Towards Operator-managed P2P Content Delivery with Application Layer Traffic Optimization

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Abstract: P2P technology provides a flexible and very popular way of content delivery for various services, including networked media applications. However, P2P-based content delivery generates large amount of backbone traffic. Recently, several approaches have been proposed for guiding P2P services based on operator preferences, in order to reduce the amount of costly backbone traffic generated by P2P applications. Application Layer Traffic Optimization (ALTO) is a one key approach for such managed P2P applications. In short, ALTO is a dedicated service, operated by a network operator or ISP, which can provide useful network layer information to application layer clients for improved peer selection and corresponding content delivery.

This paper provides an overview on standardisation and research activities for improving P2P content delivery with ALTO which are carried out within the EU FP7 project NAPA-WINE. In particular, we give an overview on standardisation efforts, present simulation results, explain our prototypical implementation of the ALTO concept, and highlight ongoing large-scale operational trials we are currently conducting within the network of Polish Telecom and among NAPA-WINE partners.

Keywords: Managed P2P Content Delivery, Application Layer Traffic Optimization (ALTO), P2P Live Streaming.

1 INTRODUCTION

Distributed networked media applications - both peer-to-peer (P2P) and client/server - use a significant amount of network capacity. In contrast to centralized applications, distributed applications access resources such as files or media relays distributed across the Internet and exchange large amounts of data in connections that they establish directly with nodes sharing such resources.

Recently, researchers have started to investigate approaches where information (such as topology, cost, or policies) provided by the underlying network layer can help reduce the overall amount of traffic generated by networked media applications (such as a high volume of inter-ISP traffic because certain applications do not consider network layer locality). Given that a certain resource is available at several clients of a decentralized application, traffic flows can be optimized if a resource consumer (i.e. a client which would like to download a certain resource) can select among different resource providers in a way which is “better-than-random”. The overall idea is that clients can choose their resource providers more efficiently (for both the application and the network) by using information about the network layer topology. Specifically, the amount of cross-area traffic which is costly for the network may be reduced.

Application Layer Traffic Optimization (ALTO) is a concept for reducing the amount of application layer backbone traffic by guiding respective applications with data provided by a network operator. By providing a dedicated service, operators can make certain types of network layer information available to applications. The vision of ALTO is that ISPs and applications can achieve a win-win-situation where applications can maintain (or even increase) their performance while ISPs can reduce traffic transmission costs [7].

NAPA-WINE (Network Aware Peer-to-peer Application over Wise NEtworks) [5] is a three years project (STREP) within the 7th Research Framework of the European Commission. The main goal is the study of novel Peer-to-Peer (P2P) architectures and systems suitable for High Quality TV live streaming over the Internet: a P2P-HQTV system. The NAPA-WINE project is proposing an innovative architecture for network-aware P2P content delivery. This network cooperative P2P-TV architecture explicitly targets the optimization of the quality perceived by the users while minimizing the impact on the underlying transport network. The focus is on the study, design and development of a P2P-HQTV system, in which peers setup a generic mesh based overlay topology, over which video chunks are exchanged according to a swarming-like approach. A source peer produces the video stream, chops it into chunks, and injects them in the overlay where peers cooperate to distribute them.

One key concept investigated and developed within NAPA-WINE efforts for network-aware P2P content delivery has been ALTO. In this paper, we give an overview of our efforts regarding ALTO standardisation and ongoing research activities. Specifically, we detail our prototypical implementation of ALTO client and server. Further, we highlight ongoing operational trials we are currently conducting in the network of Polish Telecom and among NAPA-WINE consortium partners for optimized content delivery through ALTO-guidance.

This paper is organised as follows. Section 2 gives background information on ALTO and explains goals and use cases for ALTO. Section 3 highlights ALTO standardisation
in the IETF and key contributions from NAPA-WINE. Section 4 gives an overview on ongoing research within NAPA-WINE regarding ALTO-guidance for networked media applications, focussing on P2P Live Streaming as a use case. This work includes extensive simulations, prototypical implementations, and large-scale operational trials of ALTO. Section 5 concludes the paper with a summary and an outlook on future work.

