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APPLYING LEAN PRINCIPLES FOR PERFORMANCE ORIENTED SERVICE DESIGN OF VIRTUAL NETWORK FUNCTIONS FOR NFV INFRASTRUCTURE

Concepts of Lean

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ABSTRACT

Context. Network Function Virtualization was recently proposed by European Telecommunications Standards Institute (ETSI) to improve the network service flexibility by virtualization of network services and applications that run on hardware. To virtualize network functions, the software is decoupled from underlying physical hardware. NFV aims to transform industries by reducing capital investments on hardware by using commercial-of-the-shelf (COTS) hardware. NFV makes rapid innovative growth in telecom services through software based service deployment.

Objectives. This thesis work aims to investigate how business organizations function and the roles in defining a service relationship model. The work also aims to define a service relationship model and to validate it via proof of concept using network function virtualization as a service. For this thesis, we finally apply lean principles for the defined service relationship model to reduce waste and investigate how lean benefits the model to be proven as performance service oriented.

Methods. The essence of this work is to make a business organization lean by investigating its actions and applying lean principles. To elaborate, this thesis work involves in a research of papers from IEEE, TMF, IETF and Ericsson. It results in modelling of a PoC by following requirement analysis methodology and by applying lean principles to eliminate unnecessary processes which doesn't add any value.

Results. The results of the work include a full-fledged service relationship model that include three service levels with roles that can fit in to requirement specifications of NFV infrastructure. The results also show the service levels functionalities and their relationships between the roles. It has also been observed that the services that are needed to be standardized are defined with syntax for ways to describe network functions. It is observed that lean principles benefit the service relationship model from reducing waste factors and hereby providing a PoC which is performance service oriented.

Conclusions. We conclude that roles defined are fit for the service relationship model designed. Moreover, we conclude that the model can hence contain the flow of service by standardizing the sub-services and reducing waste interpreted with lean principles and there is a need for further use case proof of the model in full scale industry trials. It also concludes the ways to describe network functions syntax which follows lean principles that are essential to have them for the sub-services standardization. However, PoC defined can be an assurance to the NFV infrastructure.

Keywords: Lean Manufacturing, Service, Roles, Virtualization.

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ABBREVIATIONS

NFV	Network Function Virtualization
VNF	Virtual Network Function
NF	Network Function
NFVI	Network Function Virtualization Infrastructure
OSS	Operation Support System
BSS	Business Support System
E2E	End to End
SLA	Service Level Agreement
PoC	Proof of Concept
SID	Information framework
SQM	Service Quality Metrics
IT	Information Technology
ETSI	European Telecommunications Standards Institute
TMF	Telecommunications Management Forum
IETF	Internet Engineering Task Force
NFV-MANO	Network Function Virtualization- Management and Orchestration
EMS	Element Management System
VM	Virtual Machine
VN	Virtual Network
TcaaS	Technology component as a Service
SoC	Separation of Concern
CAPEX	Capital Expenditure
OPEX	Operational Expenditure

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1 INTRODUCTION

Modern telecom networks are incorporated with different variety of hardware appliances. To launch a new network service or to reconfigure a network service which is already established yet requires another variety of hardware and finding the space and power to accommodate these hardware is becoming ambitious compounded by increasing costs of energy, capital investment challenges and the rarity of skills necessary to design, integrate and operate increasingly complex hardware-based appliances [1]. The hardware appliances reach end of life as the innovation cycle accelerates which is also served to be reason for the evolution of virtualization technologies.

Network Function (NF) is a functional block that is present within a network infrastructure which has a well-defined interfaces and well-defined functional behavior [2]. In today's world, network function is often termed as a network node or a physical appliance. The network function is a connection point or an end point in a distributed network routes which can store, receive and forward data among different routes. Network functions are engineered or programmed to recognize, process and forward transmission to another network routes. Network functions came in to existence with the use of packet switching and distributed networks. Some examples of network functions include forwarding, storing, transmission, translating, logging, distributing etc., The network elements which are responsible for carrying these network functions include routers, switches, load balancers, firewalls, hubs etc., In order to reduce the hardware appliances, the business organizations are transforming these physical network functions in to software or virtualized network functions using Network Function Virtualization technology.

Network Function Virtualization (NFV) is one of the key enabling technologies to centralize many network equipment types onto industry standard high volume servers, switches and storage which can be located in any data centers, network node or any end user premises [1]. For providing faster network services, the Communication Service Providers have commenced on to transformation of their network infrastructure by endorsing Network Function Virtualization (NFV). The world's leading telecom operators have initiated NFV Industry Specification Group (ISG) at ETSI to achieve a consistent and common architecture for the hardware and software infrastructure needed to support Virtualized Network Functions. Network Function Virtualization (NFV) has been introduced in the recent years into the area of Telecom industry by the principle of separating network functions from the hardware systems they run on by and deploying them as software on standardized hardware systems, called as Virtualized Network Functions (VNFs) [3]. NFV and VNF are very often interchangeable as both focuses on optimizing the network services. Network function virtualization is an emerging technology and its orchestration and management are really not defined. Network function virtualization services that need to be offered to customer using virtual network functions are to be managed. The service quality delivered by a Virtual Network Function (VNF) service to a customer depends on the service quality of the compute, storage and network resources offered by the NFVI. OpenStack NFV uses cloud virtualization to compose, deploy, chain and manage standard Virtual Network Functions running on generic physical infrastructure. In order for VNF to perform correctly in a cloud world, the NFVI needs to provide a certain number of functionalities which range from scheduling to networking and from orchestration to monitoring capacities.

Operational Support System (OSS) focuses on the status of the operation, i.e. on a set of programs that help communications service provider (CSP) to control, monitor, analyze and manage the network [4]. A true customer centric OSS requires total service quality management and complete integration at the network layer. Business Support System (BSS) handles the business interfacing with customer or end-user [5]. They are used to support various end-to-end telecommunications services like billing, order management, call center automation, or other customer facing activities such as complain handling, e.g. if the service doesn't meet the quality expectations.

MOTIVATION: NFV aims to revolutionize the telecommunication industries by reducing the CAPEX, OPEX, space to accommodate vivid hardware appliances skills to design, integrate and operate these hardware appliances [1]. It also reduces the manpower and provides easier upgrading of an existing virtual instance of a network function in a network service. Hence NFV proves that it can leverage the standards of telecommunication industry by transforming them in to faster, cheaper and efficient deployment of network services.

PROBLEM STATEMENT: Network operators aim for the new revenue earning techniques by evolving the network service from incorporating new hardware appliances. Hence NFV technology can reduce the amount of economic output more than a normal physical interface network. The business relationships that construct and contain NFV are needed to follow a standardized service flow in order to deliver value to the customer. Hence there is need to design a service performance oriented model which can fit in to NFV making it obvious that the model is lean.

1.1 OBJECTIVES

The operation and management of a complex VNF service requires monitoring of the service fulfillment. In detail, it needs monitoring the quality of the VNF service, i.e. an outside view, as well as there is a need to know what's going on with the virtualization infrastructure, i.e. inside view. The main objective of this thesis earlier was to design a Meta data structure including interfaces that can be used for specification, monitoring and analysis of SLAs for E2E services using VNFs. But, in order to model a Meta data structure, the roles and their relationships needs to be researched in depth as in order to design a structure, the information required to start with it needs to be collected which has become the aim of this thesis later on.

Hence, the aim of this thesis is to provide the service relationships between service provider, customer and user in order to validate the model with a proof of concept as one view and applying the lean principles to this proof of concept to optimize the performance is another view. The objective of thesis is to provide a service relationships and to propose Proof of Concept (PoC) for NFV network slice as a service. In addition, ways to describe a network function inherited from lean principles are provided.

The main objectives of this thesis, in order to achieve the main goal on constructing a service relationship model, are as follows:

- To provide an overview of SLA and SID.
- Identification of the network functions service quality metrics (SQM) and the integrations between the network functions.
- Making a requirement analysis for information model.
- Service Function Chaining within the business level, service-fulfillment level, and service session level.

- Construction and Modeling of a service relationship model which traverse a Service Function Chain.
- Performing a proof of concept for NFV network slice as a service for the service relationship model constructed.
- Applying lean manufacturing for the service relationship model.
- Investigate how lean manufacturing benefits proposed service relationship model.

1.2 RESEARCH QUESTIONS

A few research questions framed for this thesis are stated in this section, which are answered by defining roles relationship model.

- 1 How do the service relationships model for NFV infrastructure benefits by lean manufacturing?
- 2 What are the sufficient ways to describe network functions in the service relationships model by lean manufacturing?
- 3 Which extent does a customer need to monitor about the service delivered in the network in terms of relationships for a lean provisioning?

1.3 THESIS OUTLINE

This thesis document is organized as mentioned below:

Chapter 1 provides an overview about how network function virtualization evolved as one of the key enabling technologies. The main problem with NFV services that are to be offered to customer using virtual network functions are to be managed is discussed by exposing the view by how OSS/BSS supports the telecommunication services. The objectives and aims of this thesis in order to construct a service relationship model are classified. The research questions framed from this problem context are included in this section.

