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Improving Peer Selection in Peer-to-Peer Applications: Myths vs. Reality

Abstract

Peer-to-peer (P2P) traffic optimization techniques that aim at improving locality in the peer selection process have attracted great interest in the research community and have been the subject of much discussion. Some of this discussion has produced controversial myths, some rooted in reality while others remain unfounded. This document evaluates the most prominent myths attributed to P2P optimization techniques by referencing the most relevant study or studies that have addressed facts pertaining to the myth. Using these studies, the authors hope to either confirm or refute each specific myth.

This document is a product of the IRTF P2PRG (Peer-to-Peer Research Group).

Status of This Memo

This document is not an Internet Standards Track specification; it is published for informational purposes.

This document is a product of the Internet Research Task Force (IRTF). The IRTF publishes the results of Internet-related research and development activities. These results might not be suitable for deployment. This RFC represents the consensus of the Peer-to-peer Research Group Research Group of the Internet Research Task Force (IRTF). Documents approved for publication by the IRSG are not a candidate for any level of Internet Standard; see Section 2 of RFC 5741.

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1. Introduction

Peer-to-peer (P2P) applications used for file-sharing, streaming, and real-time communications exchange large amounts of data in connections established among the peers themselves and are responsible for an important part of the Internet traffic. Since applications have generally no knowledge of the underlying network topology, the traffic they generate is frequent cause of congestions in inter-domain links and significantly contributes to the raising of transit costs paid by network operators and Internet Service Providers (ISPs).

One approach to reduce congestions and transit costs caused by P2P applications consists of enhancing the peer selection process with the introduction of proximity information. This allows the peers to identify the topologically closer resource among all the instances of the resources they are searching through. Several solutions following such an approach have recently been proposed [Choffnes] [Aggarwal] [Xie], some of which are now being considered for standardization in the IETF [ALTO]. While this document serves to inform the protocol work going on in the IETF ALTO working group, this document does not specify a protocol of any kind, nor is this document a product of the IETF.

Despite extensive research based on simulations and field trials, it is hard to predict how proposed solutions would perform in a real-world systems made of millions of peers. For this reason, possible effects and side effects of optimization techniques based on P2P traffic localization have been a matter of frequent debate. This document describes some of the most interesting effects, referencing relevant studies that have addressed them and trying to determine whether and in what measure they are likely to happen.

Each possible effect -- or myth -- is examined in three phases:

- o Facts: in which a list of relevant data is presented, usually collected from simulations or field trials;

- o Discussion: in which the reasons supporting and opposing the myth are discussed based on the facts previously listed;

- o Conclusions: in which the authors try to express a reasonable measure of the plausibility of the myth.

  Note: Even though a myth is an unfounded or false notion, we have nonetheless chosen to provocatively assign a confirmation likelihood to each of the myths in Section 3. This is a whimsical, but we believe effective, attempt that was inspired by the TV show "Mythbusters", wherein each myth was "busted", deemed "plausible", or "confirmed" by the end of the show.

This document represents the consensus of the P2PRG. The first version of this document appeared in February 2009, and there was a sizeable discussion on the contents of the document thereafter. The document has been improved by incorporating comments from experts in the area of peer-to-peer networks as well as casual, but informed, users of such networks. The IRTF community has helped improve the number of facts and quality of discussion and enhanced the trustworthiness of the conclusions documented.

This document essentially represents the view of the participating P2PRG IRTF community between 2009 and the latter part of 2010; as such, it is like a snapshot: frozen in time. While some aspects are confirmed with references to pertinent literature, other aspects reflect the state of discussions in the RG at the time of writing and may require further investigation beyond the publication date of this document.

2. Definitions

Terminology defined in [RFC5693] is reused here; other definitions should be consistent with the terminology in that document.

Seeder:

A peer that has a complete copy of the content it is sharing, and still offers it for upload. The term "seeder" is adopted from BitTorrent terminology and is used in this document to indicate upload-only peers that are also in other kinds of P2P applications.

Leecher:

A peer that has not yet completed the download of a specific content (but usually has already started offering for upload the part it is in possession of). The term "leecher" is adopted from BitTorrent terminology and is used in this document to indicate peers that are both uploading and downloading and are used in other kinds of P2P applications.

