Cost-driven Peer Rating Algorithm

Zbigniew Duliński

Faculty of Physics, Astronomy, and Applied Computer Science, Jagiellonian University, Kraków, Poland
dulinski@th.if.uj.edu.pl

Rafał Stankiewicz, Piotr Wydrych, Mirosław Kantor, and Piotr Chołda
Department of Telecommunications, AGH University of Science and Technology, Kraków, Poland
{rstankie,wydrych,kantor,cholda}@kt.agh.edu.pl

Abstract—The paper presents a concept of a rating algorithm aiming at overall peer-to-peer traffic reduction with locality awareness and decrease of load on costly links, thus diminishing operator's costs. The rating algorithm is not only performed by a sole Oracle, as is typically proposed, but its operation is also supported by a similar entity located in other domains. Due to this concept, a usually omitted fact that the inter-domain routes are asymmetrical is properly dealt with. Simulations performed on a real topology show the usefulness of the presented approach.

Index Terms—Autonomous System (AS), inter-domain traffic, optimization, overlay networking, peer-to-peer (P2P) systems

I. INTRODUCTION

For a previous few years peer-to-peer (P2P)-related flows (overlay traffic) have represented a vast majority of the whole Internet load [1]. Thus, P2P networking has become an important branch of today's communications. It involves not only file-sharing (BitTorrent, Ares Galaxy), but also multimedia P2PTV (PPLive, SopCast) or anonymous routing (Tor) [2].

P2P applications are network-agnostic: they establish connections between overlay peers randomly. Then, majority of P2P traffic is not exchanged within an operator's domain (Autonomous System, AS) [3], but enters/leaves it over inter-domain links. This leads to suboptimalities: 1) peers that do not connect with local peers, although they are available, experience large download times; and 2) expensive inter-domain links are used to carry the traffic exchanged with remote peers. IETF has recognized this important issue by establishing ALTO (Application-Layer Traffic Optimization) working group [4]. Also European Project SmoothIT promotes an idea of the advanced Economic Traffic Management system aimed at optimization of traffic flows generated by P2P applications [5].

Our previous paper [6] emphasizes the necessity of considering the asymmetry of BGP paths between domains. It proposes an optimization mechanism supporting exchange of data on inter-domain routing paths where the direction of the traffic flows (uploading from or downloading to a domain) matters. Now, we exploit this idea but focus also on the cost of transmitting traffic. We show that the awareness of such data enables increase of transfer rates and shifting of unavoidable traffic load from expensive inter-domain links to cheaper ones. We assume that there are three basic options for the payment for inter-domain links: 1) Internet Service Provider (ISP) purchases the transit traffic, 2) ISP sells the transit traffic, 3) ISP peers the traffic.

One of the most prominent solutions for overlay traffic management uses an ISP-owned specialized device that provides a P2P client with information supporting optimized neighbor selection. It is called an *Oracle* [7]. A similar functionality is realized by ALTO server [4] or SmoothIT Information Service (SIS) [8]; but, to be general, we use only term *Oracle*. Peers contacting it are offered rating of potential neighbors. The rating algorithm uses information related to potential neighbors and applies ISP's policy. Our solution extends the set of data used for rating and proposes a new rating algorithm that takes into account link costs.

The next section gives a rationale for our work, while Section III puts our efforts in the literature context. The subsequent section presents the concept and in Section V the results give evidence that it is useful. We conclude with the summary and a sketch on further works.

II. MOTIVATION

A. Route Asymmetry with BGP

Generally, the communication between two IP nodes does not follow the same path in the upstream and downstream directions (we call this fact 'BGP route asymmetry'). The path chosen by the BGP routing protocol depends often on the type of business agreements between interconnected partners. From the economic point of view, it might be justified to select one partner for incoming traffic and another for the outgoing. In [6] we report a study on the inter-domain asymmetry. The paths differ in terms of: 1) the number of inter-AS hops, 2) the list of passed ASes, and 3) the neighbor AS for inbound and outbound traffic. According to the results, only 28.5% of all pairs of paths are fully symmetric. It means that in these cases the traffic between two communicating domains goes through exactly the same ASes and links in both directions. On the other hand, as much as 35.3% of path pairs are completely disjoint and the outbound and inbound traffic traverses different ASes and inter-domain links. Therefore, the optimization algorithms that relay on a local BGP information concerning only outbound traffic will be inaccurate (AS hop numbers are different for two directions for 51%, and ingress/egress routers for inter-domain downstream are not identical for 50.5% of path pairs, respectively).

