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Performance evaluation of traffic management mechanisms for Peer-to-Peer networks

Robert Wójcik*, Jerzy Domżał

AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland

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ABSTRACT

Most network operators, excluding tier 1, pay for the inter-domain transmissions, i.e., the data which is sent to and from their managed networks. As Peer-to-Peer applications generate a substantial amount of traffic in telecommunication networks today, the operators feel the need to manage it effectively. The problem is that the created overlay network is independent from the physical network, and is therefore, difficult to manage. We show that it is possible to efficiently influence Peer-to-Peer overlay networks in a way which provides benefits for both the operator and the peers. As a result, operators observe significant reduction of the inter-domain traffic, whereas, peers achieve better performance. We present and assess five approaches for economic traffic management. The most promising, i.e., QoS-awareness and Highly Active Peer are described in details and evaluated through simulations. We show that by providing proper incentives to end-users, traffic inside the overlay can be efficiently managed.

1. Introduction

The amount of Internet traffic grows significantly every year. Network operators and Internet Service Providers (ISPs) need to continuously upgrade their infrastructures. They have two options to guarantee a desirable Quality of Service (QoS) for end users: to add extra bandwidth or to implement mechanisms which enable prioritization of selected traffic. Usually, due to the complexity of QoS solutions the first approach is preferred. However, sometimes it is impossible to add further resources and ISPs have to implement traffic management algorithms. Currently 80% of all traffic sent in the Internet is generated by 5% of users [1,2] and although the interest of file sharing decreased over the last years, P2P users still generate a significant amount of traffic in the Internet [3]. It is a real challenge for ISPs and network operators to deal with congestions in inter-domain links [4]. Therefore it is highly desirable to provide traffic management mechanisms in networks where P2P users are very active. Moreover, as history showed, the interest in a particular type of application of connection type for that matter changes rapidly. The emergence of one application can force an interest boom. For that reason, even though the P2P traffic currently shows a decline, the interest may return and even overcome the previous level.

Although the boom has passed, still many researchers work on improving transmissions in P2P networks. In [5], two techniques aiming to optimize the distribution of content from the IETF's Application Layer Traffic Optimization (ALTO) framework are compared. Results show that the proposed approaches can be beneficial for the ISP, while the service quality perceived by users does not change significantly. The approaches presented in this paper provide benefits for both sides: the operator and the user. The authors of [6] propose a new ALTO scheme for P2P networks. In their proposal, nodes in file sharing systems have better sense of the topology of their underlying networks and can interact more efficiently. The evaluation shows that the proposed scheme can decrease inter-AS or inter-ISP traffic, optimize traffic distribution across the whole networks, and improve the quality of experience of P2P users. The solutions presented and analyzed in this paper work differently to achieve the same goal: the operator maintains an entity which guides peers to behave in a way which is mutually beneficial.

The authors of [7] discuss the potential improvement in P2P transmissions. They indicate that the cooperation between overlay and underlay, i.e., between P2P applications and ISPs, is necessary to minimize the cost of transmission and download times for end users. Generally, there are two options: to implement some sort of locality promotion or to introduce caches. In the first case, ISPs tend to maintain as much traffic as possible in their own domain. Such concepts usually focus on cooperation between ISPs and end users, which install a dedicated software. Several locality-aware solutions were proposed in literature on improve transmission of P2P traffic. One of the first proposals was presented in [8]. The authors

* Corresponding author. Tel.: +48 12 617 28 46.
E-mail address: robert.wojcik@kt.agh.edu.pl (R. Wójcik).

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propose to implement the 'oracle service' by the ISPs. This service can be installed on several machines within an ISP. Such machines are queried, e.g., by using the UDP protocol and are able to collect a set of peers based, e.g., on the geographical location. The biased neighbor selection (BNS) proposed in [9] is the solution which assumes that a set of peers is built mostly based on neighbors from the same AS. Implementation of this mechanism for the BitTorrent protocol ensures significant reduction of the inter-ISP traffic without using dedicated servers for peers selection. The complementary mechanism to the BNS, known as biased unchoking was presented in [10]. However, this time a new logic is implemented in the choke algorithm which is responsible for data exchange in Bit-Torrent networks. Such a concept additionally improves the effectiveness of the BNS algorithm.

The Ono plugin proposed for the Vuze BitTorrent client uses locality awareness mechanism based on DNS lookup correlated with a global Content Delivery Network (CDN), like Akamai [11]. The concept of caches assumes that somewhere in the network, special nodes are established to collect the most popular content exchanged by the users. Such solution is quite easy to implement in a network but has certain disadvantages. Firstly, the owner of such a node is responsible for the stored data and has to deal with e.g., the legality issues. Moreover, the analysis of the content may violate the net neutrality rules [12]. The general information on how to implement caches in a reasonable way may be found in [13]. The analysis of caches and their impact on download times of files exchanged via P2P networks is presented in [14]. The authors show that the implementation of cashes is very attractive for users. The benefits may be measured by decreased download times of P2P files and also by other QoE-related factors which are presented in [15].

