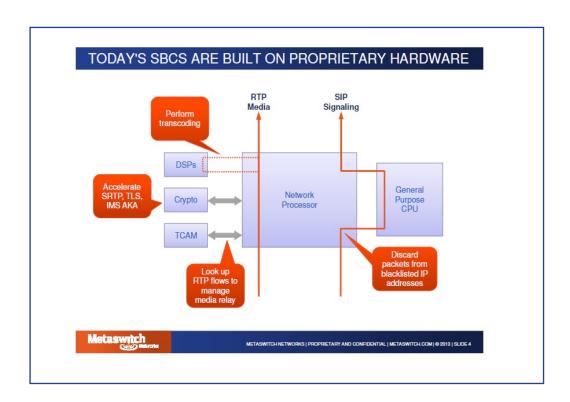
- Implement all SBC functions in software on generic server
  - Signaling plane functions
  - Media plane functions
- Achieve sensible levels of scaling
  - 200k 1M+ registered endpoints per server
  - > 20k concurrent media sessions per server
- Get all this working in a virtualised environment
  - Preserve capacity and performance
  - Preserve failover capabilities

Metaswitch

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SESSION 7 NFV



### SOFTWARE SOLUTIONS FOR THESE CHALLENGES

- Spread load across multiple cores
  - A 16-core server can do a lot of heavy lifting
- Make intelligent use of cache memory
  - · Fast look-up for media flows and IP address blacklists
- Do performance-critical jobs close to the metal
  - Custom kernel modules for low-level packet handling
- Leverage built-in crypto instruction set
  - TLS, IPsec, SRTP
- Do the best you can with software-based transcoding

Metaswitch

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SESSION 7 NFV

### PERFORMANCE OF SOFTWARE-BASED SBC

- Standard off-the-shelf server, 1U, \$9k
  - NICs need to support Receive Side Scaling (RSS)
  - If NICs support Intel DPDK integration, performance ↑ 2.5x
- Performing both signaling and media functions
  - "Integrated SBC" configuration
- Signaling throughput > 12,000 SIP messages per second
  - 6M BHCA (based on 7 x SIP messages per call)
- Media handling: up to 18,000 48,000 (DPDK) concurrent media streams
  - RTP-to-RTP relay, any codec, no transcoding

Intel claims 80M pps forwarding of 64-byte frames with 8-core Xeon and DPDK (on bare metal)

Metaswrich

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### WHAT HAPPENS WHEN SBC RUNS OVER HYPERVISOR

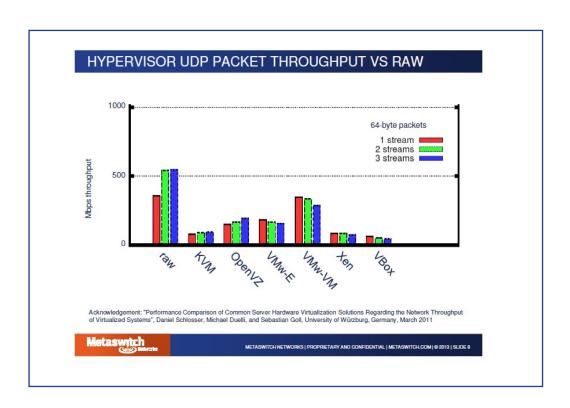
- Signaling function performs as expected
  - Hypervisor overhead in the range 5-20%
    - Cross-core locking a major impact
  - Typical of network-intensive virtualised applications
  - Can be detailed issues to resolve eg high re system clock on KVM
- Media function suffers substantial throughput reduction
  - RTP relay requires high throughput of small UDP packets
  - Bare metal performance of 4M packets/second is achievable
  - Hypervisor can introduce order-of-magnitude reduction
  - Highly dependent on hypervisor and vNIC driver choice

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SESSION 7 NFV



### HYPERVISOR PACKET THROUGHPUT CHALLENGE

- Quick fix by making use of passthrough mode
  - Nailed-up connection between SBC app and physical NIC(s)
  - Reduces flexibility of virtualised SBC
- Preferable to address hypervisor limitations
  - What's needed: improved packet throughput of vSwitch component
  - Intel very active in this space
    - SR-IOV Single Root I/O Virtualisation: virtualises the NICs resources for sharing between cores / guests
  - Also ARM + DSP SoC
  - But none currently compatable with virtual routing

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SESSION 7 NFV

### TRANSCODING IN SOFTWARE

- Historically, transcoding has been performed by DSPs
- Transcoding in software on x86 is more costly
  - Hardware costs, power consumption costs
  - Over five years, software-based transcoding ~ 2X cost of DSP-based

### BUT

- DSP resources can only be used for transcoding
- x86 resources can be used for any kind of processing
- Modern codecs (eg SILK) optimised for CPU not DSP
- Flexibility of software-based transcoding compensates for higher cost

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### REMAINING CHALLENGES

- Cohabitation of fast packet processing and virtual routing
  - Impacts NICs, servers, hypervisors and OSs
  - Needs support across that vendor ecosystem to resolve
- Plus
  - 1:1 FT needs control of instance location
  - Networking control:
    - Multiple redundant interfaces? Bonded?
  - Separate signalling and management networks / VLANs?
  - Cloud owner vs service owner management and monitoring
  - Reliability: do you depend on any cloud services (obvious or hidden)

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SESSION 7 NFV







SESSION 8
NFV and CLOUDS

### Federated identity management in network virtualization environment

### **Abstract**

This paper discusses the impact of network virtualization on identity management in federated environments. We examine the requirements that should be met from a security point of view as well as the infrastructure changes due to virtualization. We further identify the problems arising in this new deployment environment and derive the corresponding requirements for identity management and federation in network virtualization environment.

### 1. Introduction

Identity management and federation can greatly enhance the operation and scalability of an operator network. Federated identity management technologies such as, for example, OpenID [1] and SAML [2], have been developed and deployed in practice as is the case of Single Sign On (SSO) discussed in [3][4]. Further, their integration with current authentication frameworks for mobile networks has been studied; see for example earlier work in [5][6]. However, the impact of a virtualization environment on identity management, in general, and federated identity management, in particular, is only an emerging topic currently.

This paper addresses the impact of network virtualization on identity management and federation. We will examine the requirements that should be met from a security point of view as well as the infrastructure changes due to new virtualization approaches, such as the Network Functions Virtualization (NFV) approach advocated by the corresponding ETSI ISG. We contribute to emerging discussion by identifying the problems arising in a virtualized network deployment environment and deriving the associated requirements for identity management and federation in a network virtualization environment.

The remainder of this paper is organized as follows. Section 2 provides the necessary background on federated identity management. Section 3 describes the problems arising for identity management in a future NFV network deployment environment. We conclude this paper in Section 4.

### 2. Background

### 2.1 Federated Identity Management

Federated Identity (ID) management in this paper refers to the management of user and other entity identities across organizations. Using Federated ID management technologies, an operator subscriber can use one identity to access different services possibly offered by a range of organizations that have an established relationship with the operator.

Examples of federated ID management technologies include, but are not limited to the following:

- **Single Sign-On (SSO)**: SSO permits the user to log in once and gain access to multiple systems without performing login procedure again. Kerberos [7] is an example of SSO. SSO usually needs a centralized authentication server.
- **OpenID:** OpenID is an open standard [1] which can permit a user with an account issued by the so-called "identity provider" to access any website accepting OpenID authentication (the so-called "relying party"). OpenID does not need a centralized authentication server.
- **Security Assertion Markup language (SAML):** SAML is a XML-based open standard data format which is used to exchange authentication data between an identity provider and a service provider [2].
- **Liberty Alliance:** Liberty Alliance aimed to establish open standards, guidelines and best practices for identity management. Since 2009, the work of Liberty Alliance has been moved to the Kantara Initiative [8].



SESSION 8
NFV and CLOUDS

### 2.2 Federated ID Management Requirements

Security and privacy is critical to a federated system ID management system. After a careful evaluation of currently deployed federated ID management systems we can summarize the respective requirements as follows:

- Federated ID management systems shall be able to interoperate across organizational boundaries, which is the basic requirement for a federated ID management system.
- Federated ID management systems shall utilize identity storage for security and privacy.
- Federated ID management systems shall be able to manage security approaches, authentication and authorization.
- Support of different programming models is desirable so that federated ID management systems can be used between different parties using different programming models.

### 2.3 Network Functions Virtualization

As recently motivated by the establishment of the ETSI ISG on Networks Function Virtualization (see [9] and the references therein), telecommunication operators face several problems managing a variety of hardware-based network functions. For example, currently in the telecommunication world, launching new network services require operators to buy a new hardware appliance and accommodating such boxes, which is becoming more and more difficult. Network Functions Virtualization (NFV) was promoted to address and solve such issues. In short, NFV, although not a standards body per se, aims at motivating further work in carrier-grade network functions virtualization so that telecommunications software can run on standard server computers directly, dedicated computer appliances, virtual machines, and any arbitrary combination of these.

### 3. ID Management in NFV Environment

### 3.1 Problems

Currently, the threat model for a virtualized network environment is missing. We argue that the current threat models used for securing telecommunication networks are not sufficient. On the other hand, while we can take clues from cloud computing as a good reference for defining such a threat model, experience from similar technology transfers from one sector to another indicates that several further steps are necessary. In this paper, we contribute to the discussion and evolution towards a threat model for ID management in an NFV environment by considering the problems described in the following subsections.

### 3.1.1 Boundary between Different ID Domains

In a virtualized network environment, the security boundary for distinct ID domains is not clear. One device may belong to several distinct ID domains.

### 3.1.2 Storage of IDs/credentials

In a virtualized network environment, the ID/credential must be securely stored.

### 3.1.3 Authentication System

A universally standardized authentication system across multi-domains is desirable.

### 3.1.4 Trusted Partnership

Trust relationship between different partners is critical to the threat model.

### 3.1.5 Operational Isolation in Virtualized Environment

The operation performed in virtualized environment shall be able to be separated.



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NFV and CLOUDS

### 3.2 Requirements

Based on the problems identified in the previous subsection, we derive the following security requirements for ID management in NFV environment.

### 3.2.1 Authentication and Authorization

The authentication and authorization mechanisms employed in a network virtualization environment must support multi-domain scenarios. Federated Authentication and authentication proxy and delegation must be considered. The credentials need to be securely protected and managed in a centralized or distributed manner.

### 3.2.2 User Privacy

A subscriber may have different IDs and credentials to be used between different ID domains. Therefore, the attacker must not be able link two IDs belonging to different ID domains. The IDs issued by different ID domains need provide unlinkability in the multi-domain environment we are addressing. Subscriber anonymity must be provided.

### 3.2.3 Secure Storage

Leakage of sensitive information, such as permanent secrets, shall be prevented.

### 3.2.4 Extensibility

The mechanism shall be able to work in case of a larger range of service providers.

### 3.2.5 Isolation and Robustness

Security isolation is important to provide robustness when one part of the system is compromised. It is desirable that compromise of one service shall not compromise the security of another service, and compromise of application server or an external server shall not compromise the security of the whole system

### **3.2.6** Flexible Control for the Operator

Control system-level security either by operating the system themselves or by contractual agreements with trusted partners

### 3.2.7 HSS impact

In the telecommunication network, operators use the Home Subscriber Server (HSS) to store ID/credentials. The interfaces should keep the complexity of HSS low, while interfacing with HSS should not lead to HSS information leakage.

### 3.3 Standardization Challenges

Open standards are always desired for a system or service which involves different parties since open standard can avoid interoperation problems as much as possible and open new possibilities for innovation. The first issue needed to be considered is which parts are required to be standardized when one is trying to standardize federated ID management system. Then the next issue is which standardization groups need to be enrolled with. A clear definition of the threat model for federated ID management in Network Function virtualization environment shall be the first step when specifying the standard, then detailed security analysis can be performed based on said threat model.

### 4. Conclusion

Network virtualization is triggering a revolution in telecommunication systems. This paper contributes to the discussion on new open topics for research and standardization in this direction by examining the problems and requirements arising for identity management in a network virtualization environment. In particular, we point to the security mechanisms for identity management in the network virtualization environment which need to be carefully re-considered, including the definition of a threat model and authentication mechanisms.



