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

   Peer-to-peer traffic optimization techniques that aim at improving
   locality in the peer selection process have attracted great interest
   in the research community and have been 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, we 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 Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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1. Introduction

Peer-to-peer (P2P) applications used for file-sharing, streaming and realtime 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 (ISP).

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 looking for. 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 which 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 for and against the myth are
   discussed based on the facts previously listed;
o Conclusions: in which the authors try to epress a reasonable
   measure of the plausibility of the myth.

This document represents the consensus of the P2PRG. The first version of this draft appeared in February 2009 and there was a sizeable discussion on the contents of the document thereafter. The draft 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, 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 a frozen snapshot 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 it.

2.1. 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 also in other kinds of P2P applications.

2.2. 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, also in other kinds of P2P
applications.

2.3. 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 chuncks of a
particular file; however, in this document it is used more generally,
for example, in the case of P2P streaming applications, to refer to
all peers receiving and/or transmitting the same media stream.

2.4. 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.

2.5. 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".

2.6. Transit

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

2.7. Peering

The direct interconnection between two separate networks for the purpose of exchanging traffic without recurring to 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 way 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 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 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 at 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, realtime 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 and 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 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 the locality
      policy tries to reduce the traffic on. 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 are 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 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-bandwiwth 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 which 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 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:
o 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
   re-negotiate the contract ruling the peering agreement;
o ISPs with similar customer bases:
   * ISPs with different access technologies: customers of the ISP
      which 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 and thus the
      conditions under which the peering agreement had been
      established would not change much.

As a consequence of the reasoning above, it seems reasonable 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 technique 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 bi-directional.

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 ISP that are also transit providers to artificially
increase the amount of data exchanged with networks they provide
transit to (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 contentions concerning transit and peering agreement have teached so far [CogentVsAOL] [SprintVsCogent] is that, at the end of the day, no economic factor, no matter how much 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 [I-D.weaver-alto-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 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.

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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	

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| Improved P2P Caching   |           |              | X           |
| (Section 3.7)          |           |              |             |
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