Swarm:

The group of peers that are uploading and/or downloading pieces of the same content. The term "swarm" is commonly used in BitTorrent, to indicate all seeders and leechers exchanging chunks of a particular file; however, in this document, it is used more generally (e.g., in the case of P2P streaming applications) to refer to all peers receiving and/or transmitting the same media stream.

Tit-for-Tat:

A content exchange strategy where the amount of data sent by a leecher to another leecher is roughly equal to the amount of data received from it. P2P applications, most notably BitTorrent, adopt such an approach to maximize resources shared by the users.

Surplus Mode:

The status of a swarm where the upload capacity exceeds the download demand. A swarm in surplus mode is often referred to as "well seeded".

Transit:

The service through which a network can exchange IP packets with all other networks to which it is not directly connected. The transit service is always regulated by a contract, according to which the customer (i.e., a network operator or an ISP) pays the transit provider per amount of data exchanged.

Peering:

The direct interconnection between two separate networks for the purpose of exchanging traffic without requiring a transit provider. Peering is usually regulated by agreements taking in account the amount of traffic generated by each party in each direction.

3. Myths, Facts, and Discussion

3.1. Reduced Cross-Domain Traffic

The reduction in cross-domain traffic (and thus in transit costs due to it) is one of the positive effects P2P traffic localization techniques are expected to cause, and also the main reason why ISPs look at them with interest. Simulations and field tests have shown a reduction varying from 20% to 80%.

3.1.1. Facts

1. Various simulations and initial field trials of the P4P solution [Xie] on average show a 70% reduction of cross-domain traffic.

2. Data observed in Comcast's P4P trial [RFC5632] show a 34% reduction of the outgoing P2P traffic and an 80% reduction of the incoming.

3. Simulations of the "oracle-based" approach [Aggarwal] proposed by researchers at Technischen Universitat Berlin (TU Berlin) show an increase in local exchanges from 10% in the unbiased case to 60%-80% in the localized case.

4. Experiments with real BitTorrent clients and real distributions of peers per Autonomous System (AS) run by researchers at INRIA [LeBlond] have shown that ASes with 100 peers or more can save 99.5% of cross-domain traffic with high values of locality. They have also shown that on a global scale, i.e., 214,443 torrents, 6,1113,224 unique peers, and 9,605 ASes, high locality can save 40% of global inter-AS traffic, i.e., 4.56 Petabytes (PB) on 11.6 PB. This result shows that locality would be beneficial at the scale of the Internet.

3.1.2. Discussion

Tautologically, P2P traffic localization techniques tend to localize content exchanges, and thus reduce cross-domain traffic.

3.1.3. Conclusions

Confirmed.

3.2. Increased Application Performance

Ostensibly, the increase in application performance is the main reason for the consideration of P2P traffic localization techniques in academia and industry. The expected increase depends on the specific application: file-sharing applications witness an increase in the download rate, real-time communication applications observe lower delay and jitter, and streaming applications can benefit by a high constant bitrate.

3.2.1. Facts

1. Various simulations and initial field trials of the P4P solution [Xie] show an average reduction of download completion times between 10% and 23%.

2. Data observed in Comcast’s P4P trial [RFC5632] show an increase in download rates between 13% and 85%. Interestingly, the data collected in the experiment also indicate that fine-grained localization is less effective in improving download performance compared to lower levels of localization.

3. Data collected in the Ono experiment [Choffnes] show a 31% average download rate improvement.

   * In networks where the ISP provides higher bandwidth for in-network traffic (e.g., as in the case of a Romanian ISP (RDSNET), described in [Choffnes]), the increase is significantly higher.

   * In networks with relatively low uplink bandwidth (as the case of Easynet, described in [Choffnes]), traffic localization slightly degrades application performance.

4. Simulations of the "oracle-based" approach [Aggarwal] proposed by researchers at TU Berlin show a reduction in download times between 16% and 34%.

5. Simulations by Bell Labs [Seetharaman] indicate that localization is not as effective in all scenarios and that the user experience can suffer in certain locality-aware swarms based on the actual implementation of locality.