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### 5. References

- 1. Recordon, David, and Drummond Reed. "OpenID 2.0: a platform for user-centric identity management." In Proceedings of the second ACM workshop on Digital identity management, pp. 11-16. ACM, 2006.
- 2. Maler, Eve. "Assertions and Protocols for the OASIS Security Assertion Markup Language (SAML)." OASIS, September (2003).
- 3. Harding, Patrick, Leif Johansson, and Nate Klingenstein. "Dynamic security assertion markup language: Simplifying single sign-on." Security & Privacy, IEEE 6, no. 2 (2008): 83-85.
- 4. Jeong, Jongil, Dongkyoo Shin, and Dongil Shin. "An XML-based single sign-on scheme supporting mobile and home network service environments." Consumer Electronics, IEEE Transactions on 50, no. 4 (2004): 1081-1086.
- 5. Kagal, Lalana, Tim Finin, and Anupam Joshi. "Trust-based security in pervasive computing environments." Computer 34, no. 12 (2001): 154-157.
- 6. Maler, Eve, and Drummond Reed. "The venn of identity: Options and issues in federated identity management." Security & Privacy, IEEE 6, no. 2 (2008): 16-23.
- 7. Miller, Steven P., B. Clifford Neuman, Jeffrey I. Schiller, and Jermoe H. Saltzer. "Kerberos authentication and authorization system." In Project Athena Technical Plan. 1987.
- 8. Lynch, Lucy. "Inside the Identity Management Game." Internet Computing, IEEE 15, no. 5 (2011): 78-82.
- 9. NFV— Network Functions Virtualisation web page: http://www.etsi.org/technologies-clusters/technologies/nfv

### **Presentation**

# Federated Identity Management and Network Virtualization

Yang Cui and Kostas Pentikousis

3rd ETSI Future Networks Workshop 10 April 2013 Sophia Antipolis, France



The opinions expressed in this presentation are those of the authors and do not necessarily represent the views of Huawei Technologies Co., Ltd.





SESSION 8
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## Talk Outline

- Federated ID Management Today
- Towards Network Virtualization
- Problems and Requirements
- Service Provider and Operator Co-operation
- Single Sign-On (SSO) in Network Virtualization
- Multi-factor Authentication
- Standardization Challenges

2

# Federated ID Management Today

- Single Sign-On (SSO)
  - Centralized AUTH server
    - · Reduces costs, makes user life easier, but requires highly critical auth
  - 3GPP SA3 study item -TR33.804 SSO for IMS
- · OpenID: URI as the federated ID
  - No central Certification Authority (CA) → low trust & security levels
- Security Assertion Markup Language (SAML)
  - XML-based open-standard data format
    - Exchange auth data between an identity provider and a service provider
- Liberty Alliance
  - ID mapping to different domains
  - Complexity of multiple ID providers, SAML

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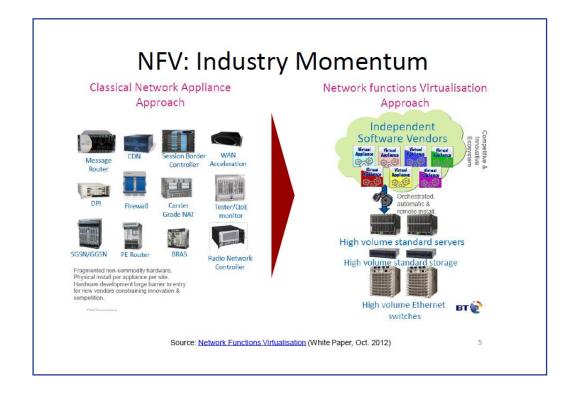


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# Federated System Requirements

- Interoperate across organizational boundaries
- · Utilize identity storage
- Manage security approaches, authentication and authorization
- · Support different programming models
- · Within a federated system, security and privacy is critical
  - Identities/credentials are stored and managed separately
  - Manage own identities
  - Share and accept identities and credentials from other members' sources

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## Network Virtualization

Scalability Experimental
Heterogeneity
IsolationProgrammability
Manageability Legacy Support
Deployment Convergence
Flexibility Stability

6

# NFV ID Management: Problems

- · Threat model in a virtualized network environment?
  - Need to be defined
  - May borrow ideas from cloud computing
- · Virtualized Network
  - No clear security boundary for distinct ID domains
  - ID/credential secure storage
  - Universally standardized authentication system in multi-domains
  - Trusted partnership
  - Operation isolation in virtualized environment

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## NFV ID Management: Requirements

- · Authentication and Authorization
  - Need to support multi-domain scenarios
  - Federated Authentication, Proxy and Delegation
  - Protect credentials (via centralized or distributed management)
- User Privacy
  - ID (and credentials) may need unlinkability in multi-domains
  - Support anonymity as needed
- Secure Storage
  - Information leakage of permanent secrets shall be prevented
- Extensibility
  - Possibility of interworking with a larger range of service providers

3

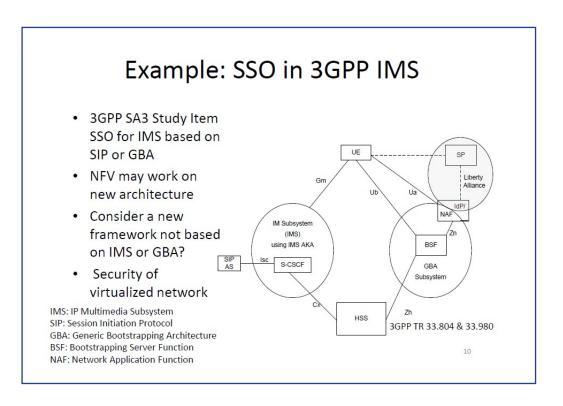
# Requirements (cont.)

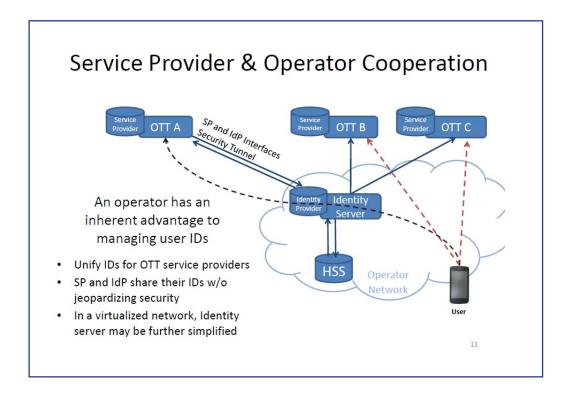
- · Isolation and Robustness
  - Compromise of one service shall not compromise the security of another service
  - Compromise of application server or an external server shall not compromise the security of the whole system
- · Flexible Control for the Operator
  - Control system-level security either by operating the system themselves or by contractual agreements with trusted partners
- In a telecommunication network, operators use HSS
  - Interfaces should keep the complexity of HSS low
  - Interacting with HSS should not lead to HSS information leakage

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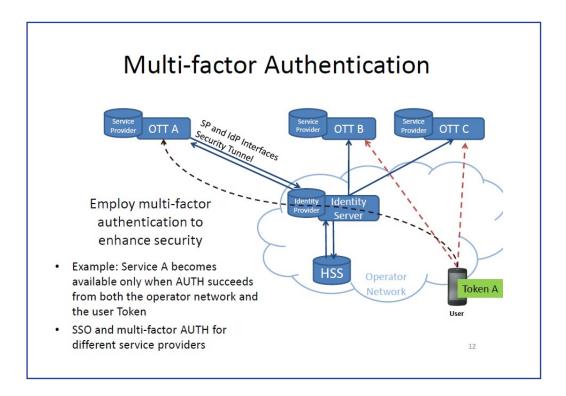
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## Standardization Challenges

- To advance standardization for federated ID management, with consideration of future network virtualization, one may need to check
  - Existing standards and frameworks
  - Standardization organization to enroll with
  - Define and clarify the threat model of federated ID management in NV
  - Detailed security analysis is needed

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## Conclusion and Future Work

- Problems and requirements of Federated ID management in NV
- Co-operation between operators and service providers is needed for extending the capability of ID management
- Security mechanism in NV need to be carefully re-considered, including threat model and AUTH mechanism, etc.

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## Thank You!

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# Future Networks Workshop



#### **Presentations**

SESSION 8
NFV and CLOUDS

Proposal on Network Functions Virtualization relationship with ITU-T Rec. <Y.CCNaa\$> (Cloud Computing Network-as-a-Service) from the holistic perspective of a converged network-computing virtualized service provisioning

#### **Abstract**

Network Functions Virtualization (NFV) aims to reduce network operators's CAPEX/OPEX, etc., as well as to speed up the roll out of new revenue earning network services, by leveraging the economies of scale of the IT industry. Meanwhile, as Cloud Computing is gaining more and more strength in the IT marketplace and ITU-T SG13 starts standardization on Cloud Computing Network-as-a-Service (CCNaaS), in this presentation, we introduce a high level concept of CCNaaS and explore its relationship with NFV from the holistic perspective of a converged network-computing service provisioning.

Service-oriented virtualization makes both networking and computing resources as a single collection of virtualized, dynamically provisioned resources. This facilitates coordinated management, control, and optimization of resources across the networking and computing domains. We propose a convergence framework where NFV facilitates for CCNaaS with a certain degree of flexibility to compose virtual networks requested by cloud service users but also Cloud Computing services (e.g., laaS, PaaS, CCNaaS, etc.) are utilized to implement NFV. Consolidated virtual appliances can be implemented, for example, by means of mashup of distributed, scalable, shared and decomposed virtualized network functions in data centres using Cloud Computing services.

We also discuss required joint collaborative efforts between NFV and CCNaaS standards, in vertualized service description, discovery and composition points of view. We are sure that incorporating Cloud Computing in key trends interacting with NFV will deliver many benefits.





SESSION 8
NFV and CLOUDS

## **Agenda**



- Cloud computing for NfV
- ITU-T Cloud computing standardization briefs
- · Proposed requirements for the architectural framework
- · Required joint collaborative efforts
- Summary

ETRI

1

## What's happening



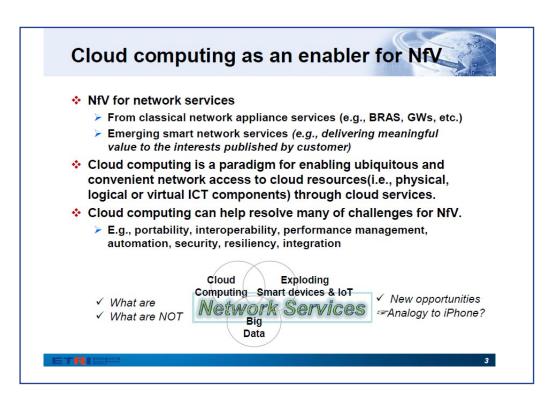
- Cloud computing
  - Key characteristics
    - On-demand self service, broad network access, multi-tenancy, resource pooling, rapid elasticity and scalability, measured service
- Exploding smart devices and emerging IoT
  - How to exploit the opportunity of tremendous information sources and consumers with mobility issues
- Big data
  - Enables revenue generating service innovation, reducing opex and enhancing customer experience, building smart pipes providing QoS and security assurance
- \* NfV & SDN, ...
- Putting those all together, implications on the network operator's business?

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SESSION 8
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#### ITU-T SG13 (study period 2013~2016) 19 Qs in 3 WPs(NGN-e and IMT, Cloud Computing and Common Capabilities, SDN and Networks of Future) Collaborative Team(CT) of ITU-T SG13/WP2 and ISO/IEC JTC1/SC38/WG3 Cloud computing overview and vocabulary(CT-CCVOCAB) Cloud computing reference architecture(CT-CCA) Y.ccdef Cloud computing definition and vocabulary Q17/13 CT-CCVOCAB Cloud computing framework and high-level requirements Q17/13 Consent rel. 1 (Y.3501) Y.DaaS Requirement and reference architecture of desktop as a service Q17/13 Working draft Rec. Y.ccic Framework of inter-cloud for network and infrastructure Q18/13 Working draft Rec. Y.ccinfra Cloud computing infrastructure requirements Q18/13 Consent (Y.3510) Y.ccra Cloud computing reference architecture Q18/13 CT-CCA Y.e2eccmr End-to-end cloud computing resources management requirements Q19/13 Consent (Y.3520) Y.VNC Resource control and management for virtual networks for cloud services (VNCs) Q19/13 New work item Y.cclaaS Functional requirements and architecture of laaS service Q18/13 Y.ccNaaS Requirements, use cases and functional architecture of Network as a Service



SESSION 8
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## ITU-T SG13 Y.CCNaaS & Y.CClaaS(NWI)

- Network as a Service(NaaS) is a cloud service category where the capability provided to the cloud service customer is transport connectivity and related network capabilities
  - Subject to be discussed at next ITU-T SG13 & CT meeting
- Other cloud services can employ NaaS (need consensus)
- These recommendations will describe:
  - High level concept, framework and relationship with cloud reference architecture
  - Functional requirements, functional architecture, reference points, and typical use cases
- · Relationship with NfV
  - NfV facilitates the service provisioning of NaaS with a certain degree of flexibility (as a Cloud Service Provider's Role)
  - Cloud resources are utilized to implement NfV through cloud services (as a Cloud Service Customer's Role)



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## Looking forward to a new ICT env.