Chapter 2 is literature research done on previous related works in the area of NFV and service management models, and business roles.

Chapter 3 depicts the concepts and techniques such as NFVI, NFV service quality metrics, network slicing, OSS/BSS, service relationships, service chaining which are required for service design in NFV.

Chapter 4 depicts the methodologies such as lean manufacturing and requirements analysis that are used to design a service relationship model for the NFVI and to optimize its performance.

Chapter 5 contains results obtained from methodological proposition of model with proof of concept having a detailed analysis of how to design a service of network functions for NFVI.

Chapter 6 gives a conclusion obtained from results and detailed analysis. This chapter motivates the conclusion statement that is derived from results. It also contains the future work which can be implemented practically in terms of scalability.

1.4 SPLIT OF WORK

This section provides details about the contributions of work in this document

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5.2	Individual results	Sasank Sai Sujan Adapa
6	Conclusion and future work	Sasank Sai Sujan Adapa Saiphani Krishna Priyanka Kolluri

Table 1: Table displaying the list of contributors for each section in this document

2 RELATED WORK

The literature research done is prior to design the service relationships model and to gain knowledge concerning the NFVI, SLAs and service roles and their relationships.

In reference [1], the authors explained how the networks are getting over populated with large and increasing variety of proprietary hardware appliances besides discussing about what requirements does the network operators need to have to launch a new service. They explained a basic purpose of NFV how it aims and benefits to transform the way that network operators architect networks by evolving the standard IT virtualization technology. This ETSI white paper further provided the knowledge about NFV and how to overcome the challenges faced in order to implement NFV that there is a certain need to be addressed by the community interested in accelerating progress.

In reference [2], the authors explained about NFVI which is totality of the hardware and software components that build up the environment in which VNFs are deployed. This ETSI paper defines about how the management and orchestration block operates, automates and manages the distributed NFVI. This paper provided with the knowledge of the NFVI and the components involved in it which is served as an advantage for applying the NFV network slice as a service to the designed service relationship model.

In reference [6], the authors explained about the objectives of the NFVI besides provided a NFV reference architectural framework and identification of NFVI domains. This further explained about the cloud service definitions (X as a service). It helped us in understanding about different service providers present in cloud network in order to efficiently drive the standardization between the services and produce an efficient service.

In reference [7], the authors explained about the service quality metrics for NFVI, management and orchestration service qualities that impact the end user service qualities delivered by VNF instances deployed on NFVI. This helped us to investigate further how the NFV management and orchestration can also present subtle risks to VNF service quality if elastic resource growth or repair is slow or faulty.

In reference [8], the authors explained about service and customer domains. This TMF paper further explained its view towards the key characteristics or concepts for current framework and component framework. The business process framework, information framework and application framework explained in this reference paper helped in categorizing the activities in the business level and service levels.

In reference [9], the authors explained about the agreements, its characteristics and also its terms and conditions. This paper gives a detail description about the service level agreements and their types which helped in understanding the business relationships and entities that make up the aggregate business agreements. This is helpful in designing the service relationship model up to some extent.

In reference [10], the authors explained about the service chaining concept, its use and also about how it enables operators to create services using the VNFs. This white paper helped in figuring out the service relationships between service provider and customer in the form of service chain.

In reference [11], the authors explained a generic management service model and defined the service related terms and concepts and structuring rules for designing the model. This research paper helped in understanding few service related concepts which helped in developing the service relationship model.

In reference [12], the authors explained in detail about the services and the roles associated with the services in the cloud infrastructure. This paper helped us in outlining the service provider and customer roles and their relationships.

In reference [13], the authors explained about the network functions, network slice and the purpose of NFV. The author also gave an example of the network slices in the evolved packet core which helped us in understanding about the network slice and also about the components in it.

In reference [14], the authors explained about how the lean manufacturing principles does reduce the waste of company and the removal of no value added systems so as to bring valuable time deliverances. The authors distinguished the wastes in to three certain categories which are to be considered when a large scale company is managed to get efficient deliverance.

3 CONCEPTS AND TECHNIQUES

The basic concepts required for this thesis are NFV architecture, NFVI, NFV-MANO, OSS/BSS, network slicing, business roles, service relationships, service function chaining, and service roles relationships. In order to build a performance oriented service model, the need to understand about the service model, its entities, requirements and functions is very important. The techniques that are involved is to frame a design how the business roles are related to each other and in what way do we need to interpret them in service deployment such that we can make the relationship fits for our model.

3.1 NFV ARCHITECTURAL FRAMEWORK

In non-virtualized networks the network functions are implemented as they are combined with specific software and hardware which are referred as network elements. NFV is a step forward for the stakeholders in telecommunication network. NFV introduces different changes in the service provisioning from present such as decoupling software from hardware, flexible network function deployment, and dynamic operation. Network Function Virtualization confronts the implementation on top of network function as only software entities that run over the Network Function Virtualization Infrastructure (NFVI) [15]. Figure.1 depicts a high-level NFV framework.

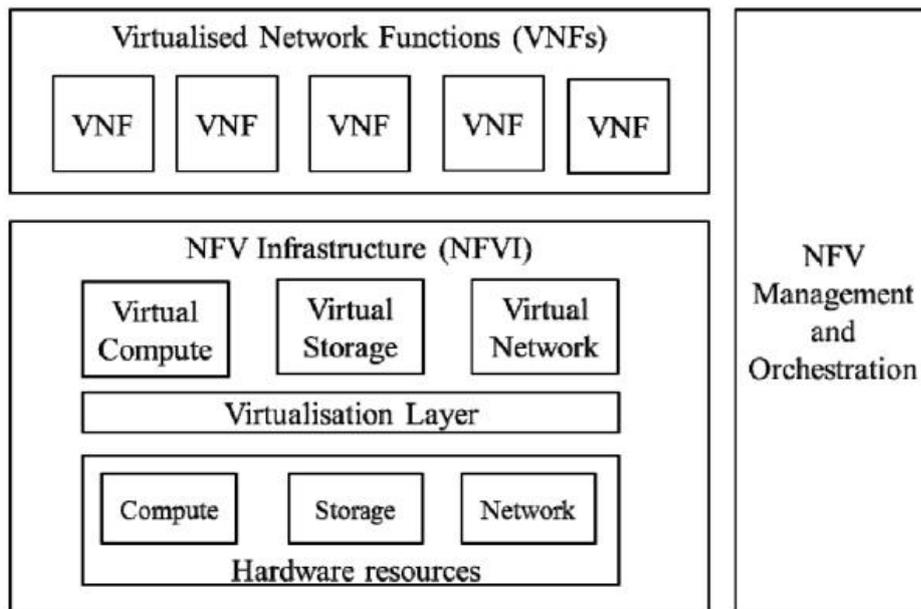


Figure 1: High-level NFV framework [15]

The three main components identified in NFV are:

3.1.1 Virtualized Network Function (VNF)

It refers to implementation of a network function that can be deployed on NFVI using software that is decoupled from the underlying software. A VNF is a virtualization of network function in a legacy non-virtualized network. The VNF is a virtualized form of PNF (Physical Network Function). Example of NFs are Domain Name Server (DNS), Dynamic Host Configuration Protocol (DHCP) servers, firewalls, etc., [15]. The functional behavior of PNF and VNF are expected to be same and independent with the state of them as virtualized or non-virtualized. However, the whole VNF can be deployed in multiple VMs or in single VM as well.

EMS which are located above VNFs as shown in figure.3, a single or multiple VNFs are monitored by Element Management System (EMS). EMS are those whose typical functionality is to manage and maintain the VNFs assigned.

3.1.2 NFV Infrastructure (NFVI)

It is the totality of all hardware and software components that build up the environment in which VNFs are deployed [2]. NFV Infrastructure is also known as SID in TM Forum organization.

3.1.2.1 Hardware Resources

The hardware resources include computing, storage and network physical network elements. Computing hardware is commercial of the shelf as it opposes the purpose to build software. Storage hardware can be distinguished in to storages that resides on the server and the storages that are shared. Network hardware include routers, wired or wireless links [15].

3.1.2.2 Virtualization Layer and Virtualized Resources

The virtualization layer abstracts the hardware resources and decouples the VNF software from underlying hardware ensuring a hardware independent life cycle which can be deployed on different physical hardware resources [15].

3.1.3 NFV Management and Orchestration (NFV-MANO)

It contains functions collectively provided by VIM, VNFM, and NFVO.

3.1.3.1 Virtualized Infrastructure Manager (VIM)

It is responsible for controlling and managing NFVI compute, storage and network resources within one operator's infrastructure domain. It can be also possible to deploy multiple VIM instances. As per the hardware resources mentioned the role of VIM are:

- Resource management: software invention, enabling virtualization, infrastructure resource and allocation management.
- Operations: visible management of NFVI, fault mitigation analysis from NFVI perspective, collection of information for capacity planning, monitoring and optimization.

3.1.3.2 Virtualized Network Function manager (VNFM)

It is responsible for life cycle management of VNF. Multiple VNFM can be deployed for each VNF or a single VNFM can serve multiple VNFs.

