Comcast's ISP Experiences in a Proactive Network Provider Participation
                    for P2P (P4P) Technical Trial

Abstract

   This document describes the experiences of Comcast, a large cable
   broadband Internet Service Provider (ISP) in the U.S., in a Proactive
   Network Provider Participation for P2P (P4P) technical trial in July
   2008. This trial used P4P iTracker technology, which is being
   considered by the IETF as part of the Application Layer Transport
   Optimization (ALTO) working group.

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1. Introduction

   Comcast is a large broadband Internet Service Provider (ISP), based
   in the U.S., serving the majority of its customers via cable modem
   technology. A trial was conducted in July 2008 with Pando Networks,
   Yale, and several ISP members of the P4P working group, which is part
   of the Distributed Computing Industry Association (DCIA). Comcast is
   a member of the DCIA's P4P Working Group, whose mission is to work
   with Internet Service Providers (ISPs), peer-to-peer (P2P) companies,
   and technology researchers to develop "P4P" mechanisms, such as so-
   called "iTrackers" (hereafter P4P iTrackers), that accelerate
   distribution of content and optimize utilization of ISP network
   resources. P4P iTrackers theoretically allow P2P networks to
   optimize traffic within each ISP, reducing the volume of data
   traversing the ISP's infrastructure and creating a more manageable
   flow of data. P4P iTrackers can also accelerate P2P downloads for
   end users.

   P4P's iTracker technology [SIGCOMM] was conceptually discussed with
   the IETF at the Peer-to-Peer Infrastructure (P2Pi) Workshop held on
   May 28, 2008, at the Massachusetts Institute of Technology (MIT), as
   documented in [RFC5594]. This work was discussed in greater detail
   at the 72nd meeting of the IETF, in Dublin, Ireland, in the ALTO BoF
   (Birds of a Feather meeting) on July 29, 2008. Due to interest from
   the community, Comcast shared P4P iTracker trial data at the 73rd
   meeting of the IETF, in Minneapolis, Minnesota, in the ALTO BoF on
   November 18, 2008. Since that time, discussion of P4P iTrackers and
   alternative technologies has continued among participants of the ALTO
   working group.

The P4P iTracker trial was conducted, in cooperation with Pando, Yale, and three other P4P member ISPs, from July 2 to July 17, 2008. This was the first P4P iTracker trial over a cable broadband network. The trial used a Pando P2P client, and Pando distributed a special 21-MB licensed video file in order to measure the effectiveness of P4P iTrackers. A primary objective of the trial was to measure the effects that increasing the localization of P2P swarms would have on P2P uploads, P2P downloads, and ISP networks, in comparison to normal P2P activity.

2. High-Level Details

As noted in Section 1 of [DynamicSwarmMgmt], a swarm is defined in the following way:

> The content and the set of peers distributing it [a file] is usually called a torrent. A peer that only uploads content is called a seed, while a peer that uploads and downloads at the same time is called a leecher. The connected set of peers participating in the piece exchanges of a torrent is referred to as a swarm.

There were five different swarms for the content used in the trial. The second, third, and fourth used different P4P iTrackers: Generic, Coarse Grained, and Fine Grained, all of which are described in Section 3. The fifth was a proprietary Pando mechanism. (The results of the fifth swarm, while satisfactory, are not included here since our focus is on open standards and a mechanism that may be leveraged for the benefit of the entire community of P2P clients.) Comcast deployed a P4P iTracker server in its production network to support this trial, and configured multiple iTracker files to provide varying levels of localization to clients.

In the trial itself, a P2P client begins a P2P session by querying a pTracker, which runs and manages the P2P network. The pTracker occasionally queries the P4P iTracker, which in this case was maintained by Comcast, the ISP. Other ISPs either managed their own P4P iTracker or used Pando or Yale to host their P4P iTracker files. The P4P iTracker returns network topology information to the pTracker, which then communicates with P2P clients, in order to enable P2P clients to make network-aware decisions regarding peers.