B. Peer-to-Peer Transfer Modes and Neighbor Selection

As a typical networking application, a P2P system is used to exchange data. What is specific, is the fact that the traffic generated by these applications is much more symmetric than in the client-server approach, and it is possible that the clients both download and upload large volumes of data one from another. Therefore, we can distinguish three situations related to different types of transfers that in a selected moment of time are relevant: 1) download: e.g. a peer connected to a streaming overlay is a leaf (a node only taking and not giving data); 2) upload: e.g. a seeding node in file-sharing; 3) simultaneous download and upload: e.g. a typical node of a file-sharing application with a not-finished file transfer, or a forwarding peer in a live TV P2P network.

Another difference with a classical network application is the fact that peers are not interested in a connection to a selected node in the Internet like a server with a well defined localization, but rather to a content provided by other PCs placed randomly. Although this is the largest advantage related to P2P systems, it is also a root of suboptimalities. Without any additional mechanisms, the peer and ISP cannot influence the application-specific algorithm of neighbor selection. Usually, it ignores the underlay routing. The works aimed at optimized management of P2P traffic concentrate on reduction of inter-domain traffic and decreased cost for ISP by modifying this neighbor selection mechanism. The best effects are obtained when peers cooperate with their ISPs. A necessary condition to adopt these methods in practice is to assure that they at least preserve the user perceived service quality (e.g. download times are not increased when the cooperation is in force).

III. Previous Works

It was shown for the Gnutella network that only 2-5% of existing connections are formed within the same operator suggesting that there is much space for optimization [9]. A classification of methods using the underlay properties to improve the operation of P2P networks is presented in [10]. First, they can be based on knowledge which ISP a peer network is assigned to (our approach can be classified here). Second, the nodes might store additional information on other peers (e.g. when they serve as super-nodes) in order to enable close to optimal connection establishment. Third, some latency assessment might be used; and fourth, a geo-location information may be a base for peer nodes selection. The research has been mainly focused on file-sharing [11], [12], with introduction of methods like biased neighbor selection or biased unchoking [13]. The research related to video streaming has also appeared [14], [15]. There are two ways to improve the ISP-overlay cooperation, that is network caching [16] and proximity awareness. The latter perspective is taken here as more promising, generic, and not involving risk of operator's liability. As the most recognized approaches, the paper by Aggarwal and Feldmann [7] can be mentioned, where the *Oracle* concept is introduced. A similar idea, more grounded in the BitTorrent context, is known as P4P [11].

IV. Peer Rating Algorithm

This section describes the proposed peer rating algorithm that takes into account the ISP cost of inter-domain traffic while being aware of the route asymmetry. The rating procedure is performed by the local *Oracle*. The decision is based on the knowledge of a path to a remote peer. To evaluate the cost on inter-domain traffic, the necessary information concerns the first/last hop of the upstream/downstream path to/from the remote peer. Information on the upstream path is easily available locally from BGP databases. To obtain information on the downstream path, the local *Oracle* communicates with the remote one and requests the routing information. It is not necessary to ask for the full AS_PATH information which might be restricted as confidential. The only information needed is the neighbor AS number, which informs about the inter-domain link passed by the downstream traffic from the remote domain to the local AS. Thus, the remote *Oracle* must share only the information on the last inter-domain hop.

Inter-domain links can be classified as *peering*, *provider* and *customer*. In the case of a *peering* link, the traffic is exchanged between ISP without a monetary cost (provided in- and outbound loads are balanced). If ISP has to pay another ISP for the traffic sent over a link that connects them, this is a link of the *provider* type. The ISP might receive payment from another ISP (its customer) for the traffic transferred through a *customer* link. Depending on a payment agreement an operator is obliged to pay for upload, download or for both. Those types of agreements can be taken into account by the peer rating algorithm. ISP may also differentiate its preference for links of the same type of agreement but of different unit cost.