- Proposed requirements for the architectural framework to relate NfV to Cloud Computing
  - From holistic perspective of a converged network-computing service provisioning
    - Need to make both networking and computing resources as a single collection of virtualized, dynamically provisioned resources
      - This facilitates coordinated management, control, and optimization of resources across the networking and computing domains
  - Need to support following key features (SOA as a reference design methodology)
    - Loosely-coupled interaction among heterogeneous systems in the architecture, reusable services, formal contract among services, service abstraction, service autonomy, service discoverability, and service composability

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SESSION 8
NFV and CLOUDS

## Required joint collaborative efforts

- Roles and activities to be implemented by function components, which are subject to develop with NfV input, include
  - Cloud Service Customer related activities
    - · Selection and purchase of cloud service
    - · Integration between existing ICT systems and cloud services
  - Cloud broker as a sub-role of Cloud Service Partner
  - Cloud Service Provider related activities
    - · Automate system processes
    - · Define service offerings
    - · Aggregation for composite services
- Functional components related to cross cutting aspects
  - Cross cutting aspects are behavior or capability which needs to be implemented and coordinated across roles
    - Cross cutting aspects include interoperability, portability, reversibility, security, privacy, resiliency, performance, availability, governance, maintenance and versioning, SLA

ETRI BOOK

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## Required joint collaborative efforts

- Functional components, which need input from NfV, includes
  - > laaS service category component in Services Layer
    - · NfV as a Cloud Service Customer
  - NaaS service category component in Services Layer
    - · NfV as a Cloud Service Provider
  - Resource Abstraction & Control component in Layered Functional Architecture
    - Enables a Cloud Service Provider to offer qualities such as rapid elasticity, resource pooling, on-demand self-service and scale-out
    - Can include software elements such as hypervisors, VMs, virtual data storage, and time-sharing
  - Integration component in Cross Layer Functions
    - · Provides service orchestration function

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SESSION 8
NFV and CLOUDS

## **Summary**



- Smart network services will emerge from the new ICT environment with Cloud computing, Big data, and tremendous amount of information.
- Key characteristics of Cloud Computing make itself a good enabler for NfV.
- ITU-T SG13 Cloud Computing related standardizations are briefly discussed.
- Requirements for the architectural framework to relate NfV to Cloud Computing are proposed, leveraging SOA as a reference design methodology for the converged network-computing service provisioning.
- Some of required joint collaborative work items are addressed. Incorporating NfV into Cloud computing standards will benefit both parties.

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# SESSION 9 ENABLING TECHNIQUES

#### Which Information Model for Autonomic Mechanisms?

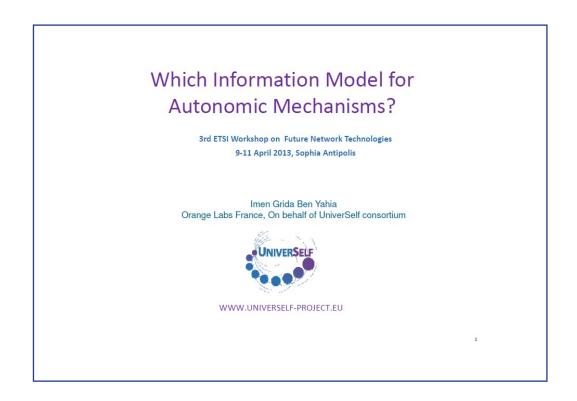
#### **Abstract**

Telco's ecosystem faces today a growing complexity, mainly caused by the advent of new types of resources and technologies related to virtualization, SDN and cloud storage. Such complexity is pushing towards the adoption of autonomic management that considers the use of the well-known self-x functions in order to fulfill dynamic provisioning and configuration enhanced with rapid and effective fault management. In this context, a novel Unified Management Framework (UMF) is being specified in UniverSelf project. UMF targets the embodiment of intelligence into network entities (physical or virtualized), in the form of autonomic elements named Network Empowered Mechanisms (NEMs). At the same time it defines a set of Core functions, operations and mechanisms for their proper governance, coordination and knowledge exchange between these autonomic elements.

In such context, the design of an information model able to support the management operations of thousands of vendor-specific NEMs, becomes of utmost importance. Moreover, it is mandatory that this information model supports the seamless integration with existing operator's management systems.

The aim of this presentation is to propose subsets of information model for NEMs that is based on the TM Forum's Information Framework (a.k.a. SID-Shared Information and Data). The extensions of the SID model were designed to achieve the specification of UMF interfaces and cover the structure and lifecycle of NEMs, actions and information manipulated by the NEM, as well as the policies driving the NEM behaviour. Along with the information model extensions, their usage in governing and managing the NEMs will be also described. The application and associated implications of the proposed model to SDN related solutions and technologies will be also presented.

Acknowledgment. The research leading to these results has been performed within the UniverSelf project (www. univerself-project.eu) and received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 257513.





# SESSION 9 ENABLING TECHNIQUES

#### Outline

- MOTIVATION
- UMF-FRAMEWORK FOR AUTONOMIC MECHANISMS
- INFORMATION MODEL BASICS
- STANDARDIZATION OPPORTUNITIES: INFORMATION MODEL FOR AUTONOMIC MECHANISMS

#### Motivations

#### Context

#### Issues

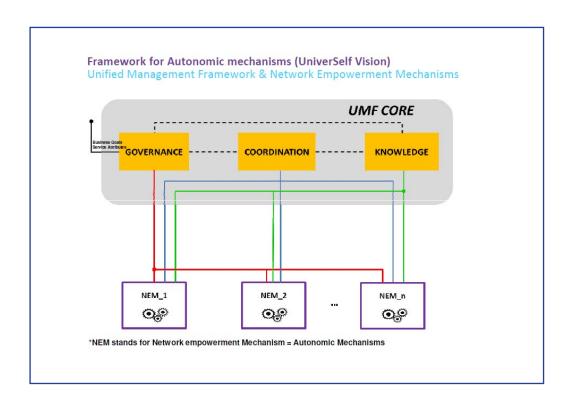
- Operators today have hundreds of millions of customers and need to ensure mass of customization
- Operators rely on thousands of different network elements with their proprietary implementations
- Operators are spending millions of euros for the adaptation and integration of network element and element manager
- Operators need to handle thousands of alarms per day are received ... in a medium size NOC

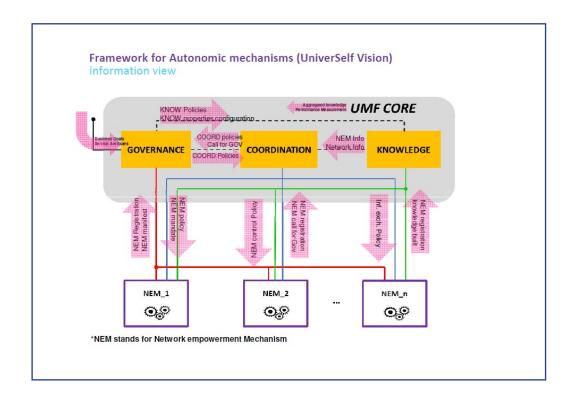
#### Goals

- Operators are seeking for advanced management operations which implements Self\* functions to handle complexity in management operations.
- Operators are looking for approaches to alleviate the integration issues to reduce CAPEX/OPEX and improve TTM.



# SESSION 9 ENABLING TECHNIQUES







# SESSION 9 ENABLING TECHNIQUES

## IM- INFORMATION MODEL BASICS Definitions



- An information model is "an abstraction and representation of the entities in a managed environment. It includes definition of their properties, operations and relationships. It is independent of any specific type of repository, software usage, platform, or access protocol."
  - "The Internet Engineering Task Force, IETF, RFC 3198, Terminology for Policy-Based Management
- An information model is a representation of business concepts, their characteristics and relationships, described in an implementation independent manner.
  - o TMF-SID v12.5
- Information Model: Information Model denotes an abstract, formal representation of entity types, including their properties and relationships, the operations (e.g. read, write...) that can be performed on them, and related rules and constrains. In the information model, entities might have network topology relationship with each other.
  - o 3GPP, terminology 32.181

#### **IM-INFORMATION MODEL BASICS**

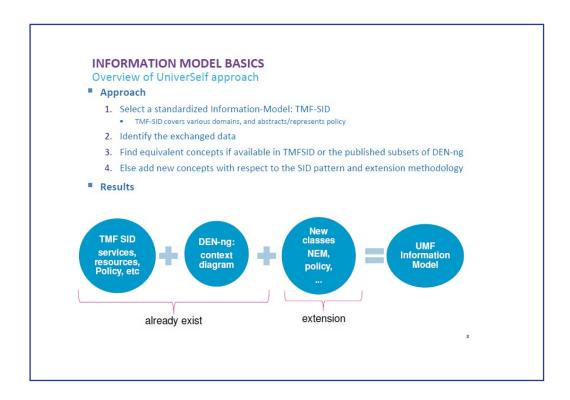
Why do we need an Information Model?

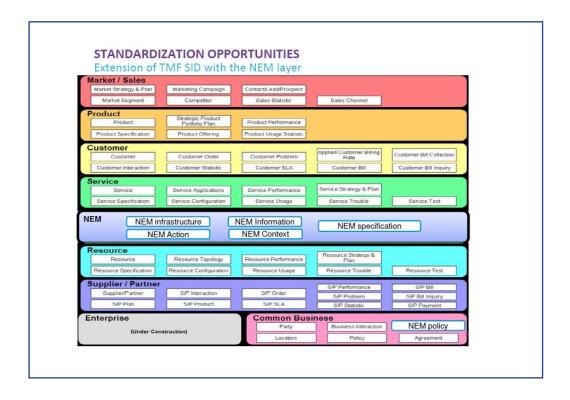
#### IM is an enabler for convergence/federation/unification of management systems

- For current and legacy management systems
  - o IM is mainly used as a reference model to define management system interfaces and to define repository data model
- For future systems in particular Autonomic mechanisms
  - IM is also an enabler for defining communication interfaces between application and upper management layers.
  - IM is an enabler for software development (good feedback from implementers inside the project)
  - o IM is an enabler for ontology development
    - for reasoning
    - model transformation (MDA, MDE, etc) An IIM will enable semantics and reasoning, opening the door to automatic translation



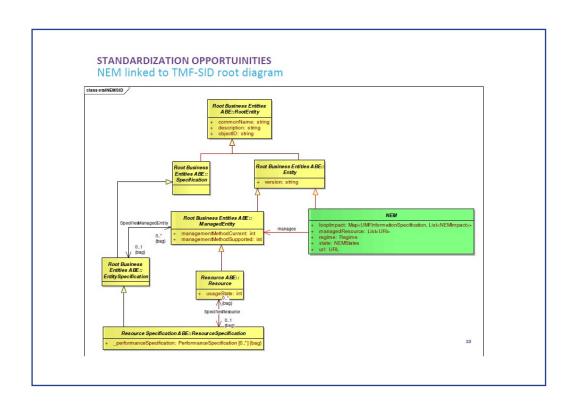
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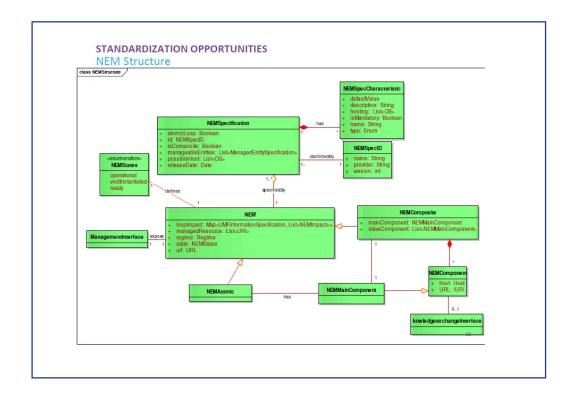






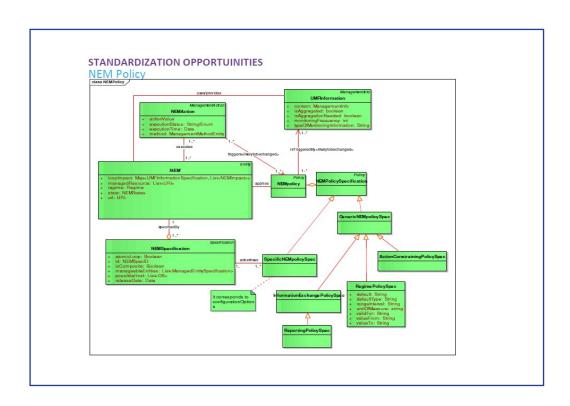
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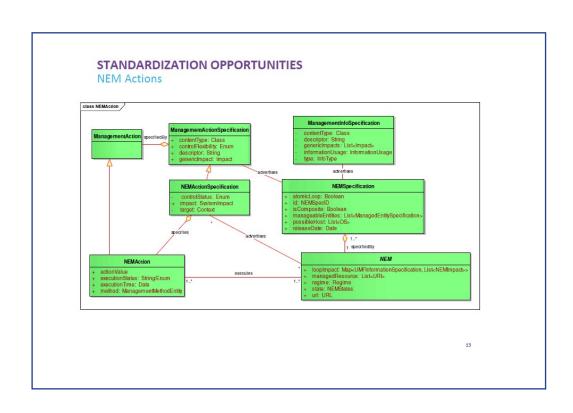






