



P2P networking and its relationship to NG-PON

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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, Mediamelon, Selfcast.com, SwarmPlayer, NextshareTV, ...

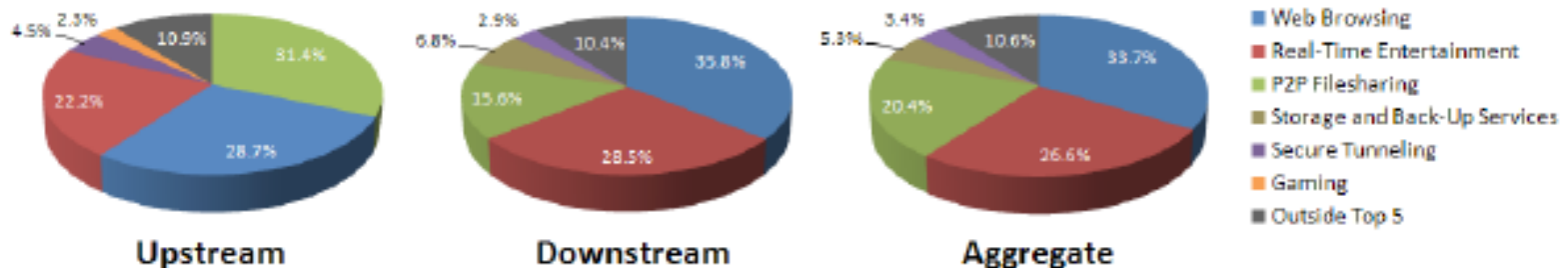
How can Next-Generation Passive Optical Network leverage these trends?

Sandvine, “2009 Global Broadband Phenomena”

“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”

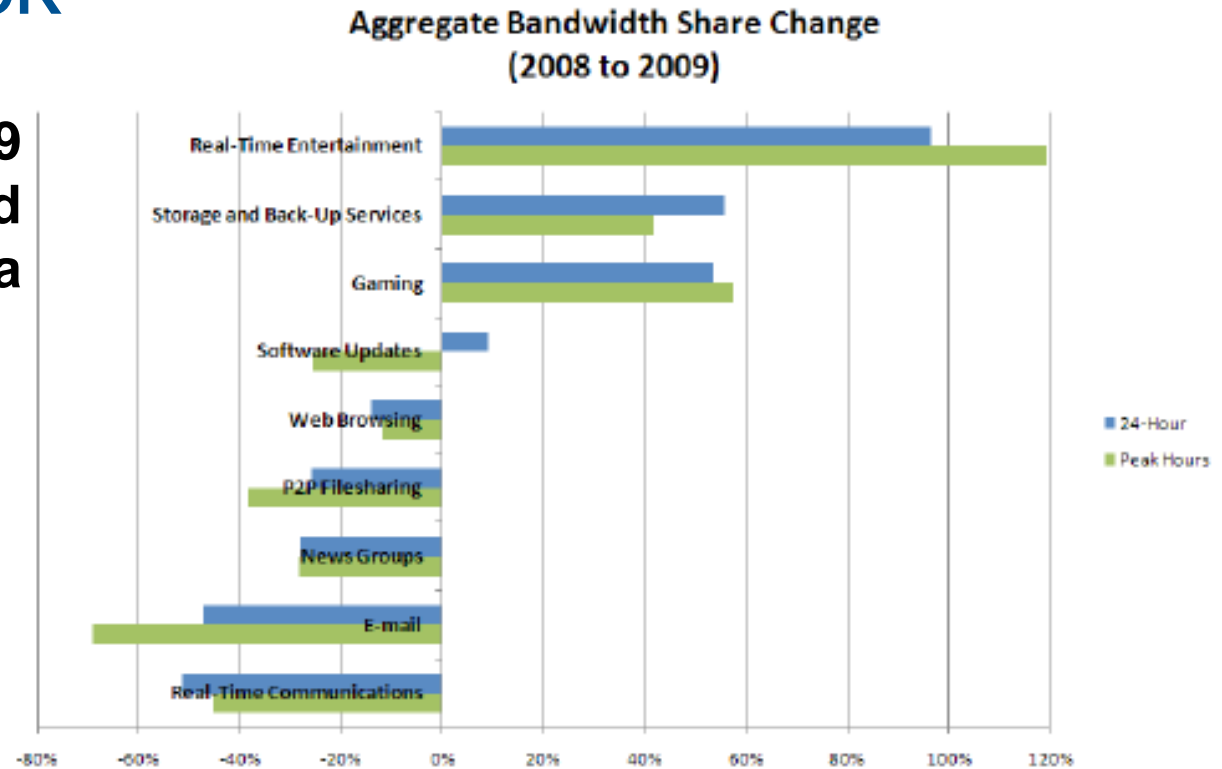
- Filesharing -> On-demand streaming real-time entertainment
- Over 1.2 Billion YouTube videos per day (TechCrunch, June 2009)