6. Experiments with real clients run by researchers at INRIA [LeBlond] have shown that the measured application performance is a function of the degree of congestion on links on which the locality policy tries to reduce the traffic. Furthermore, they have also shown that, in the case of severe bottlenecks, BitTorrent with locality can be more than 200% faster than regular BitTorrent.

3.2.2. Discussion

It seems that traffic localization techniques often cause an improvement in application performance. However, it must be noted that such beneficial effects heavily depend on the network infrastructures. In some cases, for example, in networks with relatively low uplink bandwidth, localization seems to be useless if not harmful. Also, beneficial effects depend on the swarm size; imposing locality when only a small set of local peers is available may even decrease download performance for local peers.

3.2.3. Conclusions

Very likely, especially for large swarms and in networks with high capacity.

3.3. Increased Uplink Bandwidth Usage

The increase in uplink bandwidth usage would be a negative effect, especially in environments where the access network is based on technologies providing asymmetric upstream/downstream bandwidth (e.g., DSL or Data Over cable Service Interface Specification (DOCSIS)).

3.3.1. Facts

1. Data observed in Comcast's P4P trial [RFC5632] show no increase in the uplink traffic.

3.3.2. Discussion

Mathematically, average uplink traffic remains the same as long as the swarm is not in surplus mode. However, in some particular cases where surplus capacity is available, localization may lead to local low-bandwidth leechers connecting to each other instead of trying the external seeders. Even if such a phenomenon has not been observed in simulations and field trials, it could occur to applications that use localization as the only means for optimization when some content becomes popular in different areas at different times (as is the case of prime-time TV shows distributed on BitTorrent networks minutes after getting aired in North America).

3.3.3. Conclusions

Unlikely.

3.4. Impacts on Peering Agreements

Peering agreements are usually established on a reciprocity basis, assuming that the amount of data sent and received by each party is roughly the same (or, in case of asymmetric traffic volumes, a compensation fee is paid by the party that would otherwise obtain the most gain). P2P traffic localization techniques aim at reducing cross-domain traffic and thus might also impact peering agreements.

3.4.1. Facts

No significant publications, simulations, or trials have tried to understand how traffic localization techniques can influence factors that rule how peering agreements are established and maintained.

3.4.2. Discussion

This is a key topic for network operators and ISPs, and it certainly deserves to be analyzed more accurately. Some random thoughts follow.

It seems reasonable to expect different effects depending on the kinds of agreements. For example:

- ISPs with different customer bases: the ISP whose customers generate more P2P traffic can achieve a greater reduction of cross-domain traffic and thus could probably be in a position to renegotiate the contract ruling the peering agreement;

- ISPs with similar customer bases:

  * ISPs with different access technologies: customers of the ISP that provides higher bandwidth -- and, in particular, higher uplink bandwidth -- will have more incentives for keeping their P2P traffic local. Consequently, the ISP with a better infrastructure will be able to achieve a greater reduction in cross-domain traffic and will be probably in a position to re-negotiate the peering agreement;

  * ISPs with similar access technologies: both ISPs would achieve roughly the same reduction in cross-domain traffic; thus, the conditions under which the peering agreement had been established would not change much.

As a consequence of the reasoning above, it seems sensible to expect that the simple fact that one ISP starts localizing its P2P traffic will be a strong incentive for the ISPs it peers with to do that as well.

It’s worth noting that traffic manipulation techniques have been reportedly used by ISPs to obtain peering agreements [Norton] with larger ISPs. One of the most used techniques involves injecting forged traffic into the target ISP’s network, in order to increase its transit costs. Such a technique aims at increasing the relevance of the source ISP in the target’s transit bill and thus motivate the latter to sign a peering agreement. However, traffic injection is exclusively unidirectional and easy to detect. On the other hand, if a localization-like service were used to direct P2P requests toward the target network, the resulting traffic would appear fully legitimate and, since in popular applications that follow the tit-for-tat approach peers tend to upload to the peers they download from, in many cases also bidirectional.

3.4.3. Conclusions

Likely.