3.1.3.3 Network Function Virtualization Orchestrator (NFVO)

It manages network service life cycle and coordinates the management of network service life cycle, VNF life cycle and NFVI resources to ensure optimized resources allocation and connectivity.

The NFV framework dynamic construction and enables management of VNF instances and the relationships between data, control, management, dependencies and other attributes. These perspectives include VNFs are as follows:

- A virtualization deployment/on-boarding perspective where the context can be a virtual machine (VM).
- A vendor-developed software package perspective where the context can be several inter-connected VMs.
- An operator perspective where the context can be the operation and

management of a VNF received in the form of a vendor package.

3.2 OSS/BSS

Operations support systems (OSS) and Business support systems (BSS) play a vital role in the operations of telecom networks. OSS are the computer systems used by telecommunications service providers to manage their networks [4]. OSS focuses mainly on maintenance of networks. OSS provisions the ability of service provider to perform FCAPS (Fault management, Configuration management, Accounting management, Performance and Security management) for the designed service which is to be delivered to customer. It deals with the processes such as maintaining network resources, providing services, configuring network elements and managing faults. BSS are the components that telecommunications service providers use to run their business operations such as product management, customer management, revenue management and order management with their customers [5]. BSS are mainly responsible for managing the business aspects with the customers. Merely, OSS is the operational part and BSS is the management part of a telecommunication services. OSS/BSS are often used together in the Telecommunication networks as they are the main key points of contact from a service provider to the complete network.

OSS and BSS systems interact with each other to deliver a satisfactory service to the customer including business aspects, but they are not similar to each other. As mentioned above, OSS is the operational and maintenance part of the network while the BSS is the business interface to the customer. OSS can be termed as a backend desk to the organization while BSS is the frontend desk which interacts with the customers. In a business environment, the BSS is the first functional block that interacts with customers followed by the OSS system maintaining network and then the physical hardware infrastructure that is responsible for modelling the service and managing the network functions. This is clearly shown in the figure 2 below.

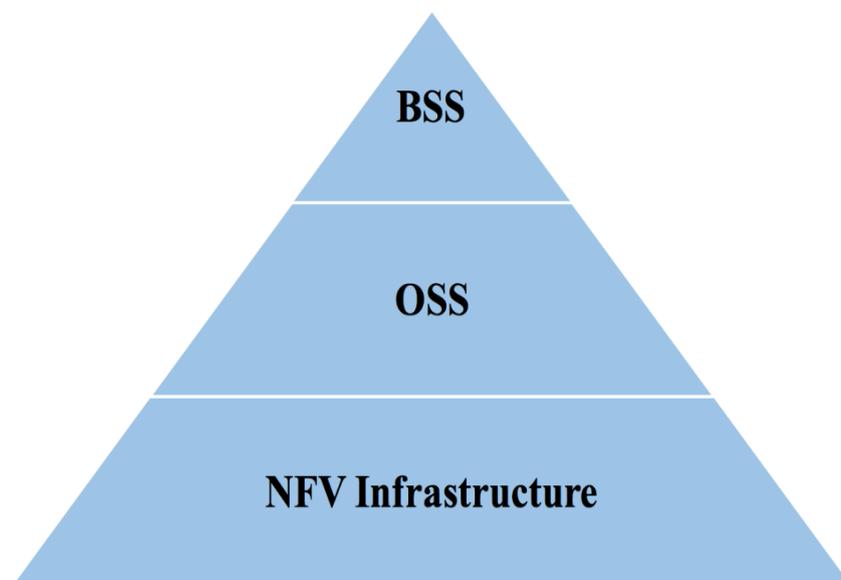


Figure 2: BSS, OSS and NFV top down framework

At the present growth rate of technologies, the telecommunications service providers will be at the edge of high demands for maintaining the future OSS/BSS which are needed to be inter bridged across various large scale NFV solutions which may contain different vendor specific tools for a particular node. Figure.3 depicts the initial relationship between NFV and OSS/BSS.

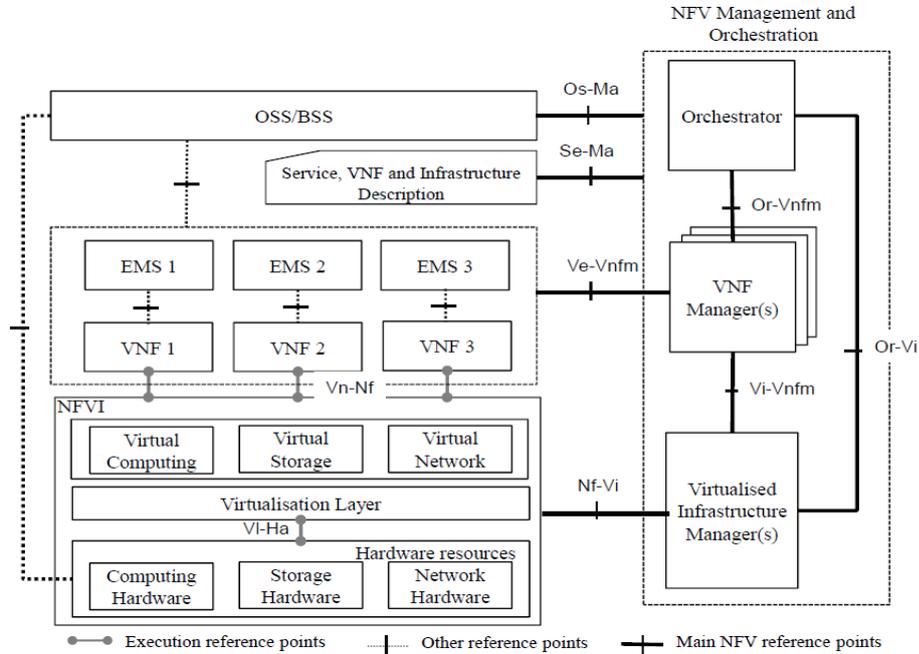


Figure 3: NFV Infrastructure and its initial relationship to OSS/BSS Systems [15]

The virtualization infrastructure is designed so that it can distribute Virtualized Network Service workloads effectively across multiple distributed compute, storage and network resources. An OSS framework of modular virtualized services in future OSS/BSS architectures aims at defining a set of performance and Service Level Agreement (SLA) interfaces and data structures for VNFs as well as for other services provided by the virtualized infrastructure. OSS architecture base further defined network management by ISO using the FCAPS model.

3.3 NFV SERVICE QUALITY METRICS

End users experience service delivered by VNF instances which are deployed on the NFVI. The quality of service delivered by VNF instances to end users depends on the virtual machine instance that host the component and also virtual network that is responsible for the connectivity. NFV service quality metrics are classified in to four suites. They are:

3.3.1 Virtual Machine Service Quality Metrics

Every VM begins its lifecycle with a request to the management and orchestration domain for allocating a new VM to serve the end user. The response from the management and orchestration domain has two cases where a new VM is allocated to integrate with VNF instances or a failure indication of non-availability of resources [7]. The VM service quality metrics apply when the allocated VM starts its lifecycle by integrating with the VNF instances provide service to the end users. The VM service quality metrics include VM stall, premature VM release ratio, VM scheduling latency and VM clock error.

3.3.2 Virtual Network Service Quality Metrics

Virtual networking is responsible for providing the connectivity between the components in a single VNF or between different VNFs or also between the single VNF component and technological components. The VN service quality metrics measured by NFVI are packet loss, packet delay, packet delay variance and packet outages.

3.3.3 Technology Component Service Quality Metrics

VNF components connect with technology components offered as a service through NFV virtual networking. The service quality metrics that apply for the TcaaS which characterize each individual component and its characteristics are TcaaS service reliability which are the rate of operations that are successful, TcaaS service latency which include individual operations and TcaaS service outage which is are the components that are unavailable to VNFs.

3.3.4 Orchestration Service Quality Metrics

Orchestration service quality metrics are divided in to two clauses based on the individual requests to establish the VM or VN connectivity [7]. The clause for the VM orchestration service quality metrics apply when there is a request to establish the VM. This include metrics VM provisioning latency, reliability, VM dead on arrival, VM placement policy compliance and VM failed release ratio. Similarly, the clause for the VN orchestration service quality metrics apply when there is a request for the VN connectivity which include metrics VN provisioning latency, reliability and diversity compliance.

3.4 NETWORK SLICING

A logical instantiation of network is often called a network slice [16]. When a network slice covers only a part of the network topology, it is called as sub-network slice. Network slicing implies an increase in the number of (logical) networks, which in turn implies increased demands on the network planning/engineering and network operation parts of the service provider's organization to plan, offer and manage these networks i.e. network slice governance. Network slicing technology is critical for networks to become innovation platforms for new types of applications. Programmable networks enabled by network slicing represent an opportunity to move the network dimension closer to the device and application dimensions, becoming an important contributor to value creation and an integral part of new and existing ecosystems. Clouds ensures speed as new slices can be instantiated with applicable architecture rapidly. This is all possible by the Ericsson network slice solution with resources (pools) which are fully isolated and separately configurable allowing for different architectures.