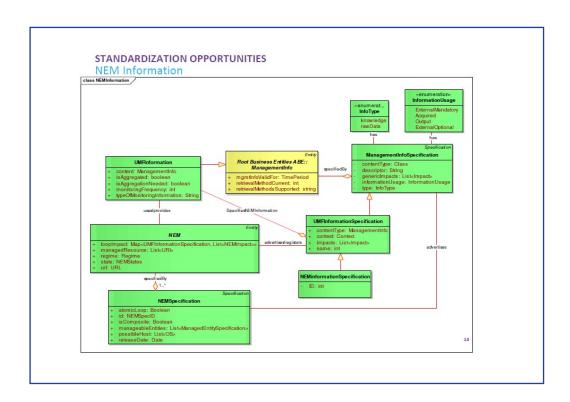
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# SESSION 9 ENABLING TECHNIQUES



#### STANDARDIZATION OPPORTUNITIES

Key messages

- Autonomic Mechanisms need to be managed and integrated
  - o UMF CORE BLOCKS + Information Model for Autonomic Mechanisms
- Information Model for Autonomic Mechanisms is an enabler to abstract and represent what operators need to know in order to deploy, configure and activate efficiently autonomic mechanisms
- WITHOUT Information Model, Autonomic Mechanisms are
  - o "vendors specific" with "proprietary implementations"
  - o sometimes black boxes
  - o increase of integration issues
- Room for discussion in
  - o NGMN NGCORE (part of the Umbrella Model)?
  - o ETSI AFI for the WI#2 (MBTS?)
  - o TMF-SID extension for managing Autonomic Mechanisms
  - o 3GPP while specializing the IM for 3GPP SON





# SESSION 9 ENABLING TECHNIQUES

#### Acknowledgments

- The research leading to these results has been performed within the UniverSelf project (www.univerself-project.eu) and received funding from the European Community's Seventh Framework Programme FP7/2007-2013) under grant agreement n° 257513.
- The following co-authors contributed to this work elaboration:

Pierre PELOSO (Alcatel-Lucent Bell Labs), Makis STAMATELATOS(NKUA) Kostas TSAGKARIS (UPRC), Beatriz FUENTES(Telefónica I+D)

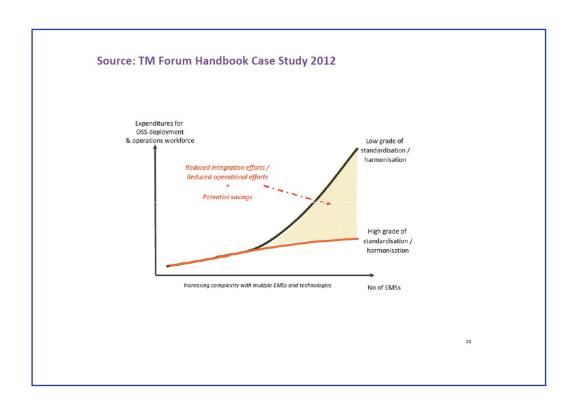
- Laurent CIAVAGLIA (Project Coordinator), Alcatel-Lucent Bell Labs France
- Christian DESTRE (Technical Manager), Orange Labs France

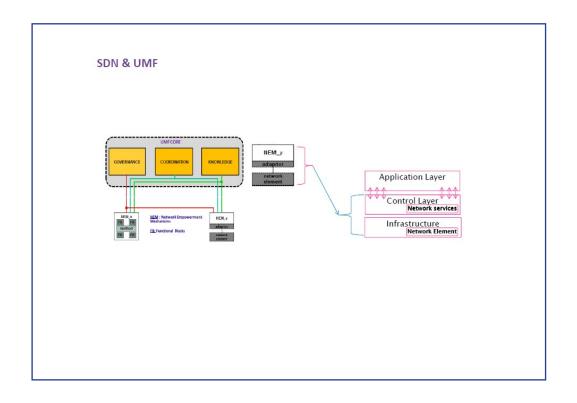
**QUESTIONS & ANSWERS** 

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# SESSION 9 ENABLING TECHNIQUES

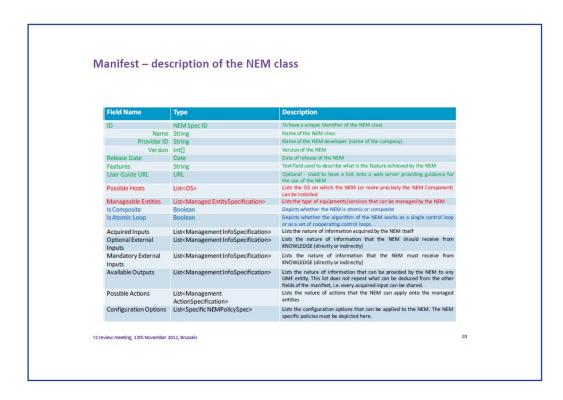








# SESSION 9 ENABLING TECHNIQUES





# SESSION 9 ENABLING TECHNIQUES

#### Solving Specification Methodology for NfV Systems and Interfaces

#### **Abstract**

The work of the new ISG on network functions virtualisation brings into focus three significant problems for specification sufficient to successfully achieve interoperability.

- Interface specifications generally do not include any specification of behaviour.
- There is no well-established method for representing the process of deploying, activating, and the operating a virtual function.
- Methods of representing abstract views tend to apply to the design phase of a system and cannot be defined after a system is operational.

The first of these has been apparent for many years, however, proposed solutions such as REST interfaces don't solve the problem, they only push the problem elsewhere. As modelling techniques such as UML have developed with embedded programming language friendly constructs, the other two issues seem to have become harder to deal with rather than simpler. Modelling techniques, even BPMN and SysML, have become ever more focussed on the design (ie coding) phase at the expense of the operational phase.

This paper presents fresh but compatible modelling methodology which mathematically unifies systems engineering and object modelling. At its heart is the concept of a configurable host system. This concept is an extension of both systems engineering and object orientation and unifies both. It is possible to assimilate most existing modelling constructs – and therefore graphical representations – while adding critical extra constructs which resolve the above issues. Mathematically, it also provides a unification of Shannon information and Kolmogorov information as is believed to be fully compatible with pi calculus.





# SESSION 9 ENABLING TECHNIQUES

#### Background

- Many systems, including telecommunications systems are specified and interconnected functional blocks
- Underpinned by formal mathematics of systems engineering theory and automata theory
- However, there are the following difficulties
  - Tend to exclusively specification interfaces which generally do not include any specification of behaviour.
  - Methods of representing abstract views tend to apply to the design phase of a system and cannot be defined after a system is operational.
  - There is no well-established method for representing the process of deploying, activating, and the
    operating a virtual function.
- Commonly used techniques for specification do not directly address these requirements
  - Modelling techniques such as UML have developed with data centric constructs increasingly embedded in the language
  - Modelling techniques, even BPMN and SysML, have become ever more focussed on the design (ie coding) phase at the expense of the operational phase
- Need a technique which is
  - Natural and easy extension of current techniques
  - Capable of supporting and defining virtualisation
  - Capable of supporting abstract, even abstract implemented while run time operational
  - Deductive rather than assertive
  - Mathematically sound and robust

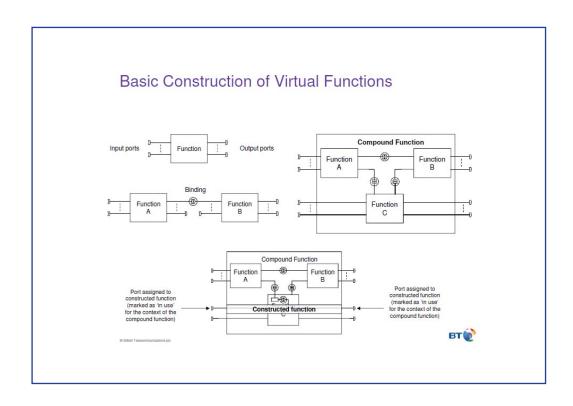
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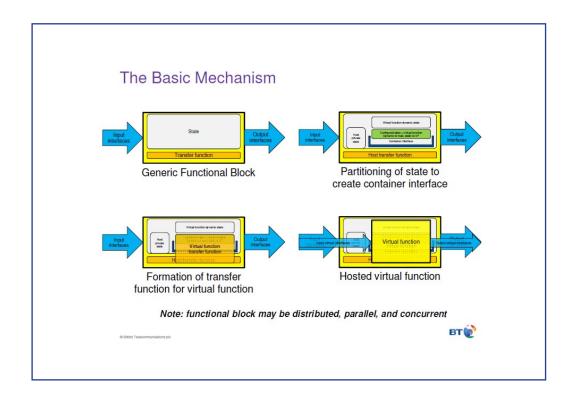


### Virtualisation - Key Specification Requirement Virtualisation of functional blocks results in CKS results in Division of a functional block between a host function and a virtualised network function Creation of a new container interface between host and VFB Division of the interface between an infrastructure interface and a virtualised interface. Interface Interface virtualisation The virtualised functional block (VFB) is not a functional block independent of it host function The container interface is not an interface between functional blocks equivalent to other interfaces. BT



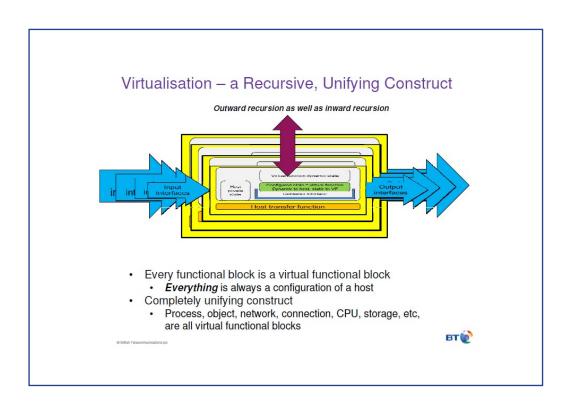
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# SESSION 9 ENABLING TECHNIQUES



Virtual Function ⇔ Abstract Function
Host Function ⇔ Domain Specific Language Run-Time

\*\*Abstraction\*\*

• The VFB is, by nature, abstract
• Every viable abstract function is a virtual function
• Every (abstract) VFB can be implemented on a wide variety of hosts functions

\*\*Domain specific languages (DSLs)\*

• Every container interface defines a configuration language – a domain specific language (DSL)
• The run time of every DSL is a host function
• DSLs are layered as VFBs are layered



# SESSION 9 ENABLING TECHNIQUES

# Absolute Specification and Relative Specification Functional Equivalence, Π-Calculus

- · VFB can have a formal, precise, absolute specification
  - Input value range, output value range, state value range, state transition transfer function (pure logic specification)
- VFB can have formal, precise, specification relative to host VFB, ie its defining configuration
  - 'running code', reference implementation
- · Need to establish equivalence
  - Conformance testing (the practical and every day solution)
  - Formal methods (difficult to scale and implement)
  - Mathematical definition of equivalence strong bi-similarity
- Need to create ante hoc and/or post hoc equivalence
  - Ante hoc formal sub-sets of VFB specification
  - Post hoc translation interpreter, script, compiler
  - Should have equivalence to  $\pi$ -calculus
  - 'new' is equivalent to reconfiguration in host VFB

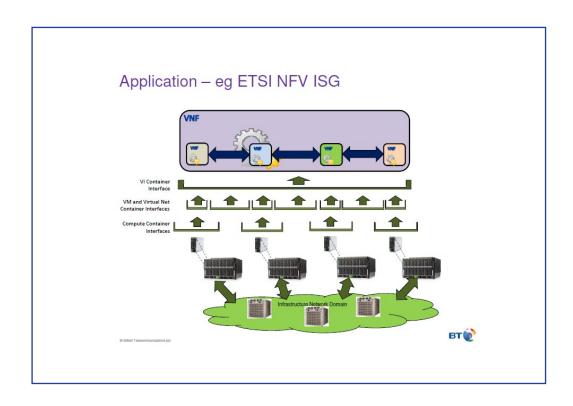
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#### Shannon Information ⇔ Kolmogorov Information Shannon Information Four separate sets of Shannon Information Defined as • A sele ction k from a set of possible values K Measured by $I = \sum_{k \in R} p_k \log_2 \left( \frac{1}{p_k} \right)$ Applies to Input, output, state Configurable transfer functions Kolmogorov Information Kolmogorov Information Defined as The complexity of an output signal (assumes no input) Measured by Length of shortest programme to create output Applies to Configurable transfer functions



# SESSION 9 ENABLING TECHNIQUES





# Future Networks Workshop



#### **Presentations**

# SESSION 9 ENABLING TECHNIQUES

#### Defining ontologies for IP traffic measurements at MOI ISG

#### **Abstract:**

Network management and future Internet services implementation require IP traffic monitoring. Operators and different research groups have been developing systems and measurement tools that offer partial views on how applications use network resources. Their results are stored in different structures, expressed in different units and sometimes they are calculated by different algorithms, meaning different concepts. Not only for business reasons, to clarify service level agreement parameters, but also to achieve a unified context for information exchange, a common information model of measurement parameters and units has to be agreed.