2 RATIONALE FOR APPLICATION LAYER TRAFFIC OPTIMIZATION

P2P content delivery often does not account for the specifics of the underlying network topology. Consequently, the high bandwidth requirements for networked media content result in large amounts of traffic generated by P2P content delivery. The overall rationale for ALTO is that selection of a good peer from an overlay in topological proximity has a large impact on the overall traffic generated [7].

Figure 1: Generic ALTO Architecture

In short, ALTO - as envisioned by the IETF - is a dedicated service, operated by a network operator or ISP, which can provide useful network layer information to application layer clients about resource providers [13]. The kind of information that is meaningful to convey to applications via an out-of-band ALTO service is any information that applications cannot easily obtain themselves and that changes on a much longer time scale than the instantaneous information used for congestion control on the transport layer. Examples for such information are operator's policies, geographical location or network proximity (e.g., the topological distance between two peers), the transmission costs associated with sending/receiving a certain amount of data to/from a peer, or the remaining amount of traffic allowed by a peer's operator (e.g., in case of quotas or limited flat-rate pricing models) [7]. One way for ISPs to achieve cost reduction through ALTO is through traffic localization: suggesting to resource consumers other resource providers through ALTO which are in the same ISP or within the same intra-ISP area (e.g. PoP).

2.1 ALTO Architecture

Figure 1 [12] shows the overall idea behind an ALTO service. Assume that Client 2 in the figure wants to download a particular resource, i.e. Client 2 is a resource consumer. Assume further that Client 2 has received through its application protocol several candidate clients which can offer the desired resource. In the figure, Client 2 can potentially download the desired resource from Client 1 or Client 3, i.e. Client 1 and Client 3 are resource providers. At this stage, Client 2 can query an ALTO service for guidance on which Client to select for downloading. The ALTO service is a source of information for the querying Client regarding network layer information which the Client cannot obtain (or not obtain easily) otherwise. The ALTO service can answer queries based on information provided by the Client’s ISP such as information regarding the topology, routing state, policies, or operational costs. In the example depicted it is likely that the ALTO service would suggest downloading from Client 3 because this Client is physically located in the same network as Client 2 [12].

Figure 2: ALTO-Guidance in a Tracker-based P2P Live Streaming System

2.2 ALTO Use Cases

Different kinds of applications can benefit from ALTO, and application requirements have to be taken into account when designing an ALTO service. It is important to acknowledge that the ALTO concept does not apply to P2P applications only. However, P2P applications (such as filesharing or live streaming) are core use cases expected to benefit from ALTO [7][12]. Other types of applications which can potentially use ALTO include optimal cache/mirror selection with respect to the user’s location, or choosing an optimal relay for real-time communications (such as VoIP) [7][12].

Figure 2 [13] exemplifies how ALTO can be included in a tracker-based P2P Live Streaming system. A peer retrieves a list of candidate peers from a tracker (e.g. peers which are watching the same channel) (1, 2). The peer sends this list to the ALTO-server of its ISP (3) which returns a sorted/ranked list (4). Based on the sorted/ranked list of candidate peers returned by the ALTO server, the peer selects other peers with which it starts to exchange chunks.

3 STANDARDISATION

ALTO standardisation is an explicit activity and contribution of the EU FP7 project NAPA-WINE. The IETF has formed an ALTO working group to standardise an ALTO client-server protocol [4]. From the beginning, NAPA-WINE has been a key contributor to this ALTO work in the IETF. The ALTO problem statement (RFC 5693) [7] has been published as first
parts of these efforts, co-edited by members of the NAPA-WINE consortium. Currently, NAPA-WINE is contributing to ALTO requirements [9], the ALTO protocol specification [8], and ALTO deployment considerations [10]. This section gives a brief overview of these ongoing ALTO standardisation efforts in the IETF.

3.1 ALTO Requirements

Within the IETF, the following high-level requirements for an ALTO protocol have been identified [9] (besides general constraints and detailed requirements regarding protocol semantics): a) Error handling and overload protection: An ALTO server must be able to express certain errors which can occur. Specifically, an ALTO server must be able to inform clients in the case it is overloaded; b) ALTO server discovery: There must be a discovery mechanism available so that ALTO clients can find ALTO servers, c) Security and privacy: Authentication and authorization between ALTO entities must be supported by the protocol. In addition, the ALTO protocol must include some protection against Denial-of-Service attacks against ALTO servers. To protect the privacy of users as well as to support the desire of network providers to hide details of their interior network topology, the ALTO protocol must support different levels of granularity regarding ALTO guidance in queries and responses.