The Pando client was enabled to capture extended logging, when the version of the client included support for it. The extended logging included the source and destination IP address of all P2P transfers, the number of bytes transferred, and the start and end timestamps. This information gives a precise measurement of the data flow in the network, allowing computation of data transfer volumes as well as

data flow rates at each point in time. With standard logging, Pando
captured the start and completion times of every download, as well as
the average transfer rate observed by the client for the download.

Pando served the data from an origin server external to Comcast's
network. This server served about 10 copies of the file, after which
all transfers (about 1 million downloads across all ISPs) were
performed purely via P2P.

The P2P clients in the trial start with tracker-provided peers, then
use peer exchange to discover additional peers. Thus, the initial
peers were provided according to P4P iTracker guidance (90% guidance
based on P4P iTracker topology and 10% random guidance), then later
peers discover the entire swarm via either additional announces or
peer exchange.

3. Differences between the P4P iTrackers Used

Given the size of the Comcast network, it was felt that in order to
truly evaluate the P4P iTracker application we would need to test
various network topologies that reflected its network and would help
gauge the level of effort and design requirements necessary to get
correct statistical data out of the trial. In all cases, P4P
iTrackers were configured with automation in mind, so that any
successful P4P iTracker configuration would be automatically
updating, rather than manually configured on an ongoing basis. All
P4P iTrackers were hosted on the same small server, and it appeared
to be relatively easy and inexpensive to scale up a P4P iTracker
infrastructure should P4P iTracker-like mechanisms become
standardized and widely adopted.

3.1. P4P Fine Grain

The Fine Grain topology was the first and most complex P4P iTracker
that we built for this trial. It was a detailed mapping of Comcast
backbone-connected network Autonomous System Numbers (ASNs) to IP
Aggregates, which were weighted based on priority and distance from
each other. Included in this design was a prioritization of all Peer
and Internet transit connected ASNs to the Comcast backbone to ensure
that P4P traffic would prefer settlement-free and lower-cost networks
first, and then more expensive transit links. This attempted to
optimize and lower transit costs associated with this traffic. We
then took the additional step of detailing each ASN and IP Aggregate
into IP subnets down to Optical Transport Nodes (OTNs) where all
Cable Modem Termination Systems (CMTS, as briefly defined in Section
2.6 of [RFC3083]) reside . This design gave a highly localized and
detailed description of the Comcast network for the iTracker to
disseminate. This design defined 1,182 P4P iTracker node

identifiers, and resulted in a 107,357-line configuration file.

This P4P iTracker was obviously the most time-consuming to create and
the most complex to maintain. Trial results indicated that this
level of localization was too high, and was less effective compared
to lower levels of localization.

3.2. P4P Coarse Grain

Given the level of detail in the Fine Grain design, it was important
that we also enable a high-level design, which still used priority
and weighting mechanisms for the Comcast backbone and transit links.
The Coarse Grain design was a limited or summarized version of the
Fine Grain design, which used the ASN to IP Aggregate and weighted
data for transit links, but removed all additional localization data.
This ensured we would get similar data sets from the Fine Grain
design, but without the more detailed localization of each of the
networks attached to the Comcast backbone. This design defined 22
P4P iTracker node identifiers, and resulted in a 998-line
configuration file.

From an overall cost, complexity, risk, and effectiveness standpoint,
this was judged to be the optimal P4P iTracker for Comcast.
Importantly, this did not require revealing the complex, internal
network topology that the Fine Grain did. Updates to this iTracker
were also far simpler to automate, which will better ensure that it
is accurate over time, and keeps administrative overhead relatively
low. However, the differences, costs, and benefits of Coarse Grain
and Generic Weighted (see below) likely merit further study.

3.3. P4P Generic Weighted

The Generic Weighted design was a copy of the Coarse Grained design,
but instead of using ISP-designated priority and weights, all weights
were defaulted to pre-determined parameters that the Yale team had
designed. All other data was replicated from the Coarse Grain
design. Gathering and providing the information necessary to support
the Generic Weighted iTracker was roughly the same level of effort as
for Coarse Grain.