2009 Average



Video Uptick

Sandvine, 2009 Global Broadband Phenomena

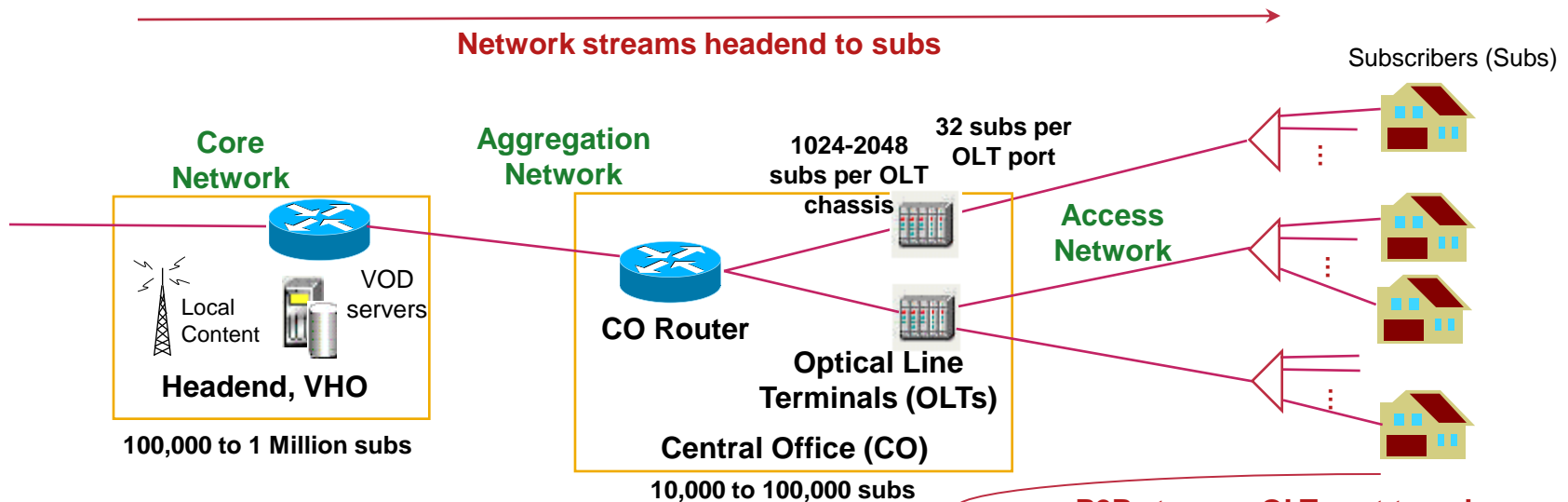


Cisco Visual Networking Index (VNI) Forecast and Methodology, 2008-2013

- 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**

P2P streams OLT port to subs

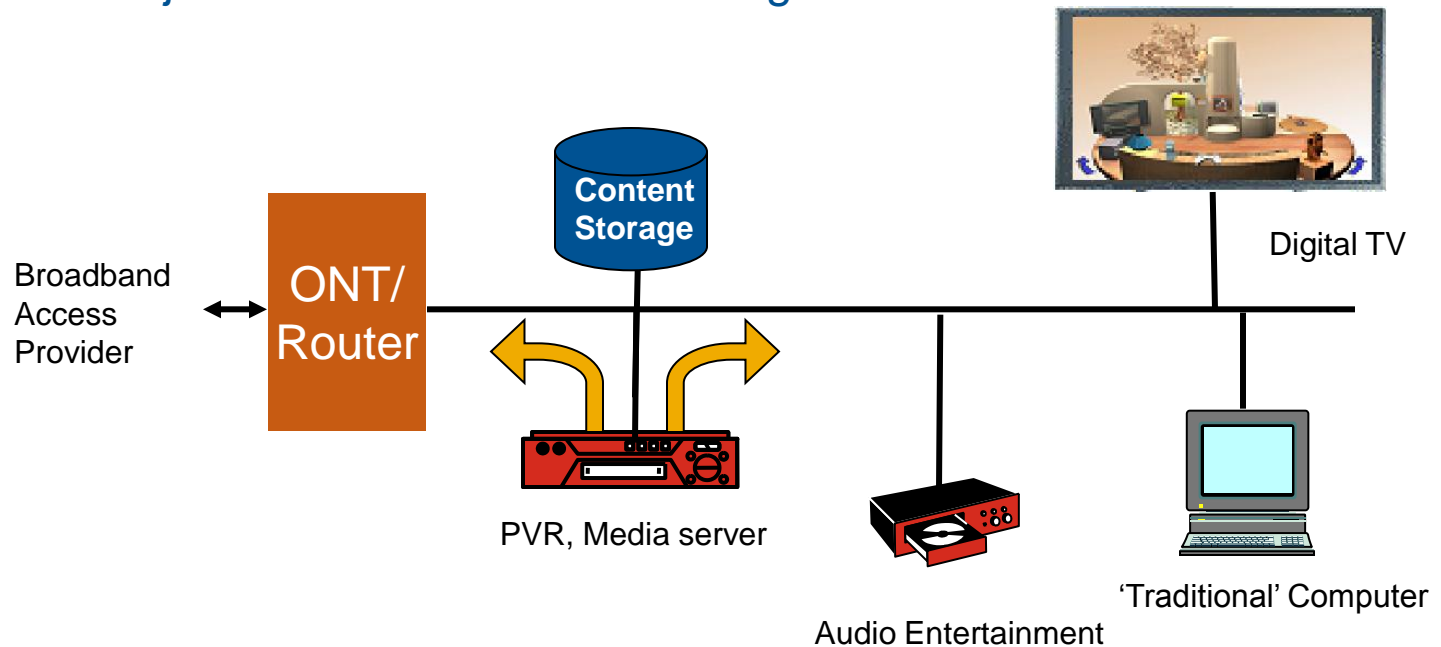
P2P streams OLT Chassis to subs

P2P streams CO to subs

“Hairpin”

Peer-to-Peer Video Service - Concept

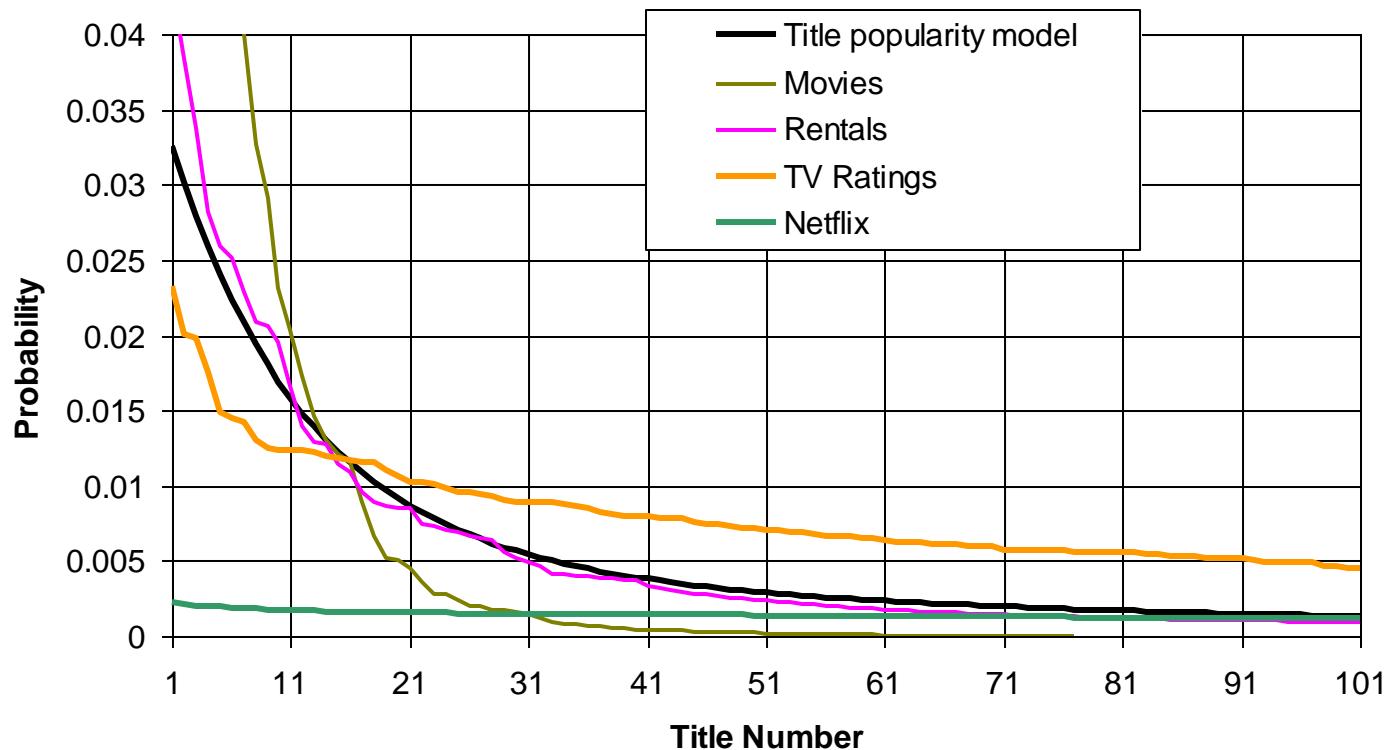
- Enabled using a personal video recorder (PVR) distributed by a network service provider
 - Or similar functionality in media server, attached storage,...
- On-demand access to TV shows, movies and other titles
- User agrees to *share* content with the network
- Network service provider can make copyright/royalty 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
 - $\Pr(0.2) e^{(-0.09 * (\text{title \#}))} + \Pr(0.8) (((\text{title \#}) + 20) * 100)^{-0.3}$
 - Sharp peak and long tail