3.2 ALTO Protocol

The ALTO protocol specifies the query-response message exchange between an ALTO client and an ALTO service. The provisioning of topology information (or other kinds of information, e.g., policies) to an ALTO service as well as the P2P application protocol itself are out of scope for IETF ALTO work. Initial proposals for an ALTO protocol were based on input by the P4P project [14], but evolved to the current specification detailed in [8]. An alternative proposal for an ALTO protocol called “H12” has been proposed in [11]. In addition to smaller issues such as the encoding of messages, the main difference between the proposed protocols and architectures is the allocation of functions between ALTO clients and servers, respectively. These decisions are mainly motivated by scalability and privacy requirements.

In general, the IETF ALTO protocol will work as follows: 1) The application using ALTO obtains candidate IP addresses of potential resource providers, e.g. using centralized or distributed databases, such as BitTorrent Trackers, DNS, DHTs, through message exchange (e.g., gossiping), or any other application-specific mechanism; 2) The application passes the list of candidate IP addresses to the local ALTO client. The ALTO client contacts the ALTO server(s) as needed and together they generate the ALTO guidance. This invocation of ALTO can be done by the peer which will eventually access the desired resource, or it can be done by a third party, such as a tracker, on behalf of the peer; 3) The ALTO client returns the list of addresses to the application, together with the ALTO guidance. The guidance can be expressed implicitly by sorting the address list according to some rating criteria, and/or explicitly by giving rating attribute values for each address; 4) The application instance can combine the ALTO guidance with locally generated ratings (e.g., based on measurements) and then connect to one or several resource providers that have been rated best. If the application is not satisfied with the actually experienced performance, it can connect to other resource providers further down the sorted list, it may query ALTO again, or it can proceed without ALTO guidance.

3.3 ALTO Deployment Considerations

Recently, the IETF is also working on a document which provides key background information for ALTO deployment [10]. Besides use case scenarios, the document discusses potential limitations of ALTO as well as ALTO security considerations. One potential limitation of current ALTO standardisation relates to so called “map-based approaches” (where several subnets are grouped into one identifier). This approach has the disadvantages that information contained in such network-maps may change rather frequently, e.g. in case of IPv4 subnet reallocation, resulting in suboptimal ALTO guidance. Security considerations for ALTO deployment include potential information leakage from the ALTO server. ISPs deploying ALTO need to be cautious that not too much specifics of their network structure and settings can be inferred by multiple ALTO queries. Another security issue is that access to ALTO servers may need to be restricted to specific clients, e.g. only to the customers of the ISP which hosts the ALTO server. Such access control can help in reducing server load as well as in preventing attacks from arbitrary locations. A further concern is to enable proper authentication of ALTO guidance to prevent forged ALTO responses. Such faked ALTO response could for instance guide all traffic to a certain client in the network, resulting in a Denial-of-Service attack on this client.

4 ONGOING RESEARCH IN THE EU FP7 PROJECT NAPA-WINE

Apart from standardisation (see section 3), the NAPA-WINE project has been conducting several research activities, investigating how ALTO can optimize content delivery for networked media applications exemplified with P2P Live Streaming. This section gives an overview on simulation results, prototypical ALTO client and server implementation, and ongoing large-scale operational trials of ALTO.

4.1 Simulating ALTO-Guidance for P2P Live Streaming

We have conducted extensive simulations to assess the benefit of ALTO for P2P live streaming with respect to a) reducing backbone traffic costs, and b) reducing chunk delay. As an example, Figure 3 shows how ALTO can reduce delay compared to measurement-based peer selection (1000 peers allocated over 100 ASes, videorate = 1Mbp/s). In summary, our results indicate that ALTO can reduce the amount of inter-ISP traffic to a large extent while still allowing live streaming content to be delivered timely. Further, our simulations show that in scenarios where the system is experiencing high load
and when there is potential for intra-AS localization, ALTO can significantly reduce application layer delay. More details on cost reduction for P2P live streaming with ALTO can be found in [13].