ETSI MOI ISG has been working on the definition of an ontology to describe such information about IP traffic measurements is essential to develop complex systems for IP network monitoring based on different infrastructures. Ontologies have already made a valuable contribution to different science areas, however yet no ontology had been defined for Internet measurement and traffic monitoring systems. The specification of this ontology enables to process information semantically aside from enabling a unique framework to understand traffic measurements. An information model for all parameters that can be measured is established by setting up a vocabulary of classes and relations, providing a semantic definition of the information that network monitoring systems deal with. This presentation will provide a summary on the work MOI ISG has been doing.

#### 1. Introduction

Currently, there exist many systems to monitor network traffic, providing measurements about delay, jitter, capacity, packet loss, etc. They use different data structures, they give it in different units and sometimes they use different algorithms to run the measurements. This heterogeneity can be a problem in many situations. For instance, in SLA monitoring providers and customers need to know if the agreed service level is met, and they have to provide their measurement in a uniform way. Also, when developing complex monitoring systems that are fed from different monitoring sources, it is important that the network measurement information is mixed avoiding the heterogeneity stated above. Then, a common model of network measurement parameters and units has to be agreed.

This common information has to provide a way to homogenize the different data structures and units used for network measurements. Such model has to be agreed as a standard to solve the problems described before. For this, we propose to specify an ontology, or set of ontologies, given that they are a very flexible method to describe domains. Ontologies have already made a valuable contribution to different science areas, however yet no ontology has been standardized for Internet measurement and traffic monitoring systems. The specification of this ontology will enable to process information semantically aside from enabling a unique framework to understand traffic measurements. To promote the standardization of such ontology, ETSI has created an Industrial Specification Group (ISG) named Measurement Ontology for IP Traffic (MOI).

The perspective of ontology usage will bring interoperable and ubiquitous solutions in currently existing vendor-specific and heterogeneous infrastructures and tools. An information model for all parameters that can be measured will be established by setting up a vocabulary of classes and relations. It will provide a semantic definition of the information that network monitoring systems deal with. Furthermore, the adoption of ontological models will also allow defining a set of anonymization rules for the measurement data in order to obscure sensible fields in the data prior to publish them.

The rest of the paper is structured as follows: First of all, MOI ISG is further presented, showing the activities performed so far. Next, the use and importance of ontologies will be stressed. Then, the different work items developed at MOI will be described. The paper finally gives some conclusions and future work of the MOI ISG.



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#### 2. MOI ISG presentation

As stated before, MOI was created as an ETSI ISG to enable the specification of an ontology for IP network traffic measurements. This ISG includes in its members network operators, SMEs, research centers and universities. The work done at MOI is very related to past and present European projects of the Seventh Framework Program: MOMENT, PRISM, NOVI and OpenLab. The ISG is open for any new members willing to contribute to the MOI work program.

MOI ISG has released three documents (so called Work Items) so far:

- WI#1: Report on information models for IP traffic measurement [2].
- WI#2: Requirements for IP traffic measurement ontologies development [3].
- WI#3: IP traffic measurement ontologies architecture [4].

These work items are shown in section 4. Other work items are currently being developed.

#### 3. Use of ontologies

An ontology is defined as an explicit and formal specification of a shared conceptualization [5]. The definition can be analyzed as follows:

- Explicit: it includes concepts, properties, relationships, functions, axioms and restrictions.
- Formal: it can be interpreted by machines.
- Shared: agreed among groups of experts (such as in standardization committees).
- Conceptualization: abstract model of the represented domain.

Ontologies are currently used in every information models, due to its capabilities and the tools developed by the semantic web community.

Ontologies provide a modeling paradigm where the information can be processed at a semantic level, instead of just trying to translate syntactic data structures. This makes easier to do mappings with other existing specifications [6]. Finally, the definition of the MOI ontology will let a single framework to understand traffic measurements.

#### 4. MOI work items

Next subsections present each MOI work items released so far, where the third work item can be taken as the most relevant contribution of the ISG.

#### 4.1 Report on information models for IP traffic measurement

This first work item was defined to present other existing information models for network measurements, from different standardization bodies:

- IETF: SNMP MIBs, IPFIX, IPPM.
- Open Grid Forum: Exchange measurements in XML, as proposed by PerfSonar.
- CAIDA: DatCat measurement catalogue.
- Other network information models would include ITU's M.3100, DMTF's CIM, TMF's SID...

Existing active and passive network measurement repositories, mostly from past European projects, were also described, such as MOME, LOBSTER, RIPE, ETOMIC, DIMES, MINER...

The main conclusion that was extracted from this work item was that there were too many incompatible information models, and none of them had addressed the integration problem at a semantic level. Then, the specification of MOI ontology will be a good approach.

#### 4.2 Requirements for ontologies development

The second work item was devoted to specify the requirements that the ontology should have.

For this, key performance indicators in network operation were identified. For instance:

- Delay and delay variation (jitter).
- Packet errors, losses, reordering, duplicates.



SESSION 9
ENABLING TECHNIQUES

- Connectivity and availability.
- Throughput.

Later, several use cases were defined to obtain the requirements. Those use case were:

- IP network characterization.
- QoS measurements.
- Traffic monitoring for security applications.
- Autonomic network management.
- Law enforcement.

Then, the requirements derived from the use cases were provided, as well as other general requirements such as expandability, interoperability, or performance.

#### 4.3 IP traffic measurement ontologies architecture

The last work item takes the requirements specified before as input to describe an architecture for the MOI ontology, and assess that the requirements are met with the described ontology architecture.

The work item proposes to divide the ontology into several subontologies, as shown in Figure 1:

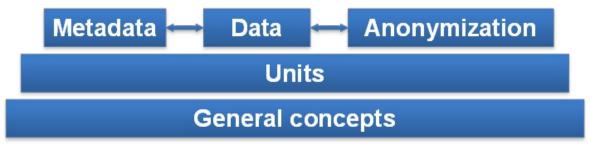


Figure 1. MOI ontology architecture.

The architecture is based on an ontology for general concepts in the network measurement domain. This ontology is complemented with a units ontology, adapted from the NASA ontology, including measurement units typical in the network domain.

From these ontologies, three ontologies are also proposed: an ontology for network measurement metadata, based on CAIDA's DatCat; an ontology for network measurements, taking measurement definitions from the Open Grid Forum and PerfSonar, as well as from as IPPM or IPFIX; finally, an ontology about the anonymization policies for the measurements.

This architecture allows working with the complexity of the problem, by breaking it in smaller ontologies. Future extensions are also possible in this architecture, where more specific ontologies can also be defined on top of the ones proposed here

#### 4.3.1 General concepts

In the general concepts ontology, a network connects different devices, as shown in Figure 2:

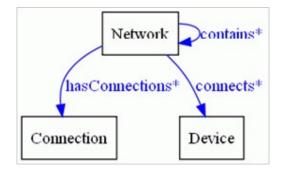


Figure 2. Network definition in the general concepts ontology.



# SESSION 9 ENABLING TECHNIQUES

Connection and Devices can also have subclasses. For instance, a Device has a RoutingDevice and an ApplicationDevice. Other concepts described in this ontology are the location of the devices, the communication stack, its protocols and structure of the elements of information, or the behavior of the network elements. All these concepts are later used in the more specific ontologies.

#### 4.3.2 Units ontology

The units ontology provides the set of interpretable units used in network measurements. Although it is based on the NASA units ontology [7], it includes units that were not defined before, and useful for network measurements. For instance, information units (bit, byte), throughput units (bps...) or network addresses (IPv4, IPv6...). It also differentiates between the metric system, where the Kilo prefix means 103 and the binary scale, where the Kibi prefix means 210. Transformation rules for the measurements are also provided, for instance to change the notation of an IP address (32-bit integer, dotted decimals...). Based on these rules, the conversion between available measurement units can be inferred automatically.

#### 4.3.3 Metadata ontology

The metadata ontology provides information about what was measured, when it was measured, who measured it, and where such measurement can be located and downloaded. It is based on the vocabulary of CAIDA's DatCat, but adding semantics and relationships to the other ontologies.

It is also possible to relate instances of the metadata ontology with instances of the data ontology, described below.

#### 4.3.4 Data ontology

The data ontology is about the measurements themselves. As shown in Figure 3, on the right, the measurement class is a sort of container that groups all information related to a measurement. Each measurement contains a set of measurement data, which will also have facets. For instance, a measurement done with the Iperf tool (Figure 3, on the left) will have information about capacity, errors or delays, and each of these data will include facets such as the data type, or the unit in which it is measured. The measurement values are described with this structure, being one instance for each class, finally containing the measured values.

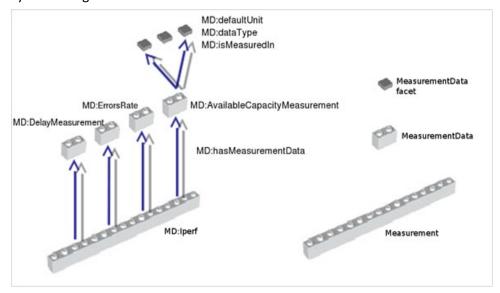


Figure 3. Structure of measurements in the data ontology.

#### 4.3.5 Anonymization ontology

Finally, the anonymization ontology identifies the common vocabulary for the various anonymization components, and it models possible Anonymization Strategies. Different policies can be defined to obfuscate privacy-related fields of Internet measurements. This ontology also considers User Roles and Usage Purposes. With this ontology it is possible to infer the correct strategy based on role and purpose assigned to user by the software system or the community.





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#### 5. Conclusions and future directions

Currently there are several incompatible information models for network measurements. Then, there is a need for a measurement ontology to homogenize network measurement data, working at a semantic level to solve the heterogeneity problem. The ontology architecture for network measurements proposed at MOI has been structured in several sub-ontologies to deal with the complexity of the problem.

Currently, MOI is addressing a new work item, devoted to the specification of a pure MOI ontology. At MOI we are also looking for people interested in using the ontology, both at research and industrial projects.

#### 6 Acknowledgement

This work has been partially funded by the by the European Commission (contract INFSO-ICT-287581) under the project Openlab of the seventh framework program. The author would like to thank other members of the MOI ISG for their valuable work in the ISG.

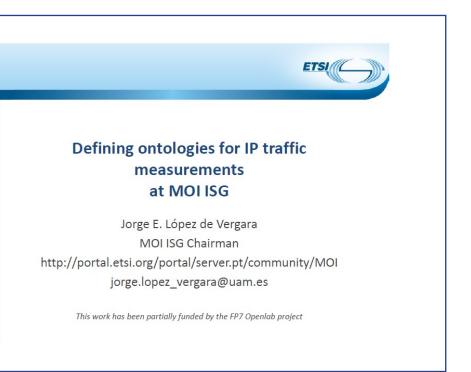
#### 7 References

- [1] ETSI, "Measurement Ontology for IP traffic (MOI) Portal," http://portal.etsi.org/portal/server.pt/community/MOI
- [2] ETSI "Measurement Ontology for IP traffic (MOI); Report on information models for IP traffic measurement," ETSI GS MOI 010 V1.1.1 (May 2010), http://www.etsi.org/deliver/etsi\_gs/MOI/001\_099/010/01.01\_60/gs\_MOI010v010101p.pdf
- [3] ETSI, "MeasurementOntologyforIPtraffic(MOI); RequirementsforIPtrafficmeasurementontologies development," ETSI GS MOI 002 V1.1.1 (2012-07), http://www.etsi.org/deliver/etsi\_gs/MOI/001\_099/002/01.01.01\_60/gs\_moi002v010101p.pdf
- [4] ETSI, "Measurement Ontology for IP traffic (MOI); IP traffic measurement ontologies architecture," ETSI GS MOI 003 V1.1.2 (2013-01), http://www.etsi.org/deliver/etsi\_gs/MOI/001\_099/003/01.01.01\_60/gs\_moi003v010101p.pdf
- [5] T. R. Gruber, "A Translation Approach to Portable Ontology Specifications," Knowledge Acquisition, Vol. 5, No. 2, 1993, pp. 199-220
- [6] Jorge E. López de Vergara, Víctor A. Villagrá, Antonio Guerrero, Julio Berrocal, "Ontology-based network management: study cases and lessons learned," Journal of Network and Systems Management, Vol. 17, No. 3, September 2009, pp. 234-254
- [7] NASA, "Units Ontology," http://sweet.jpl.nasa.gov/ontology/units.owl
- [8] CAIDA, "DatCat," http://www.datcat.org/



