P2P networking and its relationship to NG-PON

Globecom ‘09
December 2, 2009

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Internet Trends

- IP Video traffic is increasing rapidly
- Peer-to-peer (P2P) is highly popular, and is being legitimized
  - uTorrent or “BitTorrent 2.0,” automatically limits its own bandwidth when it detects network congestion
- P2P Video distribution systems are rising
  - Joost, Veoh, Nextshare, Vudu, PiCast, Vatata, Gridmedia, PPStream, PPLive, Zattoo, Octoshape, Sopcast, Tvkoo, Roxbeam, Tribler, Ustream, Mediameleon, Selfcast.com, SwarmPlayer, NextshareTV, …

How can Next-Generation Passive Optical Network leverage these trends?
“We are in the midst of a massive shift in behavior from “download now, use later” content acquisition to an on-demand mentality where bytes are consumed as they arrive. Almost two-thirds of all Internet traffic in 2009 is enjoyed on arrival”

- Filesharing -> On-demand streaming real-time entertainment
- Over 1.2 Billion YouTube videos per day (TechCrunch, June 2009)
Video Uptick

Sandvine, 2009
Global Broadband Phenomena

Cisco Visual Networking Index (VNI) Forecast and Methodology, 2008-2013
• Global IP traffic expected to increase fivefold from 2008 to 2013
• By 2013, the sum of all forms of video (TV, VoD, Internet video, and P2P) will exceed 90 percent of global consumer IP traffic
Localized Peer-to-Peer Video

- Cooperation / information sharing between the network service provider and the P2P system
- Knowledge of subscriber OLT and CO assignments assumed
- Local P2P content is preferred

- P2P Displaces downstream core and aggregation network bandwidth from network servers

“Hairpin”
Peer-to-Peer Video Service - Concept

- Enabled using a personal video recorder (PVR) distributed by a network service provider
  - Or similar functionality in media server, attached storage,…
- On-demand access to TV shows, movies and other titles
- User agrees to *share* content with the network
- Network service provider can make copyright/royalty arrangements with content providers *just as with centralized storage*
Video Demand Model

- Probability of viewing each title
- Combined model from statistics of
  - Number of TV viewers per show
  - Weekend gross for movies
  - DVD + VHS Rentals
  - Netflix data
- Title popularity model: combined exponential and power-law
  - \( \text{Pr}(0.2) e^{-0.09 \times \text{(title \#)}} + \text{Pr}(0.8) ((\text{(title \#)}+20) \times 100)^{-0.3} \)
  - Sharp peak and long tail

The most popular titles are most likely to be requested and stored

![Graph showing the probability of viewing each title over the title number.](image)
Number of Titles Viewed per Subscriber

- Ratings
  - Maximum busy hour (prime time peak) has about 66% of all households watching TV
  - Each home averages a little less than 2 simultaneous TV viewings per home in the busy hour

- FCC statistics in 2005
  - 90% of US homes had TVs
  - The average number of TV sets per household was 2.62

- Model for number of titles viewed per subscriber location in the busy hour (prime time)

<table>
<thead>
<tr>
<th>Number of titles</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>&gt;4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability</td>
<td>0.1</td>
<td>0.35</td>
<td>0.3</td>
<td>0.15</td>
<td>0.1</td>
<td>0</td>
</tr>
</tbody>
</table>

- Mean = 1.8
- Only peak usage in the busy hour (prime time) is considered here
Access Network Model: CO Serving Area

- Gamma model of CO-serving area radius
  - Well-grounded from Bell System loop survey data
    - deviation / mean = 0.2, alpha = 25

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Gamma model of CO serving area size

![Probability Histogram](image)

Truncated due to memory limits
Evaluation Methodology

- Randomly generate Central Office (CO) serving area size
- Exclude broadcast/multicast video (results only include unicast video)
  - 20 top most popular titles are broadcast -> 64.0% unicast
- Assign OLT chassis, OLT ports, and subscribers
- Randomly generate number of streams and title of each video stream demanded by each subscriber
  - Subscribers populated with variable number of demanded video titles (average 1.8 titles per sub); title numbers assigned by TV demand model
- Randomly generate titles stored by each subscriber
  - Fixed number of stored titles per subscriber assigned, also by TV demand model
- For each demanded title, find closest P2P storage of this title and assign this to peer upstream if there is sufficient OLT & P2P capacity
  - Search OLT port area (32 subs)
  - If not found, search OLT chassis area (1024-2048 subs)
  - If not found, search entire CO (about 23,000 subs)
- Repeat from the top for at least 250 random cases
- P2P stream is switched or routed from upstream back to downstream at the “hairpin” location
- Bandwidth tracked and PON limitations are accounted for
Upstream P2P Bandwidth Limitations

- **NG-PON**: 2.488 Gbps Up / 10 Gbps Down; **GPON**: 1.244 Up / 2.488 Down
- **Upstream ONLY**, downstream bandwidth would be used anyway if video network-provided and not P2P
- 19.3 Megabits per second (Mbps) per stream (ATSC HDTV)
- <= 33.3% of resources allowed to be used by P2P
  - Except max_p2p_up_streams
- **CO Router backplane bandwidth**
  - Max CO router throughput = 1000.0 Gigabits per second (Gbps); 17271 P2P video streams
- **OLT to CO link bandwidth**
  - Max OLT uplink bandwidth = 40.0 Gbps; 690 P2P video streams
- **OLT backplane bandwidth**
  - Max OLT switching capacity = 400.0 Gbps; 6908 P2P video streams
- **OLT port bandwidth**
  - Maximum per port OLT upstream = 2.488 Gbps; 42 P2P video streams
- **# Simultaneous upstream P2P video streams from one peer = 2**
Detailed Results: Average Numbers of Streams