The figure.4 describes a simple example of a single network that is connected to different industries offering different logical network services which are known as network slices. Network slice which will enable operators to provide networks on an as-a-service basis [16]. However, network slicing benefits the operators to let them focus on network solutions (i.e.), characteristics needed for a specific business [16].

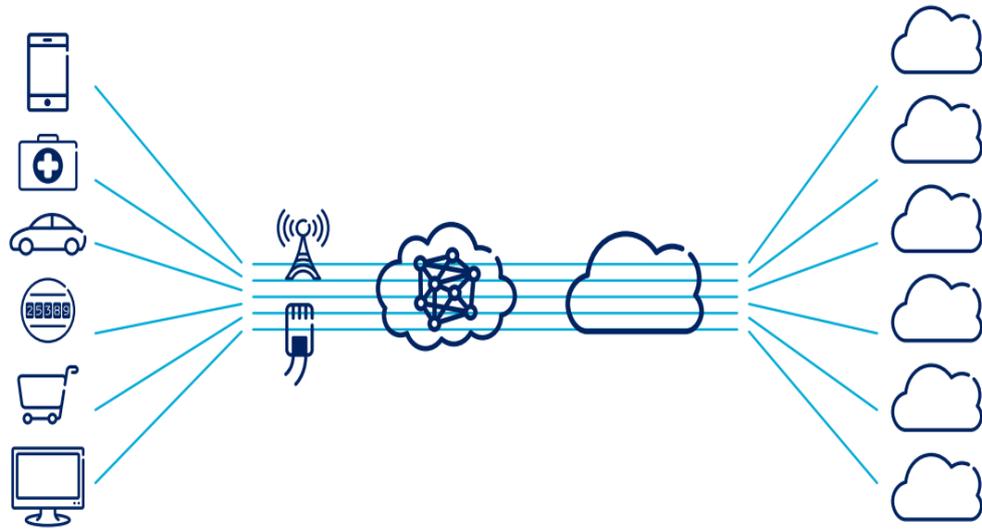


Figure 4: Network slices from different industries

3.5 SERVICE ROLES AND RELATIONSHIPS

Service is defined as performing certain tasks based on the request of an entity. In the modeling and concrete software scenarios, each individual in the organization are assigned with the specific role to perform a task. A role is associated with certain rights which are related to area of legal rights. Each role has certain requirements, obligations and tasks. Individuals assigned with roles are related with SLAs. The provider and the customer are the two main roles which involve mainly in the communication or interaction. Customer is a person who purchases a service from directly from the service provider or from a platform provider. Customer is interested in maintaining a subscribed service and performs all management activities on the customer side [11]. User adopts the service from the customer. In small firms, the user and customer are the same. Services that add value to the customer are developed and operated by service provider. Customer dimensions in telecommunications include the marketing and sales, customer support, product and service portfolio, provider brand, charging and billing costs. Service providers are responsible for enabling the service deploying, usage and management activities. Service provider dimensions include network quality, customer service and technical support, information quality, security and privacy. There are few aims for defining the roles. They are:

- To define the business relationships.
- To define the tasks, obligations and right for the roles.
- Limit/scope of roles.
- Exchange of data between the roles in order to design the relationship model.

3.6 SERVICE LEVEL AGREEMENTS

A service level agreement (also known as service level guarantee) is a type of agreement that represent a formal negotiated agreement between two parties designed to create a common understanding about products, services, priorities, responsibilities and so forth [9]. A SLA is a contract between a service provider (either internal or external) and a customer that defines the level of service expected from the service provider [17]. In order to maintain the specific quality of service between two parties, SLA is signed which includes the formal procedures and specifications regarding the service. It defines the availability, performance quality

of delivered network services such that the service is delivered to the right customer, at the right location and time, as well as safely and securely. SLA metrics for services that are built upon VNFs are affected by the Service Quality Metrics (SQM) for the virtualized infrastructure [7]. However, they are just one of the many factors that contribute to the overall SLA. The SQM metrics might be or might not be invisible to customers and their visibility depends on the business agreement between the service provider and the customer as well as on the technical capabilities to monitor the metrics. In order to maintain quality of service, the two parties agree on the set of procedures and targets formally or informally mentioned in the SLA. SLAs are divided in to three types as customer SLAs, supplier SLAs and internal SLAs. Customer SLAs are between service provider and the customer include terms related to product offering. Supplier SLAs are between supplier and the customer are aimed at ensuring the performance objectives of the service delivered by supplier. Internal SLAs in the organization functions include the service elements or the group of service elements.

3.7 SERVICE FUNCTION CHAINING

Service function chaining is to identify the abstracted view of the required services and apply them in order, for a given service [10]. They determine the way in which the things must happen i.e., the way in which the service must be designed and delivered to the end user using the network functions. It helps in identifying the ordered list of network services required for a specific service. It provides an ability to include the best networking functions in the network processing path. Service chain is a term that refers to the network function elements as they pass through the physical and virtual networks. Service function is a logical function that can be applied to a service. A service function can be integrated in to one or more network physical network elements or on to virtual instances. A network can have multiple service functions as a single NFVI can have multiple VNFs from multiple providers. Service functions are independent on each other but there is a flow of relation between them to provide a service. As there must be an orderly list of service functions but it is not necessary that every service function must rely on the other service function. Service function chain order list can be a complex set with multiple service function elements (branches) or can be a linear chain. Service chaining enables the telecom service providers to dynamically configure the virtual network elements without disturbing the underlying hardware. Service chaining can be applied to different architectural topologies and use cases as the abstraction of components is a fundamental for designing the architecture for physical, virtual and hybrid networks. IETF is still developing the service function chaining concepts and the architecture. The goal of this service function chaining is to develop the architectural building blocks in helping the network operators to instantiate a service function path for the network functions by creating the network topology. An important principle in service function chain is that the “service graph” is decoupled from the network so, the operator can configure a processing path to run across both physical and virtual components [10].

4 METHODOLOGIES

The research methodology required for this thesis primarily constitutes literature study of related works mainly regarding TMF ZOOM and ERICSSON network slice requirement analysis, modeling, and a Proof of Concept (PoC) which will be tested using NFV network slice as a service. It also includes applying the lean manufacturing methodology to the service relationship model to eliminate the unnecessary process from the system.

This thesis is concerned to focus mainly about the service relationships, Service Level Agreement (SLA), Information framework (SID), Virtual Network Functions (VNFs), E2E service. Broad literature is done to analyze the requirements needed to design the service relationship model and to apply the lean principles.

4.1 REQUIREMENT ANALYSIS

In this thesis, we first encircle the tasks which are needed to start the work. The tasks include improving knowledge of NFV, its requirements, the service roles and relationships mainly. The thesis will also apply a modified interpretation of the well-known design concept “Separation of Concerns” for computer programs [18], [19]. In this thesis, SoC aims at the isolation of influence factors on performance in virtualized service fulfillment, structuring the presentation of quality metrics according to the roles of service provider or service consumer, and the representation of these metric in the anticipated PoC, e.g. [19]. A first categorization and isolation of influence factors is shown in Figure 5. It depicts an initial structure for the dimensions that describes the scope of load and performance influencing components in virtualized infrastructures. The dimensions for the description are selected according to the three major categories of infrastructure in future virtualized networks: a) compute infrastructure, b) network infrastructure and c) virtualization mechanisms. The scope of the component increases along each dimension.

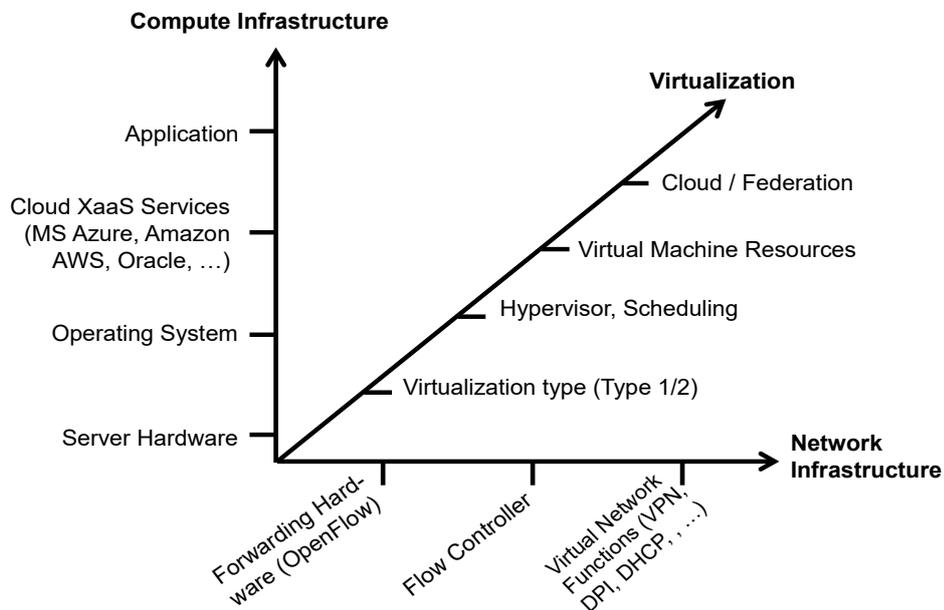


Figure 5: Separation of Concern for performance factors in CN services and infrastructures [19]

In this thesis the performance of the business relationships has been examined in two different views as one of it is categorized as role defining while the other view is to improve the service orientation of the model by reducing waste factors from the

model. The roles defining category is sub categorized into defining three service levels, stating functions in three service levels, providing roles relationship in the three service levels based on separation of concern. While the other view includes interpreting the lean strategies in to service deployment, studying business relations and then eliminating waste by classing them in to different types and then eliminating them.