It must be remembered that an ISP willing to deploy the *Oracle* service should encourage customers to use it. The incentive for users might be improved Quality of Experience (QoE). Definitely the perceived quality must be at least preserved. For instance, it was shown that promotion of local peers improves QoE for them in most cases (unless the population of local peers is small) [13]. If ISP has its own individual customers using P2P applications and simultaneously sells the access to the Internet to other ISPs, the question arises whether to promote local or remote peers located in the AS that the ISP has a *customer* link to. In such a case optimization criteria are contradictory: to preserve/improve QoE for own customers or to benefit from transferring traffic to other domains? Thus, the final rating of peers depends on an assumed ISP's policy.

In the proposed algorithm, a local operator assigns preference numbers to particular neighboring ASes. It is done according to the type of a given inter-domain link and related costs of traffic transfer. Since the cost of upstream and downstream traffic might be different, separate preference numbers are assigned for each direction.

A possible peer rating algorithm is illustrated with the following example. If an *Oracle* receives the list of potential neighbors from a peer, it assigns preference values to all peers on the list. The lower preference value, the higher rating. Peers located in the local AS always receive preference values 0. To

determine the rating for remote peers, the preference number assigned to neighbor ASes on upstream and downstream paths must be known. They might be different not only due to route asymmetry but also due to different costs of transferring upstream and downstream traffic on a single link. Various policies of calculating preference values for peers might be considered. Let us assume that a local peer requests the *Oracle* to rank 4 peers as presented in Table I. For peers `10.0.0.1`, `20.0.0.2` and `30.0.0.3` both upstream and downstream paths are symmetrical. The neighbor ASes are 1000, 2000 and 3000, respectively. Upstream and downstream routing paths to peer `40.0.0.4` are distinct. They pass AS4000 and AS3000, respectively. Preference values assigned to neighbor ASes are also presented in the table. It is assumed they reflect the cost of the traffic transfer, separately for each direction. If an operator pays only for the downstream traffic on a particular link, the preference value for upstream on this link equals 0. The way of calculating AS preference values for peers depends on ISP's policy and the relation between download and upload for a P2P network (see Section II-B). The following three approaches are proposed: 'conservative,' 'liberal,' and 'higher cost.' The sum of the downstream and upstream preference is considered as the 'conservative' approach. Since peer access links in the today's Internet are mostly asymmetrical, the 'liberal' approach is proposed: it is a weighted sum of the upstream and downstream preferences. ISP may select weights by taking into account features of a particular P2P application, speed of user access links and a traffic management policy. In the 'higher cost' approach, a peer receives the AS preference value equal to the maximum of upstream and downstream preferences.

V. Experimental Results

The experiments were performed in the Eruption.S simulator [17], an underlay-aware packet-based P2P network simulator. We used BitTorrent, one of the most popular file-sharing P2P protocols nowadays. Since BitTorrent users both download and upload files, the conservative peer rating algorithm was selected, implemented and simulated.

The proposed simulation model reflects the real situation in the Internet. The simulation topology was created by extracting a subset of real ASes existing in the Internet. AS numbers were anonymized. The set of links and routing paths between them is also realistic. Asymmetrical routing paths appear in the simulated network. The route asymmetry statistics are slightly different from those described in [6] since due to simulation constraints we use only a subset of 29 ASes while about 3500 routing path pairs were scrutinized in [6]. Three types of ASes can be distinguished in the simulated topology: 1) ASes that do not have any individual customers, thus no peers are located therein (transit ASes, usually Tier 1 or Tier 2 ISPs); 2) ASes that serve individual customers potentially interested in P2P traffic optimization by using *Oracles* and inter-*Oracle* protocol (stub ASes, usually Tier 3 ISPs); and 3) ASes that play both above roles.