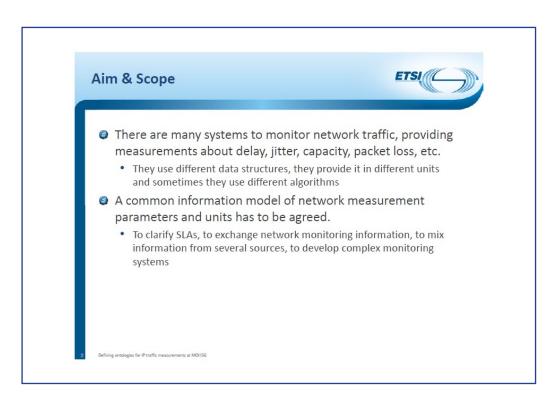


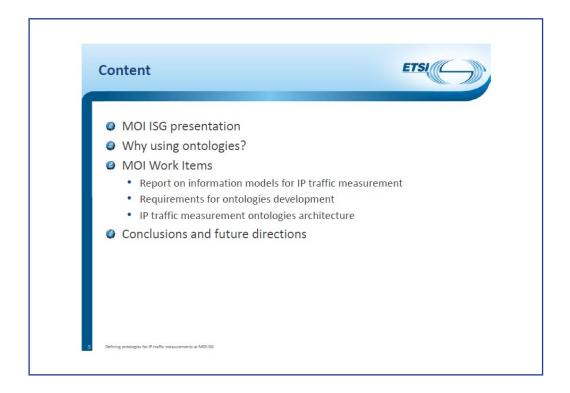
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# SESSION 9 ENABLING TECHNIQUES







# SESSION 9 ENABLING TECHNIQUES

### MOI ISG: Measurement Ontology for IP traffic ETSI

- MOI was created as an ETSI ISG to enable the specification of an ontology for IP network traffic measurements
- This ISG includes in its members network operators, SMEs, research centers and universities
- The work done at MOI is very related to past and present EU FP7 projects: MOMENT, PRISM, NOVI and OpenLab
- It has completed three documents (Work Items):
  - WI#1: Report on information models for IP traffic measurement
  - WI#2: Requirements for IP traffic measurement ontologies development
  - WI#3: IP traffic measurement ontologies architecture

Defining ontologies for IP traffic measurements at MOI ISG

#### Why an ontology?



- An ontology is an explicit and formal specification of a shared conceptualization
  - Explicit: it includes concepts, properties, relationships, functions, axioms and restrictions.
  - Formal: it can be interpreted by machines
  - Shared: agreed among groups of experts
  - · Conceptualization: abstract model of the represented domain
- Ontologies are currently used in every information models, due to its capabilities and the developed tools from the semantic web community
- The definition of the MOI ontology will allow:
  - To process information semantically
  - · Enabling a unique framework to understand traffic measurements
  - Making easier mappings with other models

Defining ontologies for IP traffic measurements at MOI ISO



# SESSION 9 ENABLING TECHNIQUES

## WI#1: Report on information models for IP traffic measurement



- It describes other existing information models for network measurements
  - IETF: SNMP MIBs, IPFIX, IPPM...
  - Open Grid Forum: measurements in XML
  - CAIDA: DatCat
  - Other: ITU's M.3100, DMTF's CIM, TMF's SID...
- Active and passive network measurement repositories are also described:
  - MOME, LOBSTER, RIPE, ETOMIC, DIMES, MINER...
- Main conclusion:
  - · Too many incompatible information models
  - None of them have addressed the integration problem at a semantic level
  - MOI ontology will be a good approach

Defining ontologies for IP traffic measurements at MOI ISG

# WI#2: Requirements for ontologies development

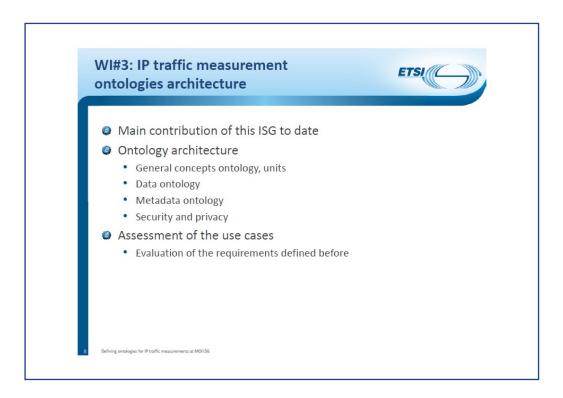


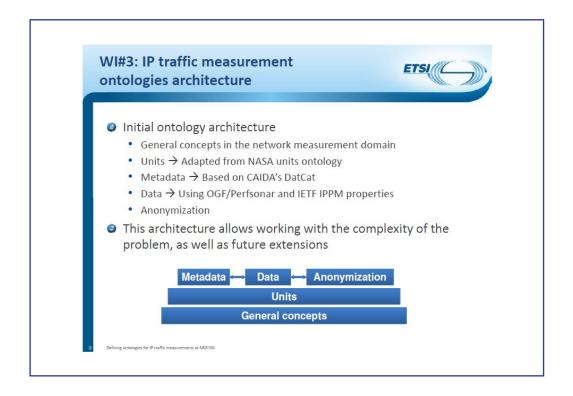
- Key performance indicators
  - Delay and delay variation
  - · Packet errors, losses, reordering, duplicates
  - · Connectivity and availability
  - Throughput
- Use cases
  - IP network characterization
  - QoS measurements
  - Traffic monitoring for security applications
  - Autonomic network management
  - Law enforcement
- Requirements derived from the use cases
- Other general requirements: expandability, interoperability, performance
- The next document is based on this one

Defining ontologies for IP traffic measurements at MOI IS



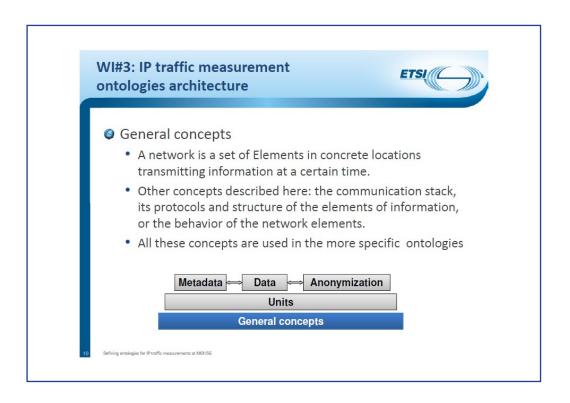
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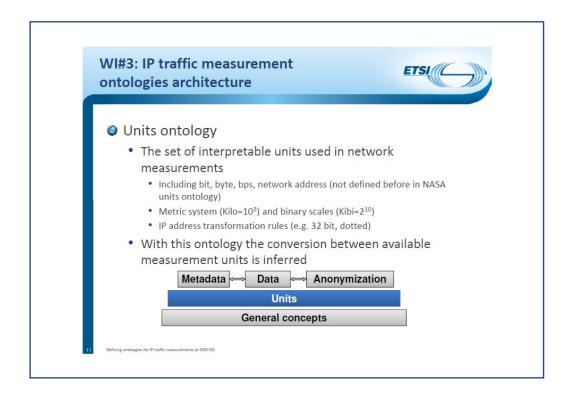






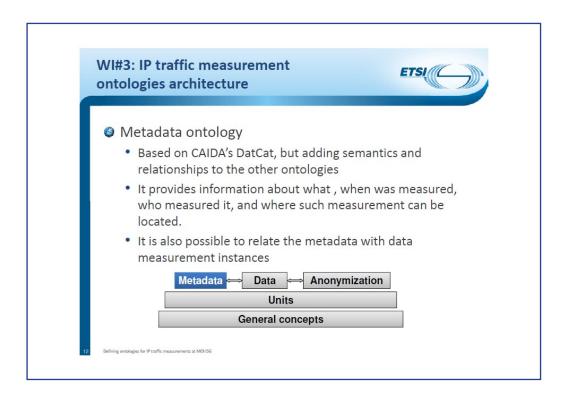
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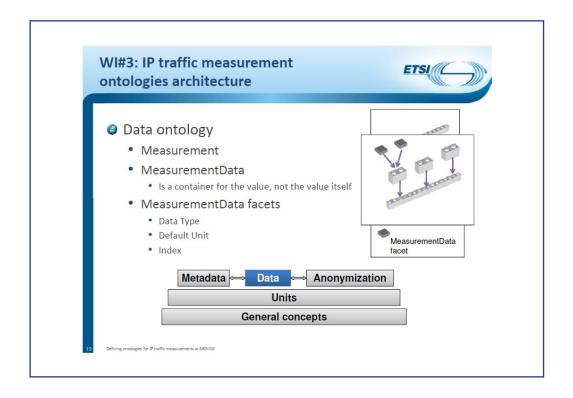






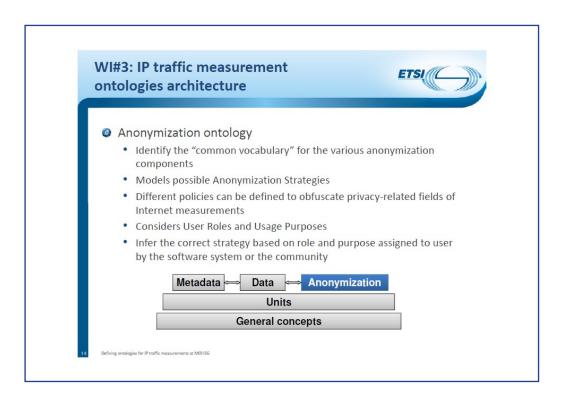
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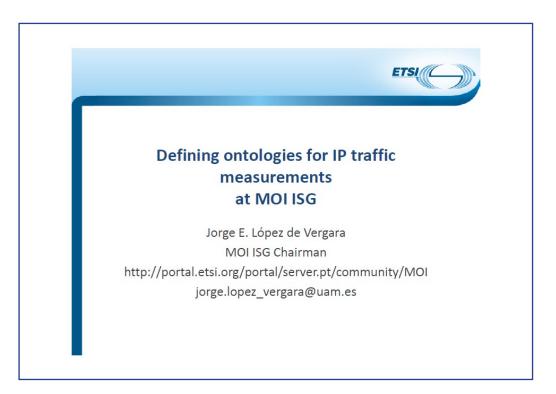


# Conclusions and future directions There are several incompatible information models for network measurements Need for a measurement ontology to homogenize network measurement data, working at a semantic level Ontology architecture has been structured in several subontologies to deal with the complexity of the problem We have to address the final specification of a pure MOI ontology. We are looking for people interested in using the ontology, aside from FP7 projects





# SESSION 9 ENABLING TECHNIQUES





# SESSION 9 ENABLING TECHNIQUES

#### An Efficient Multicast Scheme based on Openflow Technology in Enterprise Networks

#### **Abstract**

Recently the study for openflow technology is ongoing actively as an effort to change the existing networking topology to an open networking topology. Openflow technology separates the control plane from the data plane of the network nodes, i.e. switch, or router and defines the protocol for communication between the control and data plane components. The standardization for openflow is performed in the ONF. Due to the open networking topology, network operators can improve the network utilization by removing the waste of network resources and it is possible to configure and manage the network easily by removing the complexity of network operation.

Though the traditional multicast technology is essential for profitable services such as IPTV broadcasting service, telepresence service, etc, it has many waste points of network resources yet and also offers the complexity of network operation. So we propose an efficient multicast scheme based on openflow technology.

The traditional multicast technology constructs a multicast tree using the multicast protocol like PIM-SM and IGMP, and then the multicast packets are forwarded from a server to clients through the resulting tree. Because the multicast tree is unidirectional, the network utilization is low. And if each node copies multicast packet several times, it increases the load of packet processing. At last the operation of PIM-SM threatens the stability of network.

Meanwhile in the proposed multicast scheme, openflow controller establishes the transmission path of ring type through the openflow switches related to certain multicast service. And the multicast packets are forwarded through the resulting transmission path of ring type. The proposed method improves the network utilization by using the network resources equally. And since each network node is required to copy multicast packets once per port, the load of packet processing is not much. Finally it is easily configured using the openflow protocol.

The telepresence service using the proposed multicast scheme and its operation procedure are presented in the figures shown below. The simulation for the performance of the proposed method will be performed later.