4.2 LEAN MANUFACTURING

Toyota Production Systems have derived the philosophy of lean manufacturing in the early 1990s. The process of elimination of waste in a manufacturing system is termed as Lean manufacturing. Essentially, lean is centered on making obvious which adds value by reducing everything else which add no kind of value to the system. The main goal of lean is to reduce time, reduce total costs and eliminate waste by improving the quality of service delivered to the customer.

4.2.1 Lean Services

Lean services are the application of the lean manufacturing concept to service operations [20]. Service in this context could mean anything from telecommunication to service deployment. Whole service abstraction of life cycle can be handled through a lean service.

4.2.2 Lean IT

Lean IT is the extension of lean manufacturing and lean services to the deployment and management of information technology products and services [21]. It concentrates on removal of waste from the system in context of IT it concerns in removing work that adds no value to service.

Generative performance oriented organizations focus on the how to accomplish their mission. Lean gives a strategic analysis for accomplishing such missions are as follows:

- High cooperation.
- Risks are shared.
- Failure leads to enquiry.
- Novelty is implemented.
- Bridging is encouraged.

We have considered these strategic analysis cases for goal accomplishment with performance orientation and interpreted the strategic analysis in to service deployment as follows:

LEAN STRATEGIC ANALYSIS	SERVICE DEPLOYMENT
<ul style="list-style-type: none"> • High cooperation. 	<ul style="list-style-type: none"> • Standardized behaviors that can be automated (to and find standards between sub services).
<ul style="list-style-type: none"> • Risks are shared. 	<ul style="list-style-type: none"> • Detailed analysis if any risks are predicted (risk register updates).

<ul style="list-style-type: none"> • Failure leads to enquiry. 	<ul style="list-style-type: none"> • Mitigate the impacts when service provisioning fails and implementing risk response plans.
<ul style="list-style-type: none"> • Novelty is implemented. 	<ul style="list-style-type: none"> • New features in a service to customer (functionality, cost) and updated functional and communication standards.
<ul style="list-style-type: none"> • Bridging is encouraged. 	<ul style="list-style-type: none"> • Aggregating services to find standards between sub-services.

Table 2: Interpretation of lean in to service deployment

The elimination of waste is the goal of lean, and Toyota defined three broad types of waste: muda, muri and mura.

4.2.3 Muda

Muda is broken down into two types namely Muda type I and Muda type II. Muda type I is non-value added activity for end customer but it is necessary. Muda type II is non-value added activity for end customer which are not necessary.

4.2.4 Mura

In terms of business/process improvement, it is avoided through just-in-time systems which are based on keeping little or no inventory [22].

4.2.5 Muri

It can be avoided through standardized work. To achieve this a standard condition or output must be defined to assure effective judgment of quality [23].

4.2.6 Lean IT Principles

For this thesis Lean IT principles are applied to eliminate the unnecessary processes in the service relationship model. The following principles are for the IT products and services:

4.2.6.1 Value Stream Mapping

In the field of IT the services that are developed by the application and sent to parent organization which are in use customers, investors, suppliers and any other stakeholders are known as value streams. The waste reduction of any work that doesn't add any value to this service development is called value stream mapping.

4.2.6.2 Flow

It is related in eliminating the waste through just-in-time systems. JIT means just-in-time production that reduces the time gap between the parent organization and suppliers so, there will be no certain kind of flow disturbance in between. For example, a software team developed a product from coding that is familiar to just the team members and delivers the product with some hidden source code lacking due to time deadline then it is waste of production time so this will cause a time waste. So, in order to reduce the hidden wastes by standardization of work the flow principle is followed so, the code problem will be recognized and hence it is solved

by those certain team members. The flow between parent organization and suppliers must be reduced by standardizing all the work in order to avoid such circumstances.

4.2.6.3 Pull/Demand System

Pull systems are quite relevant to flow concept. A pull system is a service request from the customer or consumer of the product. For example, a customer is purchasing a product from online website which requires to complete the several forms including his personal details, card details, etc., whereas in some cases it adds no value to the system increasing time waste. Reducing such waste factor leads to use pull/demand system principle.

5 RESULTS

This chapter contains results obtained from methodological proposition of model with proof of concept having a detailed analysis of how to design a service of network functions and to improve its performance by applying lean principles.

5.1 COMMON RESULTS

This section outlines the modelling of the service relationship model verified with a PoC and applying the lean principles for the obtained PoC.

The modelling of the service relationship model includes defining three service levels and their relationships in a business organization. The functionalities and the rights of the roles in an organization have been researched thoroughly in order to construct this service oriented model which is very well suited for a service. The figure 6 below depicts the three service levels.

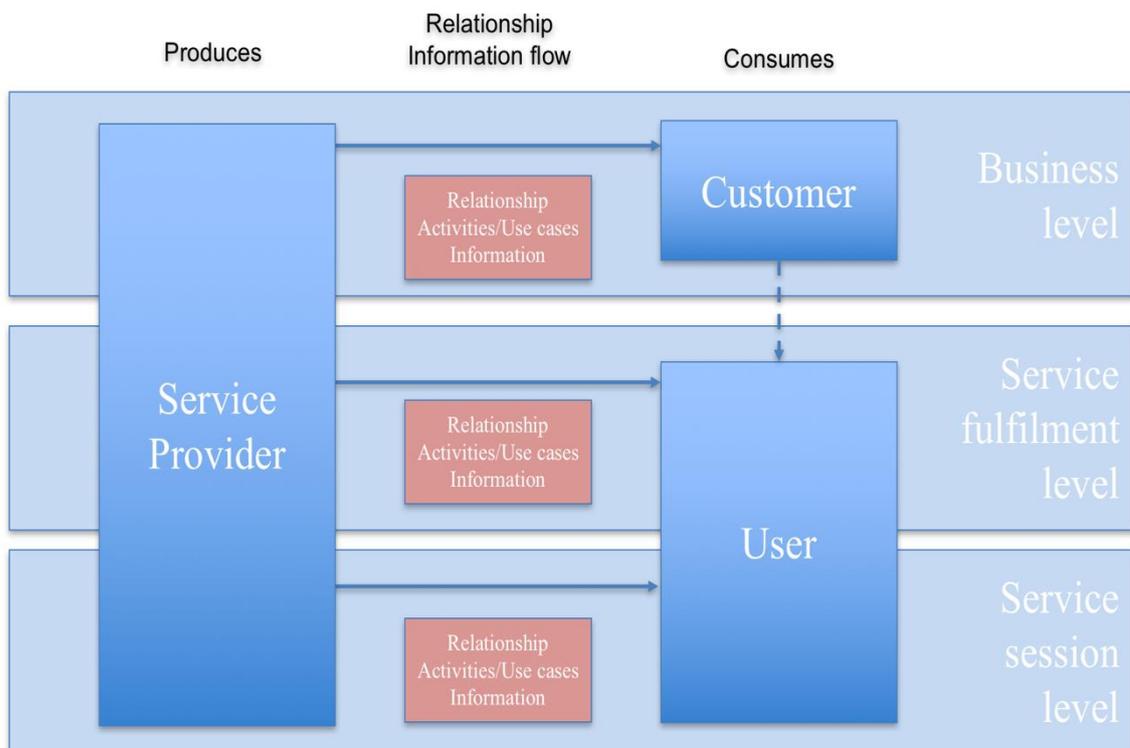


Figure 6: Service levels relationship model

The service levels are categorized in to three levels namely business level, service fulfilment level, and the service session level. The business level is responsible for all the business activities that takes place in between the service provider and the customer. The business level activities include the response for customer service, billing and charging activities and also the SLAs. The service fulfilment level mainly involves series of supply chain activities which is responsible for delivering the services to the customer and to check if the service fulfils all the customer specifications. The service session level is the third level and it includes the designing and testing of the service.

The relationship between the three levels are considered as two different cases in the PoC. As a part of first case, when a customer requests for a new service, the service provider provides with response for the request, asks about the specifications

for service and signs the SLAs. The service request is then passed to the service fulfilment level where the service provider tries to capture the needs of customer by requesting for the detail description of the specifications of the network elements and allocates the resources required to design the service. The service session level designs the service using the resources allocated by fulfilment level. The designed service is tested internally to make sure that the service is working and will be sent back to the fulfilment level where the designed service is tested on the customer infrastructure to check everything fits his requirements and is running. The business level then charges for the service delivered to the customer.

Lean principles are used in this case to reduce the waste of time factor by reducing the request from service provider to customer one time. So, the customer sends all the service specifications details in their first encounter itself. Hence the time factor is reduced.