The simulated topology is presented in Figure 1. As explained above, an AS may identify its links to neighbor ASes as *peering*, *provider* or *customer* (in figures we use acronyms for those link types: PE, PR and CU, respectively). The *peering* link is represented by a dotted line. The inter-domain link that is seen by a given AS as the *provider* type is at the same time identified as the *customer* type from a perspective of the neighbor AS it connects to. Such a link is represented in Figure 1 by a solid chock line. The AS connected at the thin end of the line sees the link as a *provider* type (i.e., this AS is a customer that is connected to another AS serving as a provider), while the thick end represents *customer* type of the link. All ASes are connected with symmetric 1 Mb/s links.

There are 20 transit ASes and 9 ASes where peers are located. One of them, labeled as AS5, plays also a role of transit AS, that is, it serves its own residential customers and provides Internet access for AS6. AS5 possesses all types of inter-domain links. Stub ASes have *peering* and/or *provider* types of inter-domain connections.

The total number of peers equals 270. Every peer is switched on during $2/3$ of the simulation time and switched off during $1/3$, on average. Peers have asymmetrical 1024/256 kb/s access links and they are unevenly distributed among ASes. The distribution of the number of peers in ASes is depicted in Figure 1 and follows the rule that the bigger AS in the Internet, the more peers it contains in the simulations. Moreover, five initial seeds are inserted into AS1. All users download one 20 MB file.

For simplicity, we abstract from the types of accounting and the real monetary costs. We assume that a traffic volume results in reduction of related costs and, therefore, we treat a traffic volume as a metric for evaluation of the proposed algorithm. In the experiments, local peers (located in the same domain with an *Oracle*) always receive AS preference value 0. Among the remote peers, the most preferred are those the traffic is exchanged with over *customer* inter-domain links. Such peers receive AS preference value 1. Peers reachable over a *peering* link receive AS preference value 2. Finally, peers to which the traffic is sent through a *provider* link receive AS preference value 3, since they are least preferred. Peers receive two separate rating values: for upstream and downstream links. The final peer rating is calculated by using the proposed conservative approach, that is, ratings for the two directions are summarized.

There are three basic simulation scenarios: A) No *Oracle*, B) 1 *Oracle*, C) 9 *Oracles*. In scenario A, no ISP implements *Oracle* service, so pure BitTorrent protocol is used. The case when *Oracle* is deployed in only one stub AS, namely AS5, is considered in scenario B. It is assumed that the rating of remote peers is based on local IGP and BGP data and information on downstream paths is obtained from Looking Glass Servers [6]. Finally, in scenario C, all ASes implement *Oracles* and inter-*Oracle* communication protocol. Each *Oracle* is able to unambiguously determine via which neighbor AS the traffic exchanged between local and remote peers goes through in both upstream and downstream directions. Therefore, a cost-driven peer rating is performed in all ASes.

Figure 2 shows the impact of the *Oracle* deployment from

Peer address	Upstream direction		Downstream direction		Peer preference		
	Neighbor AS	AS pref.	Neighbor AS	AS pref.	Conservative approach	Liberal approach[a]	Higher cost approach
10.0.0.1	1000	0	1000	20	20	20	20
20.0.0.1	2000	8	2000	8	16	10	8
30.0.0.3	3000	4	3000	5	9	6	5
40.0.0.4	4000	16	3000	5	21	9	16

[a]Sample weights used for the liberal approach under assumption of the user access link asymmetry, such that the upload/download bandwidth ratio equals $1/4$, are: $1/4$ for upstream and 1 for downstream direction, respectively.
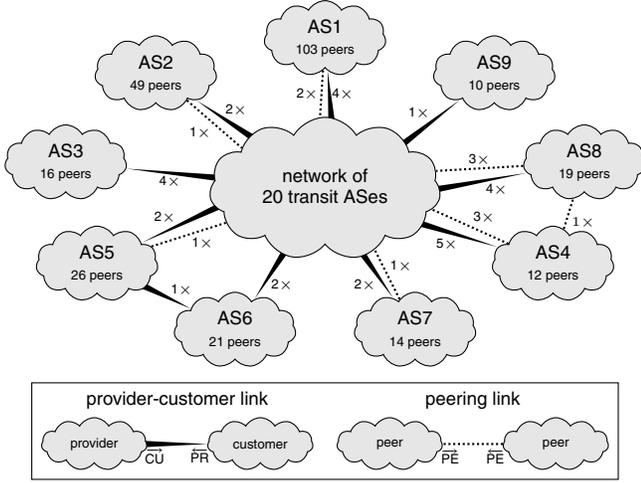
Fig. 1. Topology used in the simulations. $A\times$ means that there are A links of an indicated category between given ASes.