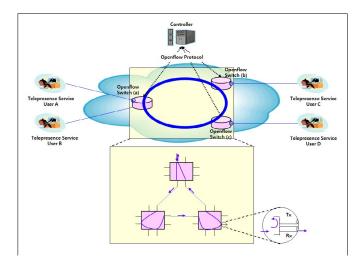


Fig. 1.
Telepresence service based on the proposed multicast scheme

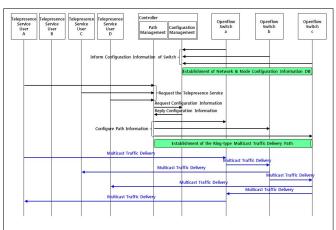
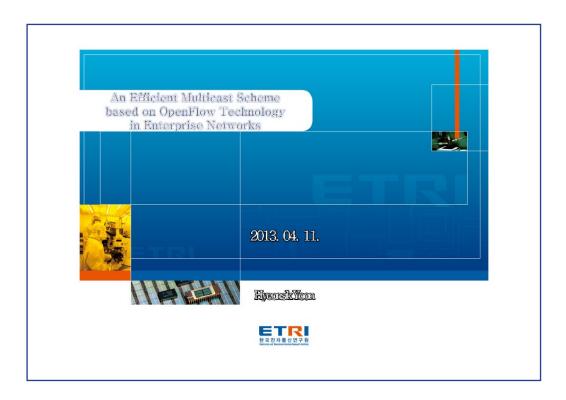


Fig. 2
Telepresence service operation procedure



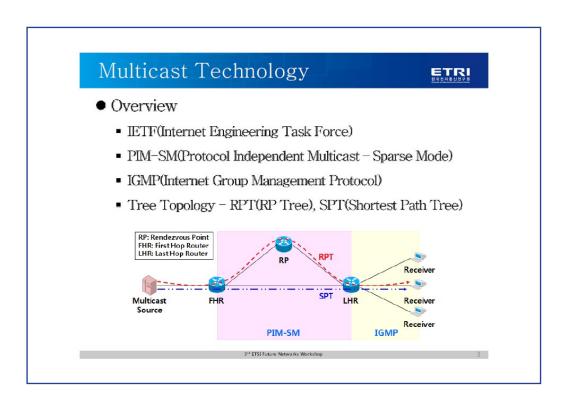
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# Agenda Multicast Technology SDN & OpenFlow Proposed Multicast Scheme Use Case: Telepresence Service Conclusions



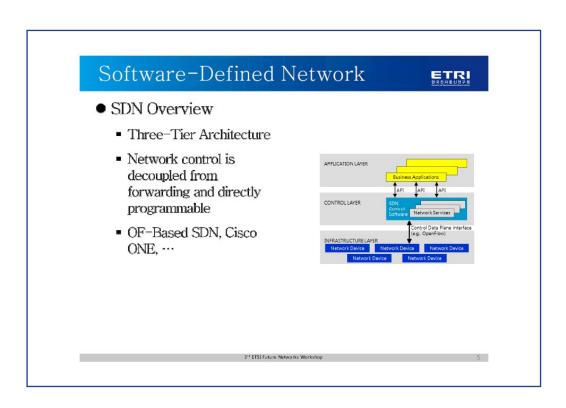
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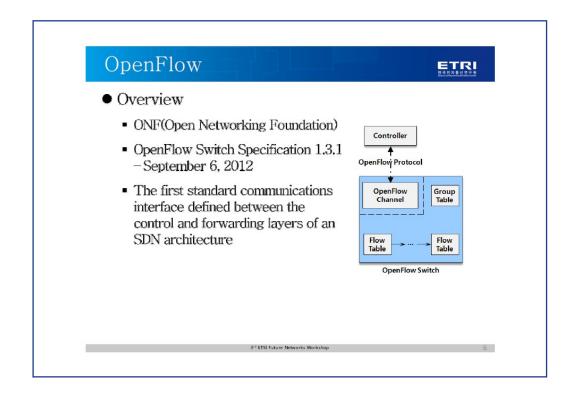


# Multicast Technology ■ Problems ■ Low network utilization due to tree topology ■ Much load for packet processing on network node due to multiple packet copies ■ Threaten the stability of network due to operation of PIM-SM RP | Multiple packet copies | Multiple packet copies | PIM-SM | Multiple packet copies | PIM-SM | Multiple packet copies | PIM-SM | LHR | Receiver | PIM-SM | LHR | Receiver | A



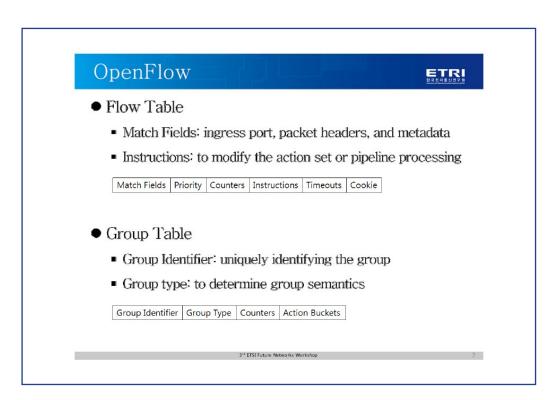
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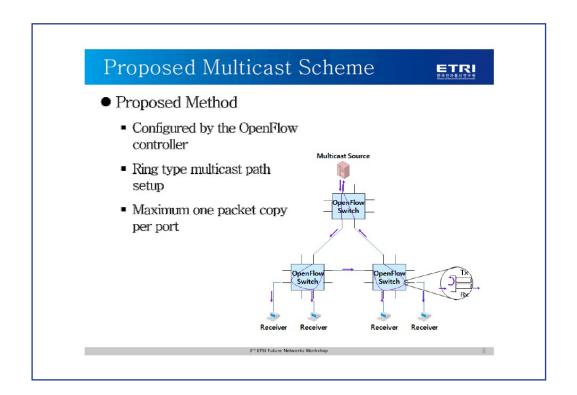






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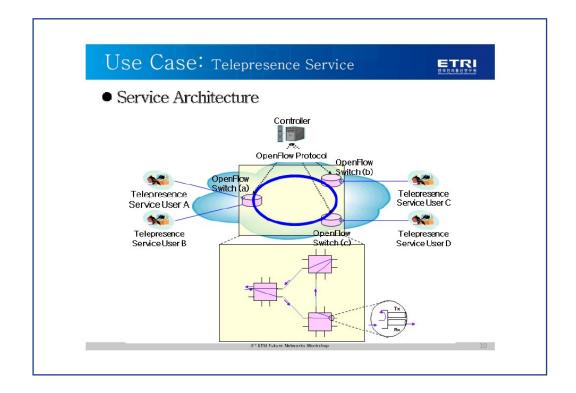
#### Proposed Multicast Scheme

**三丁尺** 

#### Advantages

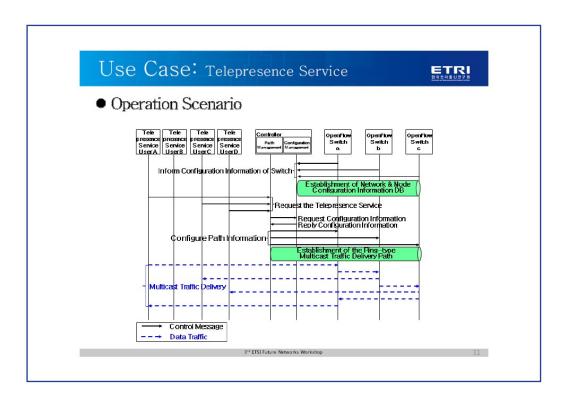
- Improves the network utilization by using the network resources equally
- The load for packet processing is not much by copying multicast packet once per port
- The multicast path is easily configured by using the OpenFlow protocol
- Easy QoS monitoring
- Provides resiliency if establish an additional path in the reverse direction

3rd ETSI Future Networks Workshop





# SESSION 9 ENABLING TECHNIQUES



Conclusions

# Further Considerations Extension of the OpenFlow protocol for multicast Structure of forwarding table Performance factor(e.g., node numbers per ring, port numbers per node, etc.)

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3<sup>rd</sup> ETSI Future Networks Workshop





# SESSION 9 ENABLING TECHNIQUES





# SESSION 10 SDN CONTENT NETWORKING

#### Information-centric networking through network function virtualization

#### Abstract:

Information-Centric Network (ICN) is a new communication paradigm that has attracted a significant following in the Future Internet research area. A key ingredient in this new paradigm is the ability to capitalize on all information bits regardless of whether they are bits on the wire, on the ether, or on storage devices.

This allows the future Internet to take advantage of in-network storage natively and in combination with other modern IT concepts that are now applied in networking such as virtualization. So far, several ICN designs have been proposed addressing naming and name resolution, routing, and security, just to name a few.

This presentation will relate ICN with network virtualization and review ongoing efforts with respect to architecture and key design features. In particular, we will examine how network function virtualization benefits certain ICN operational aspects such as resource isolation, routing, forwarding and transport.

We will then briefly compare different ICN designs with respect to the aforementioned modules. The presentation will close with an overview of the remaining challenges in ICN designs, and a short discussion on possible deployment of ICN in future infrastructure networks where network function virtualization is the norm.

# Information-centric Networking through Network Function Virtualization

W. Liu, J. Ren, C. Westphal and K. Pentikousis

3rd ETSI Future Networks Workshop

11 April 2013

Saphia Antipolis France



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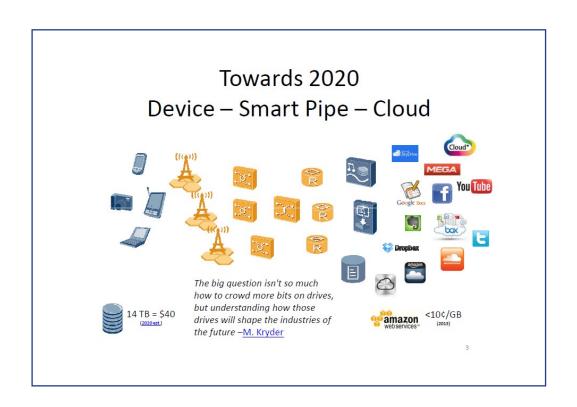


# SESSION 10 SDN CONTENT NETWORKING

#### Talk Outline

- Information-centric Networking: Short Intro
- ICN Design Approaches
  - NDN
  - MobilityFirst
  - XIA
  - Publish/Subscribe Internet (PSIRP/PURSUIT)
  - NetInf (4WARD/SAIL)
- ICN Challenges
- ICN and NFV

2





# SESSION 10 SDN CONTENT NETWORKING

#### Information-Centric Network

- Van Jacobson: we are running dissemination networks using methods from a conversational paradigm
  - Retrofitting dissemination in a conversational paradigm
  - Remote access vs. information dissemination
- · Network Paradigm Evolution
  - Telephony: focus on connecting wires
  - Internet: focus on connecting nodes
  - ICN: focus on connecting information



#### Information-Centric Network

- Core network primitives for information, not host-to-host communication and remote access
- Capitalize on all information bits regardless of whether they are bits on the wire, on the ether, or on storage devices
  - Leverages in-network storage natively and in combination with other modern IT concepts such as virtualization
- · ICN is still work in progress
  - Long way to go before standardization commences
  - Experimentation, open-source software, simulators and testbeds
  - Not a single or definitive approach
- Review of ICN approaches with respect to naming; resolution and routing; forwarding; transport
  - Backgrounder: ComMag Feature Topic on ICN





#### SESSION 10 SDN CONTENT NETWORKING

#### ICN Design Approaches (1/4)

Project	Naming security vs. scalability	Resolution & routing	Forwarding	Transport
NDN	URL	Name-based routing	Request aggression In-network cache	Hop-by-Hop
MobilityFirst	FLAT	Two phase scheme	In-network storage	Segment-to- Segment
XIA	FLAT	Two phase scheme	In-network cache	-
PSI PSIRP/PURSUIT	<sid, rid=""></sid,>	Two phase scheme	Define a Forwarding ID (FID) for fast forwarding In-network cache	End-to-End
NetInf	<a:l></a:l>	Two phase scheme	In-network cache	End-to-End Hop-by-Hop

★ URL-like names are more scalable. FLAT name are self-certifying.

PSI and NetInf make a tradeoff by using a two-level hierarchy each of which is FLAT.

### ICN Design Approaches (2/4)

Project	Naming security vs. scalability	Resolution & routing	Forwarding	Transport
NDN	URL	Name-based routing	Request aggression In-network cache	Нор-by-Нор
MobilityFirst	FLAT	Two phase scheme	In-network storage	Segment-to- Segment
XIA	FLAT	Two phase scheme	In-network cache	-
PSI PSIRP/PURSUIT	<sid, rid=""></sid,>	Two phase scheme	Define a Forwarding ID (FID) for fast forwarding In-network cache	End-to-End
NetInf	<a:l></a:l>	Two phase scheme	In-network cache	End-to-End Hop-by-Hop

NDN routes packet directly according the content name. PSI first resolves content name to an appropriate location, and then routes to this location.

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#### ICN Design Approaches (3/4)

Project	Naming security vs. scalability	Resolution & routing	Forwarding	Transport
NDN	URL	Name-based routing	Request aggression In-network cache	Нор-by-Нор
MobilityFirst	FLAT	Two phase scheme	In-network storage	Segment-to- Segment
XIA	FLAT	Two phase scheme	In-network cache	
PSI PSIRP/PURSUIT	<sid, rid=""></sid,>	Two phase scheme	Define a Forwarding ID (FID) for fast forwarding In-network cache	End-to-End
NetInf	<a:l></a:l>	Two phase scheme	In-network cache	End-to-End Hop-by-Hop

★ In-network storage is employed to satisfy requests. NDN can aggregate requests to build a multicast tree. PSI uses Bloom filters to encode forwarding trees.