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



■ ■ ■ Number of Titles Viewed per Subscriber

■ Ratings

<http://www.nielsenmedia.com/newsreleases/2005/TVviewinglevels.xls>

- 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

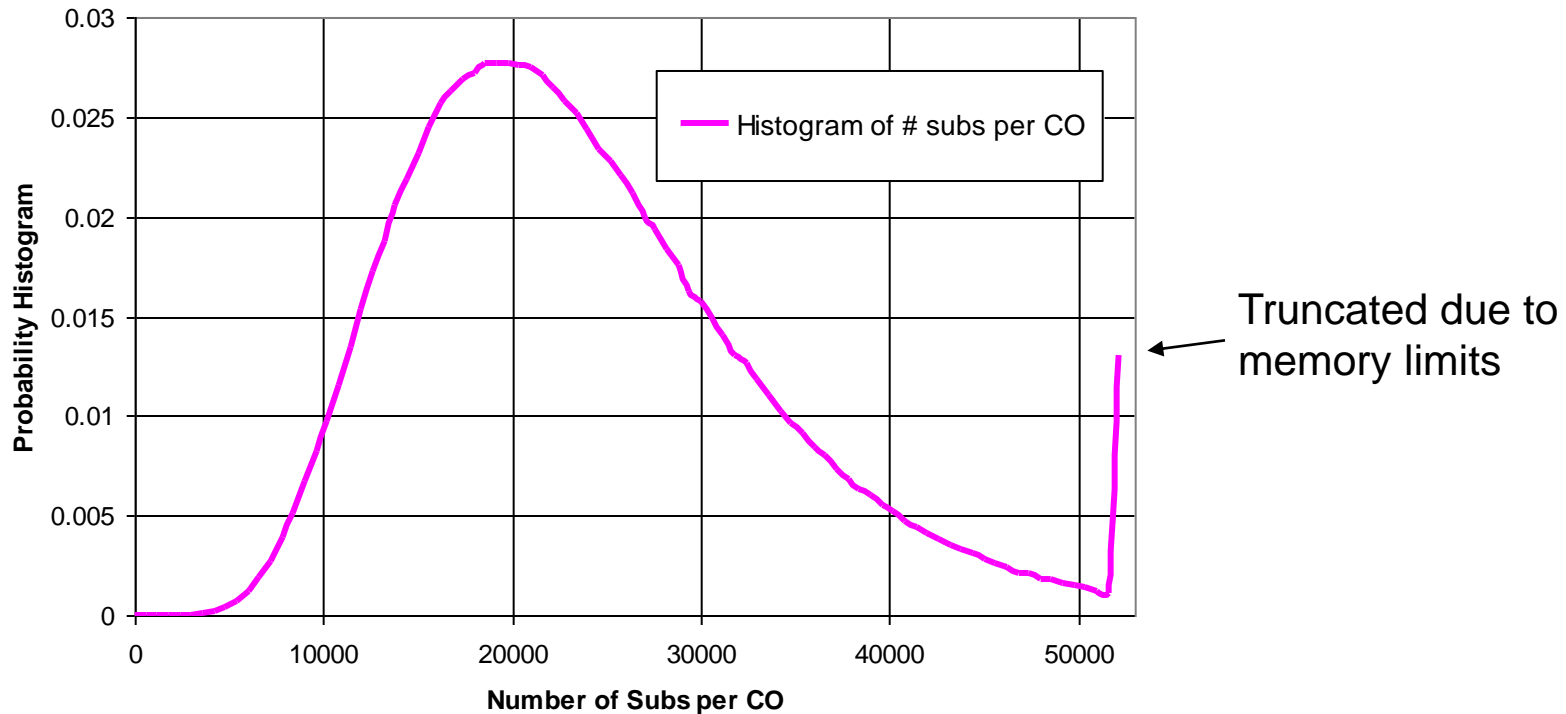
■ Model for number of titles viewed per subscriber location in the busy hour (prime time)