Certain approximate theoretical models have been defined and investigated numerically in the past [16,17]. They are, however, limited to the simplest evaluation scenarios. The issues related to the introduction of the locality awareness to overlays have been identified and evaluated in [18,19]. In the first paper, two approaches – biased neighbor selection and biased unchoking were analyzed as locality awareness algorithms. The authors proved that the win–win scenario (from an operator and user point of view) or even win–no lose situation is difficult to achieve with the considered mechanisms. In the second paper, the BGP-based Locality Promotion mechanism for P2P networks is presented. It assumes that information exchanged between routers by the BGP protocol may be used for identifying the physical location of a node. Based on this knowledge, the connections between peers in the same autonomous system (AS) are preferred over others. Also in [20] the locality mechanisms are analyzed. The authors present problems related to the locality concept and suggest improvements. They propose two locality promotion mechanisms which offer additional incentives for end users to behave in an operator-friendly way. Those mechanisms are ISP-owned Peer (IoP) and Highly Active Peer (HAP). This paper thoroughly evaluates the latter concept. More problems with P2P traffic management have been identified in [18], especially regarding the peer benefits. The authors present and evaluate refinements of current proposals, allowing all users of P2P networks to be sure that their application performance is not reduced. In the paper [21], the authors propose to monetary reward peers which store and upload particular content in a Video on Demand P2P based service. The main goal is to increase the availability of content and not to optimize traffic, however, it shows that incentivizing users to behave in a way an operator wants is a viable technique.

In this paper, we first briefly present and compare five economic traffic management (ETM) mechanisms proposed by the SmoothIT consortium [22] to manage the data exchanged by P2P applications. Two of them, i.e., the QoS-awareness and the HAP mechanisms, which in our opinion are the most promising, are analyzed by the simulation experiments in the ProtoPeer simulator [23]. The results of the simulations confirm the usefulness of the analyzed proposals. Additionally, we propose and analyze the possible implementations of these two mechanisms. We show that both approaches are able to reduce download times for all peers which use them, while, at the same time, they reduce the amount of inter-domain traffic generated. Thereby, we show that using these two mechanisms is beneficial for both the operator and the users.

The remaining of the paper is organized as follows. Section 2 shows the description of the ETM mechanisms proposed in the SmoothIT project. In Section 2.4, the QoS-awareness mechanism is described in details and the results of simulation analysis of this mechanism are presented in Section 3. The HAP mechanism is analyzed in Section 2.5. The main assumptions and implementation rules of the HAP mechanism are also presented there. In Section 4, the simulation analysis is provided for HAP and the results are shown. Section 5 summarizes the paper.

Table 1
ETM mechanisms at a glance.

SIS-enabled locality-awareness	A user obtains a list of candidate peers traditionally and sends this list to the SIS SIS ranks peers (locality preference) and sends the ranked list back to the user
Inter-SIS	Queried SIS communicates with other SISes (in other ASes) SIS has much more information and can rank peers more efficiently
IoP + locality	ISP introduces its own peer(s) to P2P community IoP has high bandwidth and resources IoP becomes attractive to local peers which naturally promotes locality
QoS + locality	SIS assigns better QoS for certain connections Peers who follow the SIS recommendations obtain higher quality transmissions
HAP + locality	ISP monitors peer behavior Peers who behave according to ISPs requests are promoted to HAPs HAPs get increased connection speed

2. Economic traffic management mechanisms

Five ETM mechanisms have been described and developed by the SmoothIT consortium to enhance traffic management in P2P networks [24]. They are as follows:

- SIS[1]-enabled locality-awareness mechanism,
- Inter-SIS mechanism,
- ISP-owned Peers (IoP ETM mechanism),
- QoS-awareness mechanism (QoS ETM mechanism),
- Highly Active Peers (HAP ETM mechanism).

The main goal of all the mechanisms is to improve the quality of transmission in P2P networks by minimizing download times for peers while reducing the amount of undesirable traffic (usually inter-domain traffic). This provides a win–win scenario for ISPs and users. Users are happy with better transmission opportunities in a P2P network, while operators can reduce their inter-domain traffic for which they must pay. Table 1 shows the main idea of five ETM mechanisms. In the following sections, each mechanism is described in details.

[1] SmoothIT Information Server.