3.5. Impacts on Transit

One of the main goals of P2P traffic localization techniques is to allow ISPs to keep local a part of the traffic generated by their customers and thus save on transit costs. However, similar techniques based on de-localization rather than localization may be used by those ISPs that are also transit providers to artificially increase the amount of data exchanged with networks to which they provide transit (i.e., pushing the peers run by their customers to establish connections with peers in the networks that pay them for transit).

3.5.1. Facts

No significant publications, simulations or trials have tried to study effects of traffic localization techniques on the dynamics of transit provision economics.

3.5.2. Discussion

It is actually very hard to predict how the economics of transit provision would be affected by the tricks some transit providers could play on their customers making use of P2P traffic localization -- or, in this particular case, de-localization -- techniques. This is also a key topic for ISPs, definitely worth an accurate investigation.

Probably, the only lesson transit and peering agreement have taught us so far [CogentVsAOL] [SprintVsCogent] is that, at the end of the day, no economic factor, no matter how relevant it is, is able to isolate different networks from each other.

3.5.3. Conclusions

Likely.

3.6. Swarm Weakening

Peer selection techniques based on locality information are certainly beneficial in areas where the density of peers is high enough, but may cause damages otherwise. Some studies have tried to understand to what extent locality can be pushed without damaging peers in isolated parts of the network.

3.6.1. Facts

1. Experiments with real BitTorrent clients run by researchers at INRIA [LeBlond] have shown that, in BitTorrent, even when peer selection is heavily based on locality, swarms do not get damaged.

2. Simulations by Bell Labs [Seetharaman] indicate that the user experience can suffer in certain locality-aware swarms based on the actual implementation of locality.

3.6.2. Discussion

It seems reasonable to expect that excessive traffic localization will cause some degree of deterioration in P2P swarms based on the tit-for-tat approach, and the damages of such deterioration will likely affect most users in networks with lower density of peers. However, while [LeBlond] shows that BitTorrent is extremely robust, the level of tolerance to locality for different P2P algorithms should be evaluated on a case-by-case basis.

3.6.3. Conclusions

Plausible, in some circumstances.

3.7. Improved P2P Caching

P2P caching has been proposed as a possible solution to reduce cross-domain as well as uplink P2P traffic. Since the cache servers ultimately act as seeders, a cache-aware localization service would allow a seamless integration of a caching infrastructure with P2P applications [EDGE-CACHES].

3.7.1. Facts

1. A traffic analysis performed in a major Israeli ISP [Leibowitz] has shown that P2P traffic has a theoretical caching potential of 67% byte-hit-rate.

3.7.2. Discussion

P2P caching may be beneficial for both ISPs and network users, and locality-based optimizations may help the ISP to direct the peers towards caches. Anyway, it is hard to figure at this point in time if the positive effects of localization will make caching superfluous or not economically justifiable for the ISP.

3.7.3. Conclusions

Plausible, if cost-effective for the ISP.

4. Security Considerations

This document is a compendium of observed issues in peer-to-peer networks with an informed look at whether the issue is known to actually exist in the network or whether the issue is, well, a non-issue. As such, this document does not introduce any new security considerations in peer-to-peer networks.

5. Acknowledgments

This documents tries to summarize discussions that happened in live meetings and on several mailing lists: all those who are reading this have probably contributed more ideas and more material than the authors themselves.

6. Informative References

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Appendix A. Myths/References/Facts Matrix

	[Xie]	[RFC5632]	[Aggarwal]	[LeBlond]
Cross-Domain Traffic (Section 3.1)	X	X	X	X
Application Performance (Section 3.2)	X	X	X	X
Uplink Bandwidth (Section 3.3)		X		
Impacts on Peering (Section 3.4)				
Impacts on Transit (Section 3.5)				
Swarm Weakening (Section 3.6)				X
Improved P2P Caching (Section 3.7)				

	[Choffnes]	[Seetharaman]	[Leibowitz]
Cross-Domain Traffic (Section 3.1)			
Application Performance (Section 3.2)	X	X	X
Uplink Bandwidth (Section 3.3)			
Impacts on Peering (Section 3.4)			
Impacts on Transit (Section 3.5)			
Swarm Weakening (Section 3.6)		X	
Improved P2P Caching (Section 3.7)			X

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