The second case is when a customer comes back for a technical support. The customer reaches to the service provider and registers a case in the business level. Then the customer is assigned to the person in a fulfilment level for an enquiry in order to find the faulty resource and the faulty service is sent to session level where it is repaired and delivered in the same way as in previous case.

However, when a service is offered to customer from service provider then there must be standardization between sub-services in the main service in order to decrease the number of network elements and cost for the main service offered. Service provider must be able to have a default syntax way of how to describe the network functions in a network virtualized infrastructure in order to standardize the sub-services.

5.2 INDIVIDUAL RESULTS

The proposed service relationship model which is extracted from thorough research in the business organizations in the section 5.1 briefly categorizes in to three different levels as business level, service fulfillment level, and service session level. When discussing about modelling and software scenarios, organization units are assigned to multi-categorical roles. These roles are associated with certain rights, which additionally contributes to the area of legal rights. So, we have defined three roles for service relationship model namely service provider, customer and user as shown in figure (section 5.1). The main roles that are involved in the communication are service provider and customer. Service providers also known as content provider and manufacturer in some cases. They develop services that are offered and deployed on the cloud computing platform and access hardware and infrastructure of infrastructure providers. They are responsible for service usage activities and service management activities. Customer buys services through various distribution channels, directly from service provider. User role is on the customer side who uses the services provided by customer.

5.2.1 PoC

As discussed in the section 5.1 the flow of service is divided in to two categories as when customer requests a new service and when a customer requests for technical support. Now we are using NFV network slice as a service to verify the service relationship model (Proof of condition). The proof of concept is shown in figures 7a and 6b explains clearly about the first category (i.e.), when customer requests a new service. It depicts how the service provider and customer roles communicate with each other, how do they function, and in which levels precisely.

The figure 8 in business level shows that a customer requests service provider for a NFV network slice with specifications defined. Service provider considers the customer requested service and define SLA's between them. Then in service fulfillment level service provider requests customer for the service in detailed description and then customer provides detailed description of specifications. Later after service provider receives customer response he estimates and allocates the number of virtual resources for network slice required to be deployed. Then in the service session level functions in which the service provider designs the network slice and tests it internally to check its functionality and efficiency.

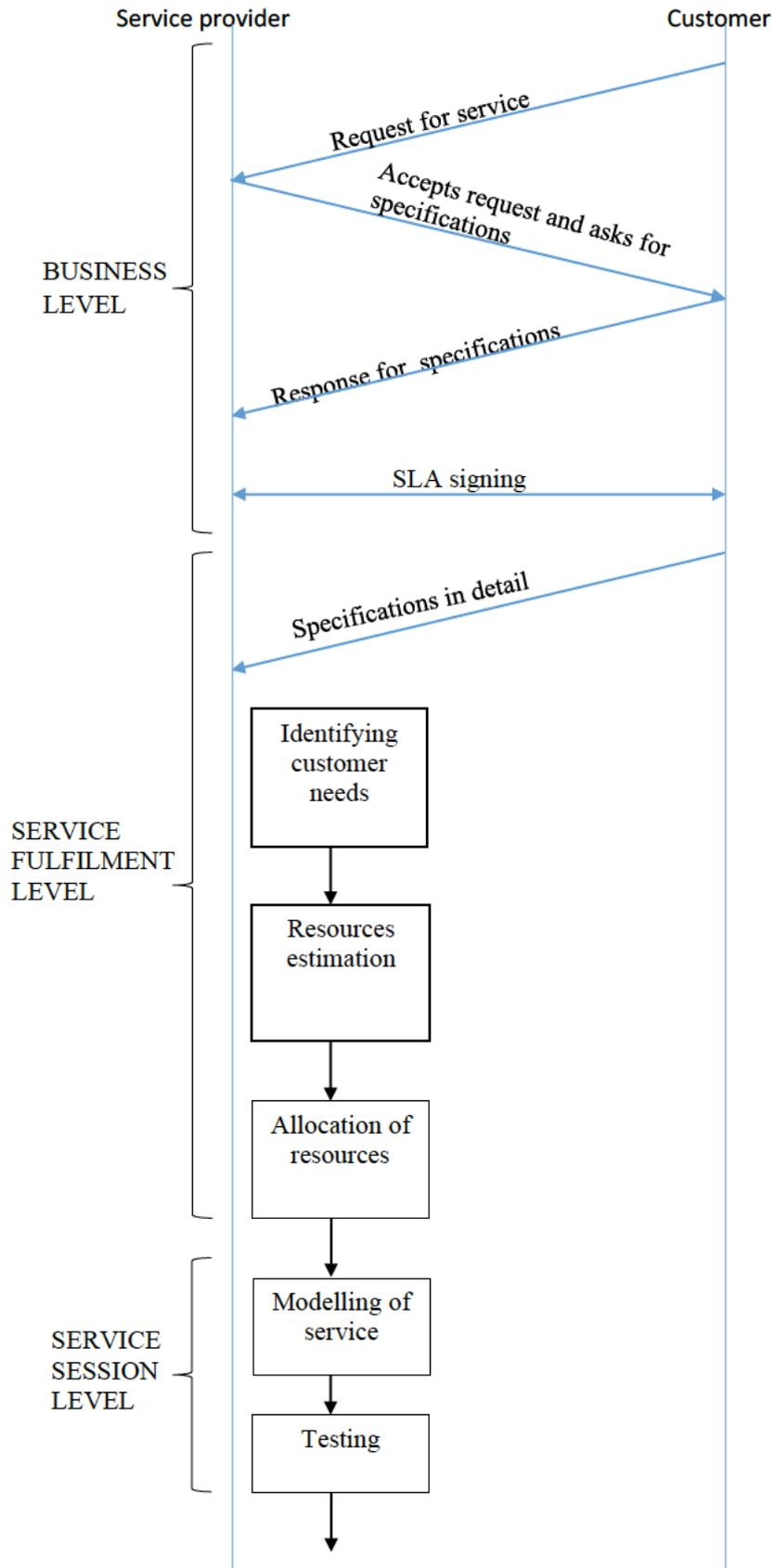


Figure 7a: PoC for modelling a service requested by customer

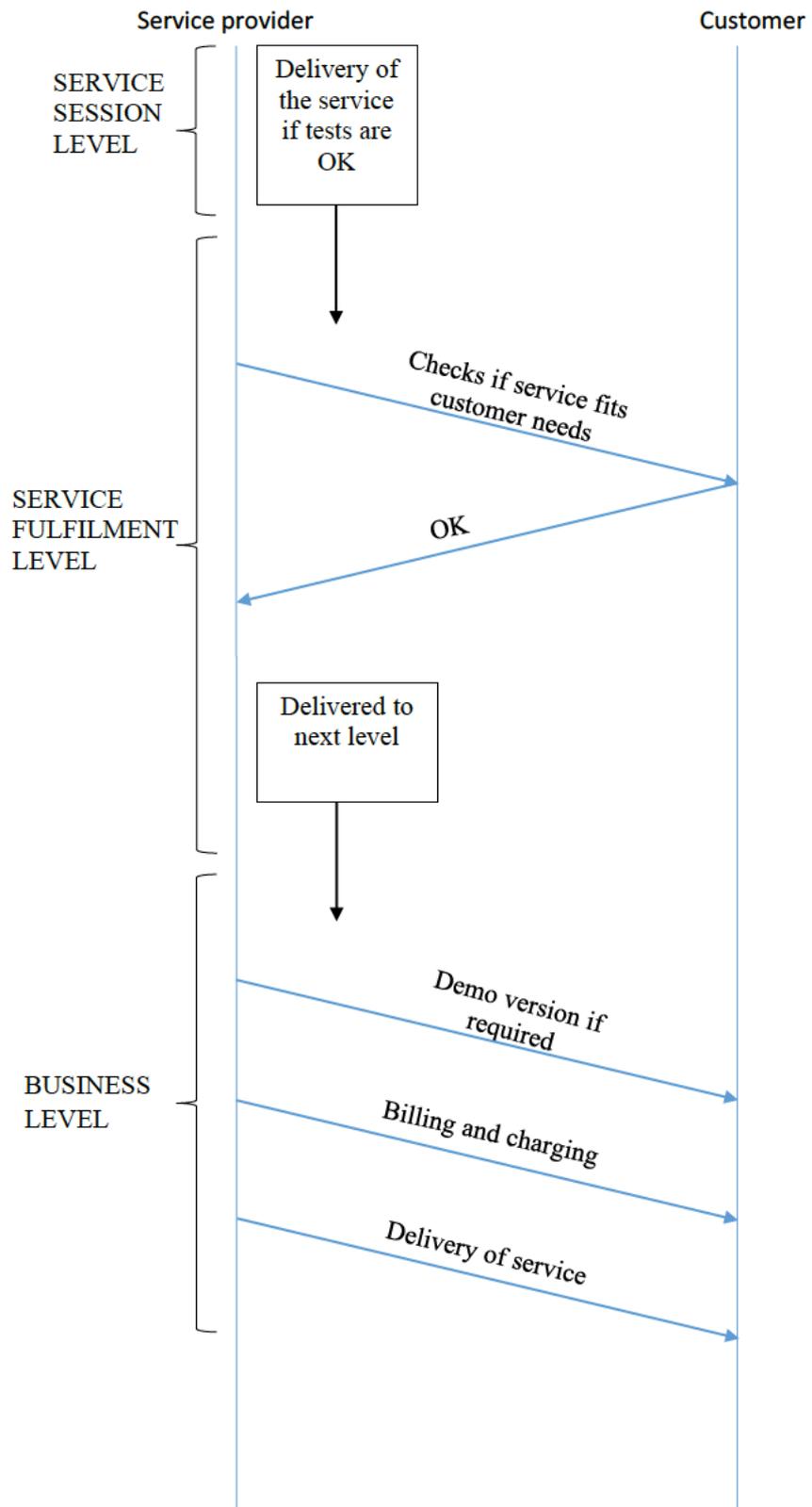


Figure 7b: PoC for delivering the service after modelling

Then in the service fulfillment level where service provider tests whether the service satisfy the customer requirement specifications. Then customer verifies the requirement specifications. Then in the business level depicts that service provider deploys the network slice with completed SLA. Service provider also offers features from BSS such as billing, charging and customer support. Customer then offers sub-services according to his user requirements (prepaid and postpaid), charging, billing and cost. The extent that customer can monitor is confined up to his security and his service. The customer doesn't need to know about the internal functions in the network.