Fig. 2. Average traffic on links to and from AS5.

Fig. 3. File download time in AS5.

Fig. 4. Average traffic on links to and from AS4.

the point of view of AS5. If only AS5 implements *Oracle* (scenario B) the traffic is slightly increased on a *customer* link. It reflects the fact that *Oracle* gives a high rating to peers to which the path passes that link. In the ranking algorithm, the most preferred peers are the local ones. The traffic between local peers does not utilize inter-domain links, thus, the total inter-domain traffic volume is reduced. The traffic on the *peering* and *provider* links gets decreased. Thus, the ISP not only pays less for the inter-AS traffic passing *provider* links but also earns more on the traffic on a *customer* link. Such scenario is also beneficial for peers located in AS5. They experience significantly lower download times (Figure 3). If all ASes use *Oracles* the traffic is decreased on all AS5 links to other ASes. Download times are even shorter.
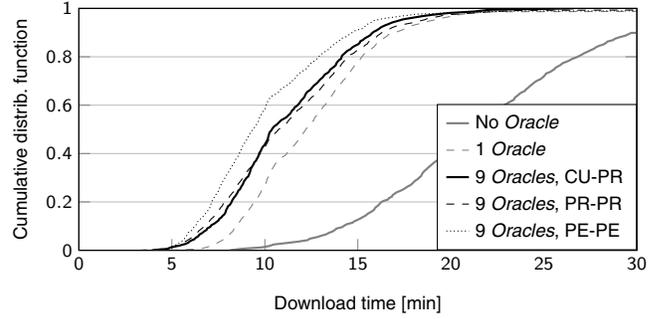
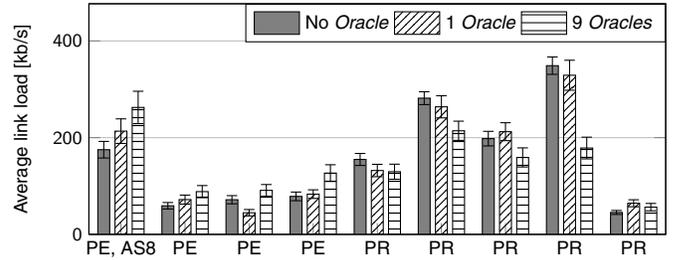The situation looks differently from other ASes point of view. If *Oracle* is introduced in AS5 only, the other ASes generally do not benefit: the overall inter-domain traffic remains, on average, at the same level or, on some links, it is even increased (Figures 4 and 5 show results for AS4 and AS1, respectively). This is especially undesirable if the traffic is increased on the *provider* type of a link. The impact on download times for peers located in ASes non possessing *Oracle* is very little. Empirical cumulative distribution functions for all peers in the swarm except those located in AS5 are shown in Figure 6. Download times are slightly decreased. However, it may happen that for some ASes they become higher (Figure 7). This may be explained by the fact, that peers located in AS5 become more selfish due to locality promotion and more traffic is exchanged between them rather than with peers located in other ASes.