4. High-Level Trial Results

Trial data was collected by Pando Networks and Yale University, and
raw trial results were shared with Comcast and all of the other ISPs
involved in the trial. Analysis of the raw results was performed by
Pando and Yale, and these organizations delivered an analysis of the
P4P iTracker trial. Using the raw data, Comcast also analyzed the
trial results. Furthermore, the raw trial results for Comcast were

shared with Net Forecast, Inc., which performed an independent
analysis of the trial for Comcast.

4.1. Swarm Size

During the trial, downloads peaked at 24,728 per day, per swarm, or
nearly 124,000 per day for all five swarms. The swarm size peaked at
11,703 peers per swarm, or nearly 57,000 peers for all five swarms.
We observed a comparable number of downloads in each of the five
swarms.

For each swarm, Table 1 below gives the number of downloads per swarm
from Comcast that finished downloading, and the number of downloads
from Comcast that canceled downloading before finishing.

                Characteristics of P4P iTracker Swarms:

Swarm	Completed Downloads	Cancellations	Total Attempts	Cancellation Rate
Random (Control)	2,719	89	2,808	3.17%
P4P Fine Grained	2,846	64	2,910	2.20%
P4P Generic Weight	2,775	63	2,838	2.22%
P4P Coarse Grained	2,886	52	2,938	1.77%

            Table 1: Per-Swarm Size and Cancellation Rates

4.2. Impact on Download Speed

   The results of the trial indicated that P4P iTrackers can improve the
   speed of downloads to P2P clients. In addition, P4P iTrackers were
   effective in localizing P2P traffic within the Comcast network.

                 Impact of P4P iTrackers on Downloads:

Swarm	Global Avg bps	Change	Comcast Avg bps	Change
Random (Control)	144,045 bps	n/a	254,671 bps	n/a
P4P Fine Grained	162,344 bps	+13%	402,043 bps	+57%
P4P Generic Weight	163,205 bps	+13%	463,782 bps	+82%
P4P Coarse Grained	166,273 bps	+15%	471,218 bps	+85%

            Table 2: Per-Swarm Global and Comcast Download Speeds

4.3. General Impacts on Upstream and Downstream Traffic and Other
      Interesting Data

   An analysis of the effects of P4P iTracker use on upstream
   utilization and Internet transit was also interesting. It did not
   appear that P4P iTrackers significantly increased upstream
   utilization in the Comcast access network; in essence, uploading was
   already occurring no matter what and a P4P iTracker in and of itself
   did not appear to materially increase uploading for this specific,
   licensed content. (A P4P iTracker is not intended as a solution for
   the potential of network congestion to occur.) Random was 143,236 MB
   and P4P Generic Weight was 143,143 MB, while P4P Coarse Grained was
   139,669 MB. We also observed that using a P4P iTracker reduced
   outgoing Internet traffic by an average of 34% at peering points.
   Random was 134,219 MB and P4P Generic Weight was 91,979 MB, while P4P
   Coarse Grained was 86,652 MB.

   In terms of downstream utilization, we observed that the use of a P4P
   iTracker reduced incoming Internet traffic by an average of 80% at
   peering points. Random was 47,013 MB, P4P Generic Weight was 8,610
   MB, and P4P Coarse Grained was 7,764 MB. However, we did notice that

download activity in the Comcast access network increased somewhat,
from 56,030 MB for Random, to 59,765 MB for P4P Generic Weight, and
60,781 MB for P4P Coarse Grained. Note that for each swarm, the
number of downloaded bytes according to logging reports is very close
to the number of downloads multiplied by file size. But they do not
exactly match due to log report errors and duplicated chunks. One
factor contributing to the differences in access network download
activity is that different swarms have different numbers of
downloaders, due to random variations during uniform random
assignment of downloaders to swarms (see Table 1). One interesting
observation is that Random has higher cancellation rate (3.17%) than
that of the guided swarms (1.77%-2.22%). Whether guided swarms
achieve lower cancellation rate is an interesting issue for future
research.