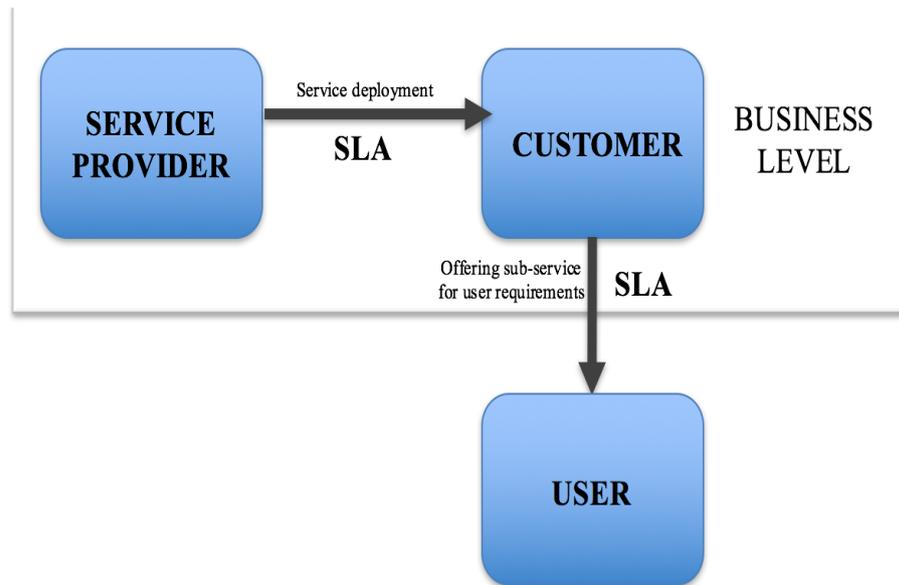


Figure 8: Roles relationship

The proof of concept shown in the figures 9a and 9b explains clearly about the second category (i.e.), when customer requests for technical support if the delivered network slice have any kind of functionality issues to serve the end-users. It depicts about how the customer reaches for technical support to service provider and how the issue is solved and in which levels precisely. The customer reports the issue of network slice and then service provider forwards the issue on to service fulfillment level where the root cause is diagnosed and the further analysis for the problem is provided. Then the network slice is forwarded to service session layer where it is repaired or a new network slice with no faults is delivered to the customer by service provider. The service function in the PoC refers to the network function elements as they pass through physical and virtual networks. So, the service function chain for the PoC is the way to decide how things should happen (i.e.) the way in which the service must be designed and delivered to end user using the network functions and the flow in between the three service levels and between the roles defined.

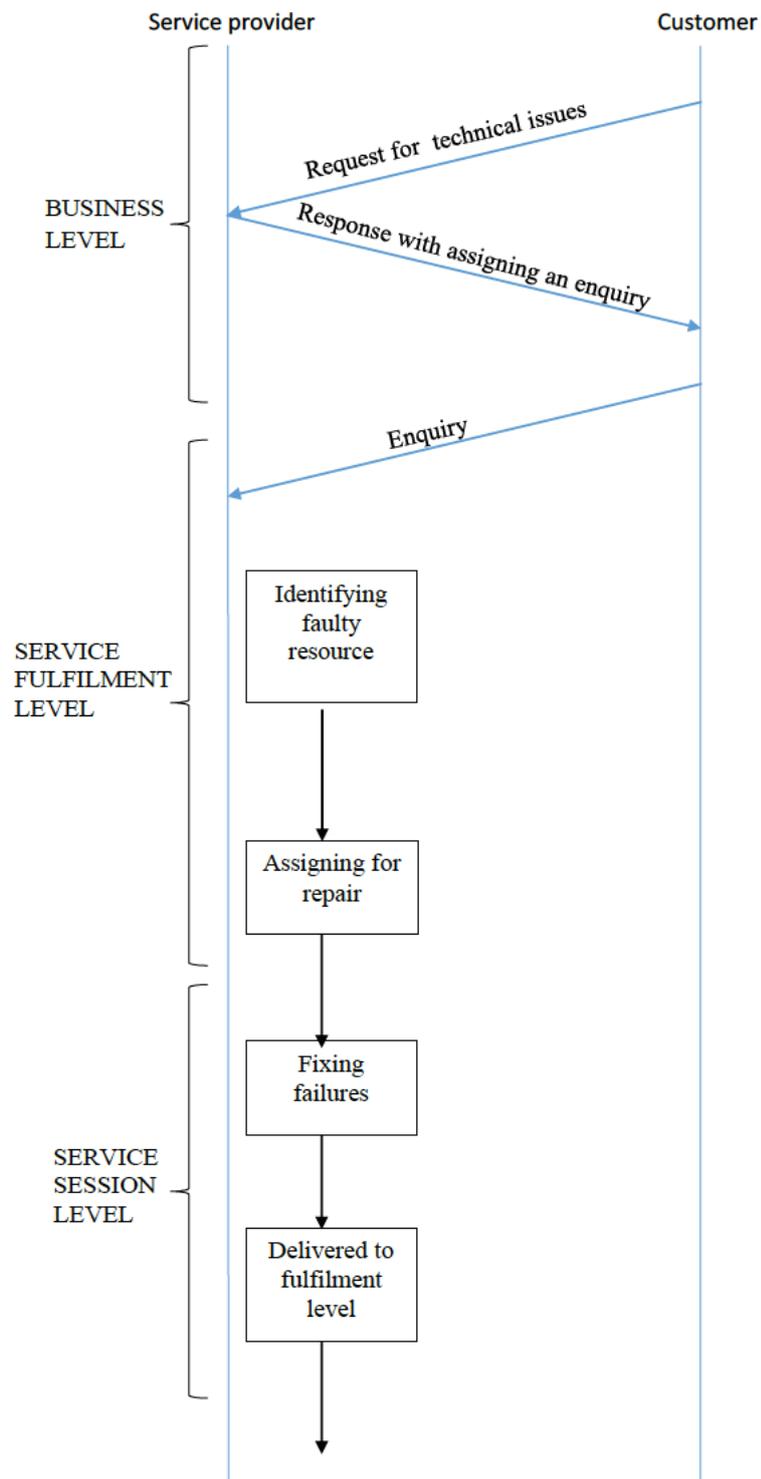


Figure 9a: PoC for reconstructing the service when customer requests for technical support