If at least one AS starts using an *Oracle*, it is beneficial to other ASes to implement it as well. The overall inter-domain traffic observed by ASes is then decreased. Traffic on links of the *provider* type is lowered in most cases. A little increase,
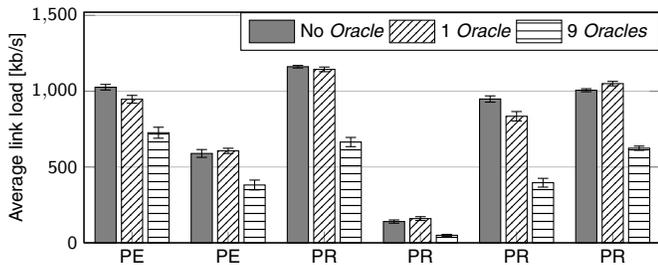
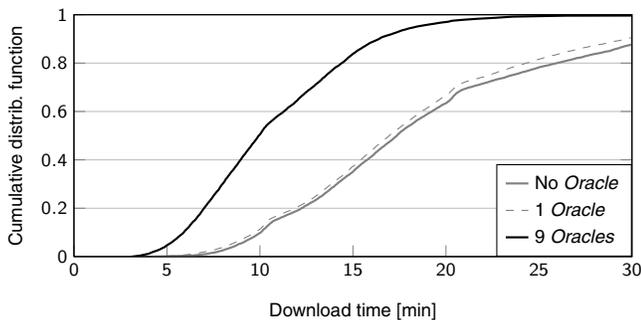Fig. 5. Average traffic on links to and from AS1.

Fig. 6. File download time in all ASes except AS5.

in comparison to scenario A (no *Oracle*), is observed on a single *provider* link of AS4. On other *provider* links of AS4 a significant reduction of inter-AS traffic is observed (Figure 4). Since *peering* links are preferred over the *provider* ones, it may happen that the traffic on the peering links will be increased (Figure 4) but this is not a rule. In the case of AS1, inter-domain traffic for scenario C is reduced on all links (Figure 5). A deep analysis of routing and rating mechanisms allows for explanation of the traffic volume changes on various links. For instance, AS4 and AS8 are directly connected through a bidirectional *peering* link. They unanimously tend to shift the traffic their peers inevitably have to exchange with remote peers to this link. As a result, the traffic on this link gets increased in comparison to scenarios A and B (Figure 4). It also happens that two ASes reach each other through the *provider* type of a link. This is the case of AS1: both its downstream and upstream paths to AS5, AS6 and AS9 go
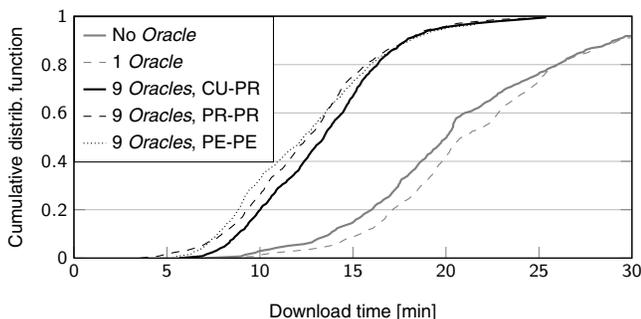

Fig. 7. File download time in AS6.

through *provider* links. Also both paths to AS1 as seen from those three ASes are over *provider* links. Thus, peers located in AS1 are discouraged to communicate with peers located in AS5, AS6 and AS9, and vice versa. This situation shows that consistent policies of two *Oracles* contribute to decrease the traffic on all AS1 *provider* links (Figure 5). It is also possible that the policies will be inconsistent. Such situation happens for some AS pairs, e.g. for AS1–AS3 and AS1–AS4. AS1 recognizes both upstream and downstream paths to AS4 and AS3 as passing *peering* links, therefore it highly rates peers located there. On the contrary, AS3 and AS4 see peers located in AS1 as reachable through *provider* links, in the downstream as well as upstream directions. As a result, peers in AS3 and AS4 are discouraged from initiating communication with peers located in AS1 (those peers receive a bad rating). Finally, we do not observe increase of the traffic as for a *peering* link between AS4 and AS8 (Figure 4), but a decrease of traffic on both *peering* links of AS1 (Figure 5). Scenarios of contradictory policies are further discussed below.

When *Oracles* are deployed in all ASes, all peers in the swarm benefit. The download times are significantly decreased (Figures 3, 6, and 7). In this case, peers benefit mostly from locality awareness. The download from local peers is usually faster. It should be noted, however, that the download time reduction might be very little if all inter-AS links were of a very high capacity and negligible delay. In such a case, the choice of peers (local or remote) has almost no impact on download times.