![Figure 3: Reducing P2P Live Streaming Delay with ALTO](image)

### 4.2 Prototypical Implementation of ALTO Client and Server

Following ongoing IETF standardisation, we have implemented a prototypical ALTO client and ALTO server.

#### 4.2.1 ALTO Server

The ALTO server is a stand-alone application which hosts the logic to guide applications to optimize network resource usage. To do so, this logic is able to combine knowledge about the serving networking architecture, quality parameters and/or operational costs of the communication links involved. The server receives requests via XML over HTTP and combines information from different resource pools based on the request parameters received from the ALTO client (see 4.2.2). Then it calculates an ALTO rating and sends it to the ALTO client as guidance. The data provided by the resource pools can represent any kind of network parameters. In our implementation we currently use the following information (provided by the network operator and imported into the ALTO server) to calculate ALTO ratings: RTT, geographical distance, monetary transmission costs, and link utilization between peers or geographical areas. Figure 4 shows a schematic view of our ALTO server architecture.

![Figure 4: Architecture of ALTO Server](image)

We tested our ALTO server on a dedicated 2Ghz AMD 64-bit Opteron with 6GB RAM, able to serve 1000 requests per second with an average response time of one second. Our implementation scales linearly with the number of ALTO requests and queried resources in these requests.

#### 4.2.2 ALTO Client

The ALTO client is an API for interacting with the ALTO server, schematically depicted in Figure 5. The client provides several interfaces (1) through which an application (denoted XXX Client) can query for an ALTO rating regarding one or more available peer addresses. All requested addresses are stored in the DB req (1, 2, 7). The ALTO client then sends all addresses contained in the DB req to the ALTO server via XML over HTTP (3, 4) requesting a rating for each. The server rates each of the addresses, applies filtering criteria where needed [11], and responds with a corresponding XML based ALTO response (4). The ALTO client receives the list of rated addresses (5). If the ALTO server to respond with ratings for subnets (to prevent data leakage [10]), these may need to be mapped to the requested peer addresses via longest prefix matching (6). After this matching is complete, the list of peer addresses along with the ALTO ranking is passed back to the requesting application (1, 2, 7).

![Figure 5: ALTO Client Architecture](image)

We have implemented the ALTO client in C; it is intended to be released as open source software soon. We have already integrated our implementation into different applications and tested it in several deployments: The NAPA-WINE P2P live streaming client (see further 4.3), a BitTorrent client, and a BitTorrent tracker (see further 4.4).

### 4.3 Integration into a P2P Live Streaming software

The NAPA-WINE project has designed and implemented an architecture for a P2P Live Streaming client software [6]. Figure 6 displays this client architecture; the reader is referred to [6] for a detailed description of the Napa-Wine software architecture and the specific components and modules.

To integrate ALTO into the Napa-Wine architecture, the external repository (Ext-REP) is used. This repository has an interface for connecting to Application Layer Traffic Optimization (ALTO) servers. Figure 6 shows how the ALTO client can be integrated into the Napa-Wine architecture: The ALTO client API is invoked via a function call by the Ext-REP to query an ALTO server with the standard ALTO protocol. The ALTO client returns to the Ext-REP a response code (indicating whether the ALTO query was successful or
not) and the list of peers the Ext-REP queried in conjunction with an ALTO-ranking for each of these peers.

4.4 Operational Trials

Based on our prototype implementation and integration of ALTO into several P2P applications, we are currently conducting large-scale operational trials of the ALTO concept.