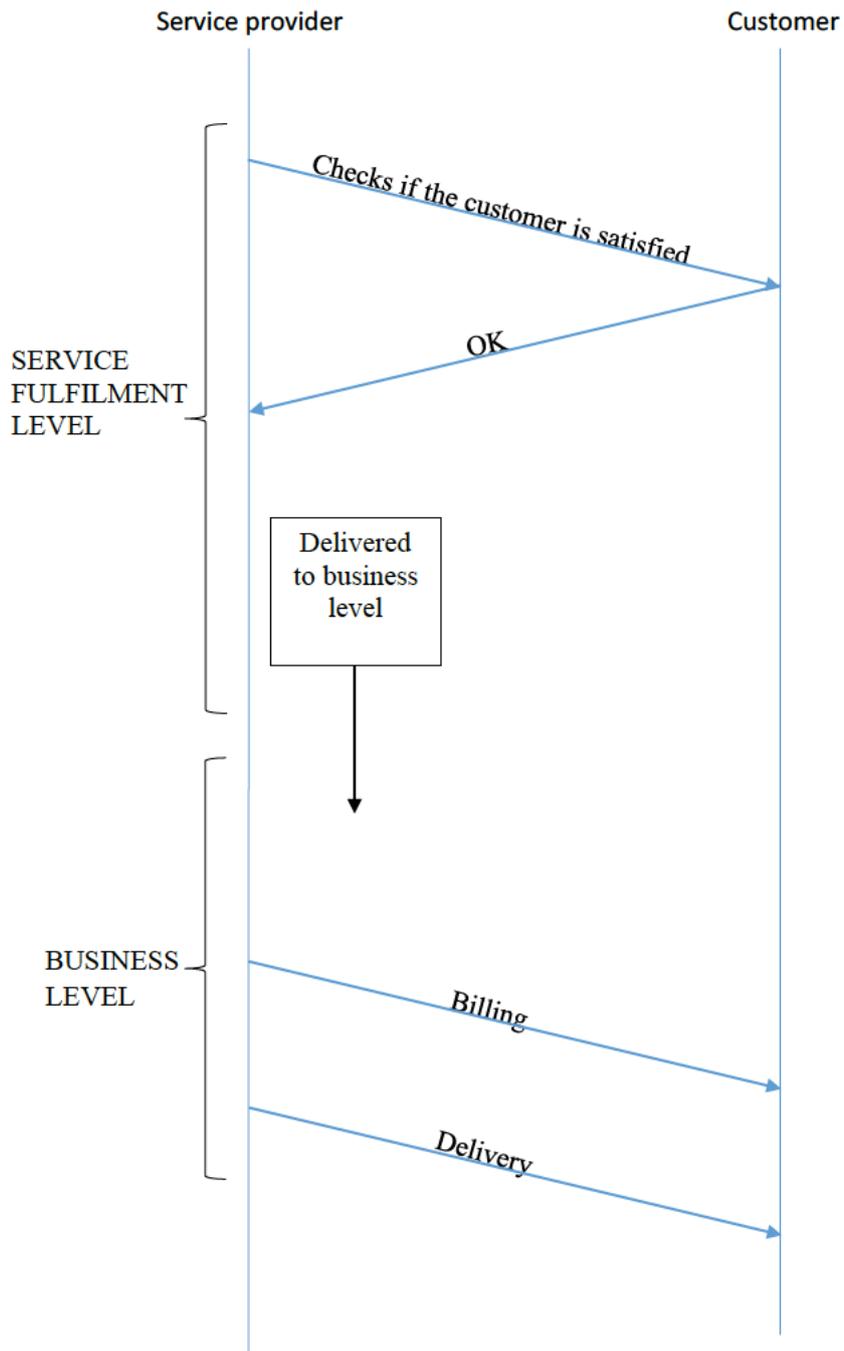


Figure 9b: PoC for delivering a service after reconstruction

5.2.2 Lean Interpretation

There are two waste factors that are observed from PoC and are interpreted with lean principles such that they benefit the present service relationship model and are listed as follows

5.2.2.1 Time Factor

When we look in to business and service fulfillment levels we understand that there is some time delay factor (i.e.), the service provider and customer discuss about the service description twice. Customer defines about the specifications in the business level once and again in detail in the service fulfillment level. This waste is identified under pull/demand lean principle where it interprets that it adds no value to the system increasing time waste. It could be considered that customer sends the request with detailed service description and defining SLA's. So, the security matter behind what customer exchanges with service provider is safe and the service request with detailed description will be finished at once. The benefit due to this lean principle is improved efficiency rate of service deployment by time factor reduction.

5.2.2.2 Standardization Factor

We may have different sub-service providers offered in the PoC. Whereas if we try to standardize different sub-services so, there can be new sub-services forming from the sub-services that are existing. Hence service provider must declare standards in order to integrate existing sub-services to provide better service features. This waste is identified under flow lean principle where it interprets that the flow won't be disturbed due to just-in-time systems (i.e.), if we provide the standardized sub-services then the new sub-services are easy to deploy with no need of extra network slice design. The benefit due to this lean principle is improved service flow by the sub-services standardization.

In order to standardize the different sub-services from different providers, the service provider needs to know the ways to describe network functions. So, it crucial and the identified sufficient ways to describe network functions in the service relationship model designed are listed as follows:

- Identify the network function: for example, name of network function.
- Describe the network function: for example, structure and syntaxes of the network function.
- Define the activities of network function: for example, input and output.
- Capability of network function: for example, limit of handling the devices.
- Identify the type of protocol: for example, datagram protocol and port number.
- Security issues of network function: for example, measures to protect data integrity and user authentication.

The service deployment is accomplished efficiently for performance oriented service. However lean principles are applied to the PoC in order show it as a performance oriented validation. The wastes are considered in different levels and are categorized in to two principles which are clearly stated with the waste reductions that show service efficiency. Now we categorize the time factor and standardization factor in to type of wastes discussed above in the section 4.2. From the below table we can see that the time factor and standardization factor are identified in to muda type – II and muri respectively. Hence the service relationships model for NFV infrastructure benefits by lean manufacturing.

TYPE OF WASTE	PRINCIPLE TO IDENTIFY	FACTOR DESCRIPTION
Muda type - II	Pull/Demand	Reducing waste (specifications in business level) which acts more time factor such as request about service twice.
Muri	Flow	Reducing waste (in service fulfillment level) standardizing between sub-services.

Table 3: Mapping lean principles to PoC

6 CONCLUSION AND FUTURE WORK

Designing service relationship service model which is validated with service oriented PoC that is benefited by applying lean principles is the main aim of this thesis. The following conclusions had been made from the research work which is contributed towards science:

- Research work for NFV and its architectural framework which describes NFVI, NFV-MANO, VNF'S, OSS/BSS.
- Detailed study on network slice: example ERICSSON, TMF documents, ETSI documents and IEEE publications about NFV architecture, roles involved in the service model, flow of service, network functions.
- Detailed study of business organizations what are their functionalities, activities, legal rights, organizational units, principles.
- Detailed study on OSS/BSS in a cloud operating network services.
- The organizational unit's categorization in to three different levels has been possible through research on the business/software organizations.
- The flow of service in the defined service relationship model is inherited from the business models and software units that use to produce a service oriented performance.
- From results it can be concluded that, the roles defined are fit for the service model designed and the model can hence contain the flow of service by standardizing the sub-services and reducing waste interpreted with lean principles. The three levels in the service relationship model defined can confine the three roles stated as service provider, customer, and user. The flow of service among those three levels among the two main units namely service provider and customer. The service relationship model fits in to NFV based on requirement specifications. It also shows the ways to describe network functions syntax which follows lean principles that are essential to have them for the sub-services standardization. It shows that the designed service relationship model is benefited by lean principles. The PoC defined can be an assurance to the NFV Infrastructure. The view of service provider pertains to the whole work flow happening in the service model.
- All the research done throughout the thesis work provides a service oriented model which depicts the roles functions and have standardized sub-services integrated by applying lean principles.
- Strict study about lean manufacturing and how can lean manufacturing be interpreted in turn that benefits NFV.
- Detailed view of lean principles that reduce waste from the service that doesn't add any kind of value to the service. This helps in considering levels separately and then proposing waste removal methods invoked by the lean principles.

6.1 ANSWERS TO RESEARCH QUESTIONS

RQ1. How do the service relationships model for NFV infrastructure benefits by lean manufacturing?

The answer to this research questions is provided by section 5.2. After the service deployment is accomplished efficiently for performance oriented service. Then the lean principles are applied to the PoC in order show it as a performance oriented validation. The wastes are considered in different levels and are categorized in to two principles which are clearly stated with the waste reductions that show service efficiency. Now we categorize the time factor and standardization factor in to type of wastes discussed above in the section 4.2. From the table.3 in section 5.2 we can see that the time factor and standardization factor are identified in to muda type – II and muri respectively. Hence the service relationships model for NFV infrastructure benefits by lean manufacturing.

RQ2. What are the sufficient ways to describe network functions in the service relationships model by lean manufacturing?

The answer to this research question is provided by section 5.2.1.2. The standardization factor waste identified in the system needs to standardize the different sub-services from different providers. So, the service provider needs to know the ways to describe network functions. The identified sufficient ways to describe network functions by lean manufacturing analogy in the service relationship model designed are listed as follows:

- Identify the network function: for example, name of network function.
- Describe the network function: for example, structure and syntaxes of the network function.
- Define the activities of network function: for example, input and output.
- Capability of network function: for example, limit of handling the devices.
- Identify the type of protocol: for example, datagram protocol and port number.
- Security issues of network function: for example, measures to protect data integrity and user authentication.

RQ3. Which extent does a customer need to monitor about the service delivered in the network in terms of relationships for a lean provisioning?

The answer to this research question is provided by section 5.2. After the service deployment the service provider offers some features to customer. Then customer also offers sub-services according to his user requirements (prepaid and postpaid), charging, billing and cost. So from this explanation the extent that customer can monitor is confined up to his security and his service. The customer doesn't need to know about the internal functions in the network.

6.2 CHALLENGES FACED

The challenges for this thesis work are as follows:

- Understanding complex business service chains.
- Extracting key roles based on service deployment.
- Defining roles, relationships and service levels required for interaction of roles.
- Mapping NFV to the complex business service roles.
- Interpretation of lean manufacturing principles to remove the waste from a system in to the analogy of service deployment.
- Analogy of automobile company waste reduction techniques to the service provisioning in order to benefit the service relationship model defined.

6.3 FUTURE WORK

- Designing a meta-model by using the service-relationship model from this thesis.
- Evolution of more use cases for the service-relationship model.

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