We also study the situation when the policies of operators are contradictory. Interesting observations were made for the link between two stub ASes: AS5 and AS6. Originally, AS5 serves as a provider for AS6, thus, from the point of view of AS5 the link is of the *customer* type, while AS6 sees it as a *provider* link. If both ASes implement *Oracles*, their policies are contradictory. AS5 promotes peers located in AS6 to other remote peers. Therefore peers located in AS5 willingly initiate communication with those located in AS6. On the other hand, the operator of AS6 wants to decrease the traffic on this link to pay less, so it discourages its peers from initiating communication with peers in AS5. This is the situation examined in scenario C. For clarity, in Figures 3, 7 and 8 this scenario is labeled as CU-PR. To avoid the situation of contradictory intentions, ISPs may agree on a consistent routing (and optimization) policy. To evaluate the results of various possible policies two additonal scenarios were simulated: D) 9 *Oracles* PR-PR, E) 9 *Oracles* PE-PE. In scenario D, AS5 agrees to decrease the traffic on the *customer* link and assigns the same priority as for *provider* links. AS6 still has to pay for the traffic sent over this link but AS5 agrees on lower income but removes contradicting policies and supports the overlay traffic optimization. Scenario E is introduced to show what would happen if the link type was changed to *peering*, i.e., the traffic would be exchanged between AS5 and AS6 with no cost.

Introducing an *Oracle* into AS5 only causes the traffic to increase (what was discussed earlier in this section). When
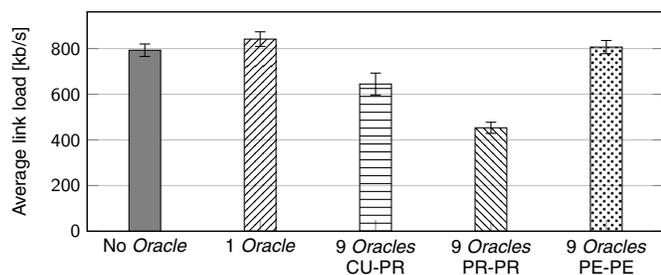
Fig. 8. Average traffic on the link between AS5 and AS6.

both AS5 and AS6 deploy *Oracles*, the volume of the traffic flowing between them decreases. However, the reduction of the traffic is not so high as it can be when both operators focus on the reduction of the traffic, what is presented in Figure 8. When both AS5 and AS6 promote the link between them, the volume of traffic is significantly higher than it is in the situation when both of them reduce the traffic.

Figure 3 shows that from the viewpoint of the P2P network users in AS5, there is no significant difference between QoE they receive when AS5 promotes the link to AS6 (scenario CU-PR) or depreciates it (scenario PR-PR). However, the behavior of AS5 influences the download times in AS6. This situation is presented in Figure 7. When both AS5 and AS6 reduce the P2P traffic on the link between them, the consistent optimization policy increases QoE observed in AS6. For both of the considered ASes, lower download times are observed in the scenario when the traffic is exchanged on the peering basis. Therefore, it can be desirable for both AS5 and AS6 to agree on such a P2P optimization policy that is consistent and favorable to their end-users.

VI. Conclusions

The paper presents an *Oracle*-like rating algorithm that supports a sole locality awareness for peer-to-peer networks with the mechanisms of the overall inter-domain traffic reduction. Thanks to locality awareness, the overall inter-AS traffic is reduced. The decrease on costly links, or at least a shift of the unavoidable traffic to less expensive ones is possible due to the usage of two types of information: the one coming from local BGP databases (to determine upstream paths) and, what is more innovative, from the remote BGP data (to determine downstream path) obtained from *Oracles* located in other Autonomous Systems via some sort of an inter-*Oracle* protocol. The latter functionality makes it possible to deal with the typical inter-domain route asymmetry, enabling to properly differentiate costs of upstream and downstream traffic, since remote peers receive rating values separately for both directions. Additionally, three methods for calculating peer rating are proposed. They support different prevailing characters of various peer-to-peer applications (e.g. much more download than upload). To prove the capabilities of the approach, results of simulations performed on a real topology (subset of the existing ASes in the Internet) are presented.