4.4.1 Trial environment

We use the MyPLC PlanetLab environment of Polish Telecom (TP) as the test platform for ALTO trials, depicted in Figure 7. This network environment provides tools for running and testing distributed applications. TP’s PlanetLab is a network of 70 servers distributed over 8 sites in Poland. With public PlanetLab (i.e. PlanetLab Central and PlanetLab Europe) it is further possible to scale up the experiments to 1000 nodes. An ALTO server has been setup and is running inside the TP commercial IP network. The ALTO server has been provisioned with the routing information of TP network imported from a Quagga server which is a part of the TP routing network. The IP prefixes learned from the TP network by the Quagga server (via BGP feed) are associated with community attributes that indicate their geographical localization within one of 14 areas of Poland as described at RIPE within AS5617 (Telekomunikacja Polska S.A., 2010; the community attributes are propagated by the BGP protocol). One matrix of RTT between these areas in the TP network has been imported into the ALTO server; other operational ALTO rating criteria will be imported in the near future. For further extension of the environment for the trial of P2P live streaming, the local testbeds of all NAPA-WINE project partners has been prepared (see Figure 8). The testing network consists of about 100 servers (including PlanetLab and OneLab nodes) placed at different locations in Europe connected via Internet links. Appropriate routing information and rating matrices for partners’ sites will be added to the ALTO server.

4.4.2 BitTorrent Trial

BitTorrent has recently emerged as a very scalable P2P file sharing system. BitTorrent applications are not aware about the geographical localization of the peers, thus imposing high traffic load distribution over the network. To verify the ALTO concept in real-world scenarios, we are conducting several BitTorrent Trials for both, an ALTO-enhanced BitTorrent client as well as an ALTO-enhanced BitTorrent tracker.

Trial Setup (FileSharing)

Both Trials use the same binary data, and query the same ALTO server, running on dedicated PlanetLab Nodes. Through appropriate configuration of the BitTorrent client software [1], we modelled the Trials to use a realistic ratio of

![Figure 6: Integration of ALTO into P2P Live Streaming Client Architecture](image)

![Figure 7: Trial environment using Polish Telecom Network and MyPLC PlanetLab](image)

![Figure 8: Trial environment among NapaWine partners](image)

![Figure 9: ALTO Filesharing Trial in TP Network](image)
For the swarm we assume one super-seed that initially provides the required content. The other peers are equally divided into seeders (peers that download and continue to provide content) and leechers (peers that download the content and disconnect). All peers fall within one of four bandwidth capacity categories (see Table 1). The peers with their configured role and bandwidth constraints are distributed randomly among the 70 PlanetLab servers. The trials are intended to demonstrate the potential benefits (savings on links utilization) of using ALTO for the network operator as well as improvements in performance (download time) for the BitTorrent application.

Table 1: Bandwidth Capacity Distribution among Peers

<table>
<thead>
<tr>
<th>Class</th>
<th>Ratio</th>
<th>Uplink (kbps)</th>
<th>Downlink (kbps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 %</td>
<td>128</td>
<td>784</td>
</tr>
<tr>
<td>2</td>
<td>40 %</td>
<td>384</td>
<td>1500</td>
</tr>
<tr>
<td>3</td>
<td>25 %</td>
<td>1000</td>
<td>3000</td>
</tr>
<tr>
<td>4</td>
<td>15 %</td>
<td>5000</td>
<td>10000</td>
</tr>
</tbody>
</table>

### 4.4.3 P2P Live Streaming Trial

After an initial experimentation phase with BitTorrent, the ALTO approach for P2P live streaming (developed in the NAPA-WINE project) is planned to be examined. The aim of the trial is to show the influence of the ALTO concept on P2P live streaming. Two main tests cases are foreseen:

- Perceived application quality – to demonstrate the influence of the ALTO approach on end-user perceived quality for different ranking rules (e.g. based on costs defined by the network operator); from the operator point of view traffic distribution in the network will be investigated in order to obtain the optimal solution for network utilization and quality of application.
- Overlay network topology – to show the influence of ALTO on peer connections in a P2P live streaming service. In this trial scenario the peer connection topologies of the NAPA-WINE P2P application with and without ALTO presence will be compared. The localization effect and its influence on the overlay topology will be studied.

## 5 CONCLUSION AND OUTLOOK

Application Layer Traffic Optimization (ALTO) is a new concept for managing P2P content delivery of networked media applications. In this paper, we have presented an overview of our research and standardisation of ALTO. Further, we have outlined our ongoing operational ALTO trials for different types of P2P applications. As future work, we intend to finalise our operational trials and consider investigating the use of ALTO for CDN networks.

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