5. Important Notes on Data Collected

Raw data is presented in this document. We did not normalize traffic
volume data (e.g., upload and download) by the number of downloads in
order to preserve this underlying raw data.

We also recommend that readers not focus too much on the absolute
numbers, such as bytes downloaded from internal sources and bytes
downloaded from external sources. Instead, we recommend readers
focus on ratios such as the percentage of bytes downloaded that came
from internal sources in each swarm. As a result, the small random
variation between number of downloads of each swarm does not distract
readers from important metrics like shifting traffic from external to
internal sources, among other things.

We also wish to note that the data was collected from a sample of the
total swarm. Specifically, there were some peers running older
versions of the Pando client that did not implement the extended
transfer logging. For those nodes, which participated in the swarms
but did not report their data transfers, we have download counts.
The result of this is that, for example, the download counts
generated from the standard logging are a bit higher than the
download counts generated by the extended logging. That being said,
over 90% of downloads were by peers running the newer software, which
we believe shows that the transfer records are highly representative
of the total data flow.

In terms of which analysis was performed from the standard logging
compared to extended logging, all of the data flow analysis was
performed using the extended logging. Pando's download counts and
performance numbers were generated via standard logging (i.e., all
peers report download complete/cancel, data volumes, and measured
download speed on the client). Yale's download counts and

performance numbers were derived via extended logging (e.g., by summing the transfer records, counting IP addresses reported, etc.).

One benefit of having two data sources is that we can compare the two. In this case, the two approaches both reported comparable impacts.

6. Next Steps

One objective of this document is to share with the IETF community the results of one P4P iTracker trial in a large broadband network, given skepticism regarding the benefits to P2P users as well as to ISPs. From the perspective of P2P users, P4P iTrackers potentially deliver faster P2P downloads. At the same time, ISPs can increase the localization of swarms, enabling them to reduce bytes flowing over transit points, while also delivering an optimized P2P experience to customers. However, an internal analysis of varying levels of P4P iTracker adoption by ISPs leads us to believe that, while P4P iTracker-type mechanisms are valuable on a single ISP basis, the value of P4P iTrackers increases dramatically as many ISPs choose to deploy it.

We believe these results can inform the technical discussion in the IETF over how to use P4P iTracker mechanisms. Should such a mechanism be standardized, the use of ISP-provided P4P iTrackers should probably be an opt-in feature for P2P users, or at least a feature of which they are explicitly aware of and which has been enabled by default in a particular P2P client. In this way, P2P users could choose to opt-in either explicitly or by their choice of P2P client in order to choose to use the P4P iTracker to improve performance, which benefits both the user and the ISP at the same time. Importantly in terms of privacy, the P4P iTracker makes available only network topology information, and would not in its current form enable an ISP, via the P4P iTracker, to determine which P2P clients were downloading any specific content, whether to determine, for example, if content was a song or a movie or even the title.

It is also possible that a P4P iTracker type of mechanism, in combination with a P2P cache, could further improve P2P download performance, which merits further study. In addition, this was a limited trial that, while very promising, indicates a need for additional technical investigation and trial work. Such a follow-up study should explore the effects of P4P iTrackers when more P2P client software variants are involved, with larger swarms, and with additional and more technically diverse content (file size, file type, duration of content, etc.).

7. Security Considerations

   This document does not propose any kind of protocol, practice or
   standard.

   The experiment did show that an ISP can improve performance without
   exposing fine-grained details about network structure, which might
   otherwise be a security concern (see Section 3.1 (P4P Fine Grain) and
   Section 3.2 (P4P Coarse Grain). Section 6 (Next Steps) mentions that
   the opt-in architecture allows P2P users to maintain privacy.

   Other security aspects were not considered in the experiment, which
   focused on performance measurements.

8. Acknowledgements

   The authors wish to acknowledge the hard work of all of the P4P
   working group members, and specifically the focused efforts of the
   teams at both Pando and Yale for the trial itself. Finally, the
   authors recognize and appreciate Peter Sevcik and John Bartlett of
   NetForecast, Inc., for their valued independent analysis of the trial
   results.

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