#### ICN Design Approaches (4/4)

Project	Naming security vs. scalability	Resolution & routing	Forwarding	Transport
NDN	URL	Name-based routing	Request aggression In-network cache	Hop-by-Hop
MobilityFirst	FLAT	Two phase scheme	In-network storage	Segment-to- Segment
XIA	FLAT	Two phase scheme	In-network cache	-
PSI PSIRP/PURSUIT	<sid, rid=""></sid,>	Two phase scheme	Define a Forwarding ID (FID) for fast forwarding In-network cache	End-to-End
NetInf	<a:l></a:l>	Two phase scheme	In-network cache	End-to-End Hop-by-Hop

★ Transport is receiver-driven and can be implemented as an IP overlay or on top of L2, with great potential in wireless networking: think broadcast + in-network caching + native multi-\*



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#### ICN Research Challenges

- Ongoing work in IRTF ICNRG
  - Naming
  - Security
  - Routing

  - Forwarding
  - Transport
  - Mobility management
  - Wireless networking aspects
  - Network management
  - In-network caching



#### **Network Functions Virtualisation**

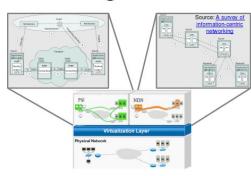
- · ICN introduced as NFV software
  - Large scale experimentation with reduced equipment and deployment costs
  - network configuration or topology management in near-real time
  - tailored services
- . If NFV is worth its salt, it would be natural to use it for ICN experimentation and deployment





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#### Running PSI and NDN side-by-side



#### Deployment

- Network slicing for different ICN architectures
- Deploying different routing, forwarding, transport mechanisms
- Traffic isolation for different ICNs

#### Management

- Flexible network configuration
- Explore interoperability
- Ease ICN traffic optimization, including in-network cache management, traffic engineering, security and so on

#### Addressing the Abstractions Divide

- · A flow-based model is not particularly well-suited for ICN
- · ICN provides content-level abstractions
  - As opposed to the flow-level abstractions in OpenFlow/SDN
  - OF routes on 12-tuple, not on content
  - Control/Data Plane separation not a big concern in ICN, yet
- · Carrier-oriented ICN Control Plane could manage content
  - ICN control plane is explicit in some proposals (say, rendezvous server) and implicit in others
  - Approaches with an explicit control plane may be easier to integrate content management with network functions (and virtualization)
  - Consider content routing, network-wide caching policy, network access management

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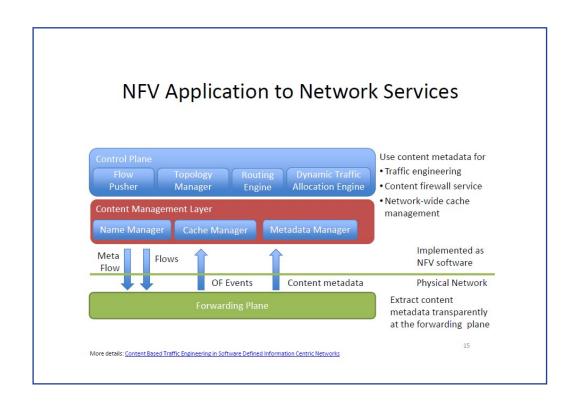


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#### Software-Defined ICN

- · Extend OpenFlow-based model to support content-centricity
  - Add caching/storage elements to the supported network elements (in addition to switching/forwarding)
  - Identify content and operate at the content level
    - · Initially, intercept content requests
      - Forward requests to the control plane for content routing/content caching/late binding decision
      - Map content to specific flow
    - · Eventually, recognize content semantics natively
- Extend network controller to operate on content: decide how to route to content, where to cache, where copies are located
- · Applications: Traffic Engineering, Content Firewalling

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#### Thank You!

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The opinions expressed in this presentation are those of the authors and do not necessarily represent the views of Huawei Technologies Co., Ltd.





# SESSION 10 SDN CONTENT NETWORKING

#### Toward a Cost-Efficient, Fair and Global Content Delivery Platform: A Mechanism for Small CDN actors Federation

#### **Abstract**

The federation of heterogeneous CDN and Cloud actors will present a main aspect of evolution of content distribution services. Indeed, as the constraints in terms of coverage and capacity (storage/ streaming/ bandwidth) of major OTTs increase, small CDN actors are tending to federate in order to overcome their individual lack of capacity/coverage and to define new business models which are attractive to all of them. We position our contribution in this particular context.

Given a large set of CDN actors with a limited footprint and/or capacity and a set of Content Providers (CPs) with different requirements over a global footprint, our goal is to statically build, on top of the heterogeneous platforms, a federated CDN system that is able to fulfill all SLAs and to define, for the so-formed system, the content distribution and requests redirection policies that allow the most cost-efficient use of global resources. The decision-making process is achieved, in a centralized manner, by a third-party broker and is subject to capacity and fairness constraints with regard to individual actors. In other terms, each participant to the federation should find an economic interest in doing so with respect to a scenario where he operates individually.

Putting in place our proposal requires a standardization effort in terms of introducing a new "broker-based" architecture for CDN interconnection and defining, in the context of this new architecture, the information to be exchanged between the CDN actors and the broker both prior to decision making and in real time for better tuning resources allocation and redirection policies.

# Federating Distributed, Heterogeneous Content Distribution Actors

Ghida Ibrahim Orange Labs/ Telecom ParisTech

Daniel Kofman Telecom ParisTech







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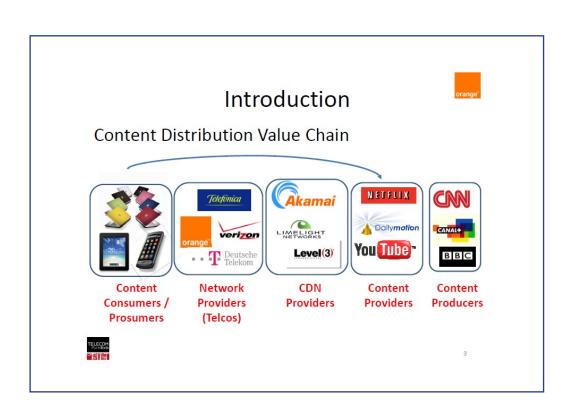
#### Agenda



- Introduction
- Main Challenge: How to enhance Telcos' Positioning in the CDN Market
- · Our Contribution
  - Context & Goal
  - Proposed Technical Solution
- Final Words and Work in Progress

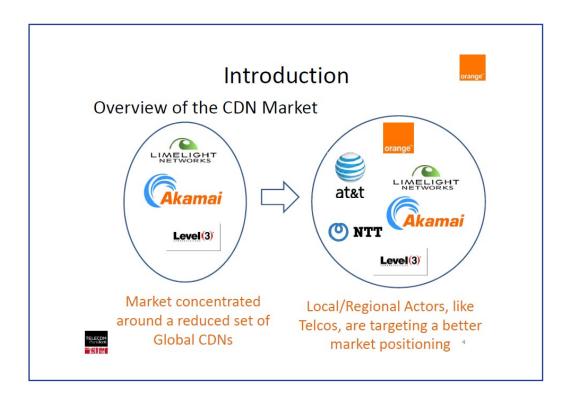


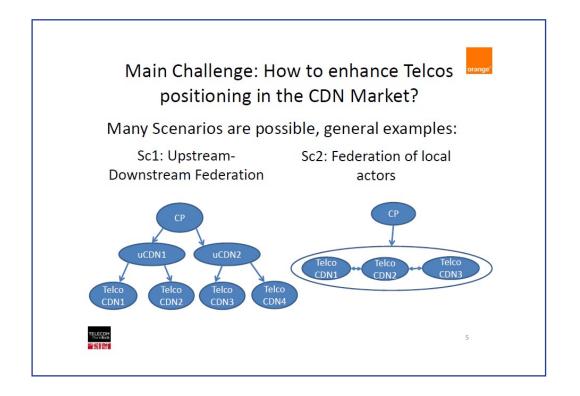
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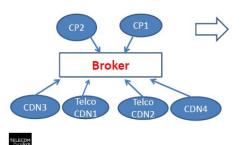


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# Main Challenge: How to enhance Telcos positioning in the CDN Market?

Many Scenarios are possible, general examples

Sc3: Orchestration of distributed CDN services



In Scenarios 2 & 3, the broker functional group has an important role

The role can be played by one of the CDNs or by a 3<sup>rd</sup> party

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#### Our Contribution: Context and Goal



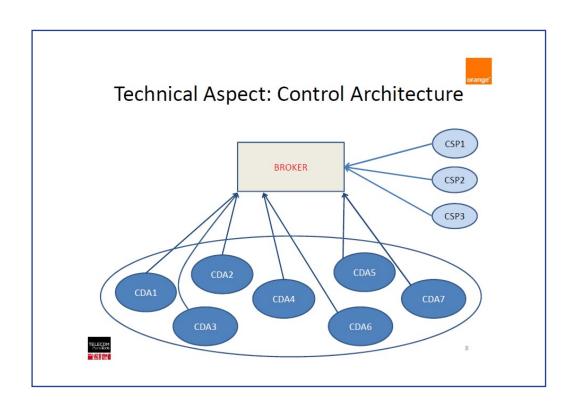
- We introduce a broker-based architecture for statically building and dynamically orchestrating large federations of content distribution actors (CDAs). Our ecosystem is composed of:
  - ➤ Heterogeneous, highly distributed CDAs
  - Content Providers and global CDNs

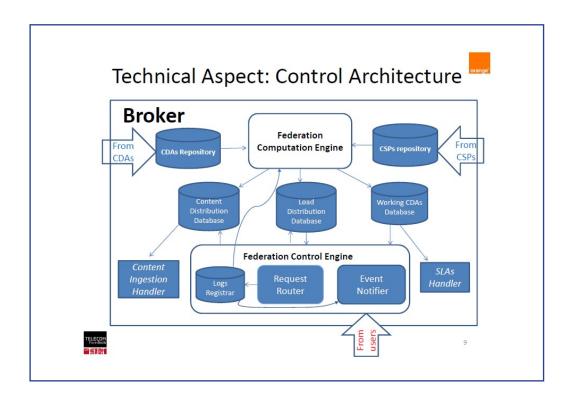
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#### **Technical Aspect: Control Architecture**

#### **Broker Role: 2 phases**

#### Static/ pre-provisioning Phase:

- At t0, repeated each T
- ➤ Handled by the "Federation Computation Engine"
- Based on Inputs gathered from CDAs and CSPs
  - ☐ CDAs inputs: Capacity, Footprint (zones) and Price information
  - ☐ CSPs inputs: Target Footprint, Demand profile, Content characteristics
- Leads to outputs concerning content and load distribution policies within different working CDAs





# Technical Aspect: Control Architecture Broker Role: 2 phases

#### Dynamic Phase

- > In ]t0, t0+T]
- ➤ Handled by the "Federation Control Engine"
- ➤ The Request Routing strategy is dictated by the output of the Static Phase
- ➤ The Broker subscribes to "CDAs" performance and adapts accordingly the static phase outputs
- ➤ The Broker maintains demand logs and uses them as inputs to re-perform the static phase at to+T





### SESSION 10 SDN CONTENT NETWORKING



#### Final Words & Work in Progress

- Telcos could be better positioned in the CDN Market
- Flexible federation and services orchestration will significantly facilitate such better positioning
  - → An **Advanced Brokering Architecture** represents in this context a major asset
- Standardization efforts should be focused on the definition of the functional and protocol architecture.
  - Includes data models and Interfaces to facilitate the autonomic orchestration to answer CSPs and external CDAs services requests.
- We are working on the design of decision making Algorithms required for dynamic CDN selection inside the federation and for resources orchestration
  - We consider different market relevant scenarios → different Points of View can be adopted
- We will be glad to further detail our proposals and to contribute to the standardization process



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#### **Food For Discussion:**

Is SDN as a technology relevant in a context of CDAs orchestration/ federation? Why? How?

#### **Thank You**

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#### **Appendix**

#### Static Phase: Decision Making Process

#### At t0 do{

- Classify SPs in "SPs Repository" into Groups on Footprint and Technology features basis
- Filter Groups per Footprint order (begin with groups with the smallest Footprint)
- For each SP Group do {
  - Identify from "CAs Repository" all Candidate actors / Foot(Actor) ≤ Foot(Group)
     & Feature(Actor) = Feature(Group)
  - Apply Mathematical Model, SPList: SPs in SP Group & CDNList: Candidate Actors
  - Remove Selected Candidates from "CAs Repository"
  - Store Selected Candidates Ids in the "Working CAs database"
  - Fill the "Content Distribution database" and the "load distribution database" with the computed content and load distribution Indicators
  - Go to Next SP Group }
- Restore "CAs Repository" Initial Content }

#### **Appendix**

#### Dynamic Phase: Decision Making Process

```
At t, \geqt0, \leq t0+T do 1 and 2{
      Intercept Incoming Requests
      For each Req do {
      Identify the originating zone and the target content
      Access the "Load Distribution database" in order to Forward the Req to the adequate
CA }
       For each CA/ CA Id in "Working CAs database" do {
     - Track CA performance Level over his footprint zones
     - If (CA.PerfLevel (zone x)< L) {
         Generate Event(CA Id, zone x)
         Fetch the "Logs Registrar" for CA recent history (]t-T1,t])
         Identify the contents that have been the most recently delivered by CA to zone x
          Decrease the share of load handled by CA over zone \boldsymbol{x} and corresponding to
          adapt the "Load Distribution database" accordingly
          Redistribute the load among other actors that cover zone x based on their
     preference order
         adapt the "Load Distribution database" and the "content distribution database" if
     required accordingly }
```