- With **NG-PON** limits on upstream P2P capacity
- **Top 20 titles** are broadcast/multicast, the rest (64.0%) is unicast, part of unicast is P2P
Core Bandwidth Reduction

- Local P2P enabled by **OLT**, customers on the same OLT port or OLT chassis can share local P2P video, Unicast video only
  - P2P hairpins at OLT chassis or OLT port
  - NG-PON, 20 most popular titles reserved for broadcast/multicast

![Graph showing bandwidth consumption](image-url)
Impact of GPON and NG-PON Bandwidth Limitations

- NG-PON bandwidth imposes minor limits on P2P video
- GPON bandwidth limits P2P video bandwidth localization to about 1/2 of max

![Graph showing bandwidth limits for GPON and NG-PON](image-url)

Localized P2P at OLT only

- GPON Capacity Limits
- NGPON Capacity Limits
- Unlimited

Number of P2P Titles Available From Each Subscriber

Gbps per CO
OLT Switching Capacity

- **NG-PON**: OLT backplane/switching capacity is varied
- Here all P2P “hairpins” at the OLT and always uses OLT backplane/switching capacity – at multiple OLTs in each CO
- 150-200 Gbps is seen to be sufficient for localized P2P video traffic
  - P2P only uses 1/3 of this capacity
  - However, other applications may contribute to needing a higher capacity

*Figure: Localized P2P at OLT only*

**Non-P2P, 100 Gbps OLT switch**
**Non-P2P, 150 Gbps OLT switch**
**Non-P2P, 200 Gbps OLT switch**
**Non-P2P, 400 Gbps OLT switch**
**Non-P2P, 800 Gbps OLT switch**
**Non-P2P, 50 Gbps OLT switch**

*Graph: Number of P2P Titles Available From Each Subscriber vs. Non-P2P Unicast Video Traffic (Gbps per CO)*
What About the Total Amount of Traffic?

- All consumer IP traffic, including IPTV and Cable IP VOD
- Broadcast only predicted to be 0.02% of traffic
  - Due to multicasting
- Some portion of IPTV, P2P video, and Internet video may become localized

<table>
<thead>
<tr>
<th>Category</th>
<th>Video?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web, email, data</td>
<td>No</td>
</tr>
<tr>
<td>P2P</td>
<td>65%</td>
</tr>
<tr>
<td>Gaming</td>
<td>No</td>
</tr>
<tr>
<td>Video communications</td>
<td>No</td>
</tr>
<tr>
<td>VoIP</td>
<td>No</td>
</tr>
<tr>
<td>Internet Video to PC</td>
<td>Yes</td>
</tr>
<tr>
<td>Internet Video to TV</td>
<td>Yes</td>
</tr>
<tr>
<td>Cable VoD</td>
<td>No</td>
</tr>
<tr>
<td>Cable IP VoD</td>
<td>Yes</td>
</tr>
<tr>
<td>IPTV VoD</td>
<td>Yes</td>
</tr>
<tr>
<td>Broadcast</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Bandwidth Trends:
Actual consumed bandwidth, not maximum rate

- MINTS data [http://www.dtc.umn.edu/mints/home.html](http://www.dtc.umn.edu/mints/home.html)
  - Global Internet average traffic growth per year currently about 40%-60%, and may be slowing; 40% assumed here

- Global Consumer Internet Traffic
- 34% annual Internet traffic growth, approximately matches MINTS data
- P2P and Video the fastest growing segments of Internet traffic
- Used further in slides 32-36…
Broadband Video Traffic

- Cisco Visual Networking Index – Forecast and Methodology, 2007-2012
- Aggregated Cisco projections: Video projected to grow to almost 75% of total consumer broadband traffic

Global Consumer Internet Traffic
Video is estimated to be 65% of P2P traffic
Internet Concentration Ratios

Data only, No CBR traffic

Concentration ratio = \[ \frac{\sum_{\text{all users}} \text{peak bit rate}}{\text{aggregated bit rate}} \]

But no statistical concentration for video!
Projected Localized P2P Growth (Intermediate variable)

- Assumes that a carrier aggressively pursues network-controlled, localized P2P (as modeled earlier here)

100% CAGR assumed here

Projected Implementation of Localized P2P

- % IPTV that becomes localized P2P (VOD only)
- % P2P video that becomes localized P2P
- % Internet video that becomes localized P2P

Year

Percentage
Combined Projection: Localized P2P Growth (Previous Slide) and Cisco Forecast

- Localized P2P projected to be able to grow to 65% of IP video traffic, 60% of all Internet by 2013
Combined Projection: Localized P2P growth, Cisco Forecast, *And* Simulation Results of Core Bandwidth Reduction from Localized P2P Video

- P2P hairpins at OLT chassis or OLT port
- NG-PON, 20 most popular titles reserved for broadcast/multicast
Summary

- Localized P2P can vastly decrease core bandwidth requirements
  - Nearly 100% reduction possible for unicast video
    - A service projected to use the most core bandwidth
    - About 60% reduction total consumer Internet traffic
  - Fully enabled by NG-PON
    - GPON has insufficient bandwidth
  - There is a need for standardized network information flows, rights management, and accounting to enable localized P2P