We can see a few avenues for the further work. First, the inter-Oracle protocol should be defined in details. Here, we only present the most general assumptions about it. Secondly, the rating algorithms can be studied more thoroughly. Among the possible extensions the following issues can be enumerated: overlay traffic engineering, that is a dynamic traffic engineering aiming either at dealing with the temporary congestions in inter-domain links or avoiding potential excess of assumed limits of traffic costs. The proposed peer ranking algorithm may be implemented on ALTO or SIS servers and extend their functionality. To make such a ranking practical a communication between remote servers must be enabled. For this purpose we have proposed an inter-ALTO communication protocol [18].

References

[1] H. Schulze and K. Mochalski, "Internet Study 2008/2009," ipoque GmbH Whitepaper, 2009.

[2] D. Clark *et al.*, "Overlay Networks and the Future of the Internet," *Comm. Strategies*, vol. 63, no. 3, pp. 1–21, 2006.

[3] H. J. Kolbe *et al.*, "Monitoring the Impact of P2P Users on a Broadband Operator's Network," in *Proc. IM 2009*, Long Island, NY, Jun. 1-5, 2009.

[4] J. Seedorf and E. W. Burger, "Application-Layer Traffic Optimization (ALTO) Problem Statement," IETF RFC 5693, Oct. 2009.

[5] S. Oechsner *et al.*, "A Framework of Economic Traffic Management Employing Self-organization Overlay Mechanisms," in *Proc. IWSOS 2008*, Vienna, Austria, Dec. 10-12, 2008.

[6] Z. Duliński *et al.*, "Optimal Choice of Peers based on BGP Information," in *Proc. ICC 2010*, Cape Town, South Africa, May 23-27, 2010.

[7] V. Aggarwal and A. Feldmann, "Locality-Aware P2P Query Search with ISP Collaboration," *Netw. Heterog. Media*, vol. 3, no. 2, pp. 251–265, Jun. 2008.

[8] T. Hoßfeld *et al.*, "An Economic Traffic Management Approach to Enable the TripleWin for Users, ISPs, and Overlay Providers," in *Towards the Future Internet—A European Research Perspective*, G. Tselentis *et al.*, Eds. IOS Press Books Online, 2009, pp. 24–34.

[9] M. Ripeanu *et al.*, "Mapping the Gnutella Network," *IEEE Internet Comput.*, pp. 50–57, Jan./Feb. 2002.

[10] O. Abboud *et al.*, "Underlay Awareness in P2P Systems: Techniques and Challenges," in *Proc. IPDPS 2009*, Rome, Italy, May 23-29, 2009.

[11] H. Xie *et al.*, "P4P: Provider Portal for Applications," in *Proc. SIGCOMM 2008*, Seattle, WA, Aug. 17-22, 2008.

[12] I. Rimac *et al.*, "A Survey on Research on the Application-Layer Traffic Optimization (ALTO) Problem," RFC 6029, Oct. 2010.

[13] S. Oechsner *et al.*, "Pushing the Performance of Biased Neighbor Selection through Biased Unchoking," in *Proc. P2P 2009*, Seattle, WA, Sep. 9-11, 2009.

[14] A. Kovačević *et al.*, "Location Awareness—Improving Distributed Multimedia Communication," *Proc. IEEE*, vol. 96, no. 1, pp. 131–142, Jan. 2008.

[15] F. Picconi and L. Massoulié, "ISP-Friend or Foe? Making P2P Live Streaming ISP-aware," in *Proc. ICDCS'09*, Montreal, Canada, Jun. 22-26, 2009.

[16] N. Leibowitz *et al.*, "Are File Swapping Networks Cacheable? Characterizing P2P Traffic," in *Proc. WCW-7*, Boulder, CO, Aug. 14-16, 2002.

[17] W. Krzysztofek *et al.*, "Eruption.S." [Online]. Available: http://www.kt.agh.edu.pl/~wydrych/research/eruption-s/

[18] Z. Duliński *et al.*, "Inter-ALTO Communication Protocol," Internet-Draft, Jul. 2010.