Number of titles	0	1	2	3	4	>4
Probability	0.1	0.35	0.3	0.15	0.1	0

- 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
 - K. J. Kerpez, "Statistical Variables for Evaluating Compatibility of Remote Deployments," T1E1.4/2001-132, May 10, 2001
 - deviation / mean = 0.2, alpha = 25



Gamma model of CO serving area size

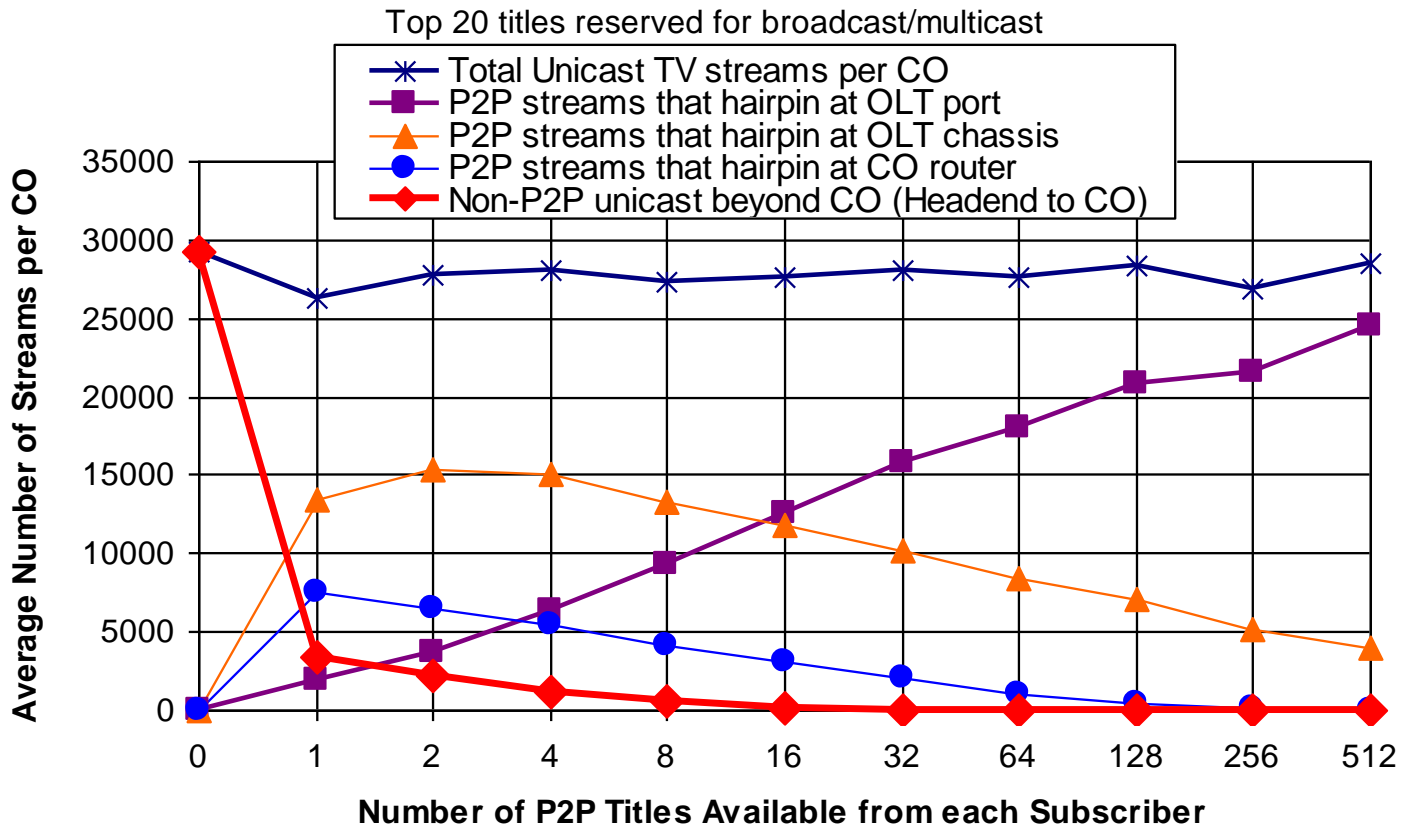
■ ■ ■ Evaluation Methodology

- **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**

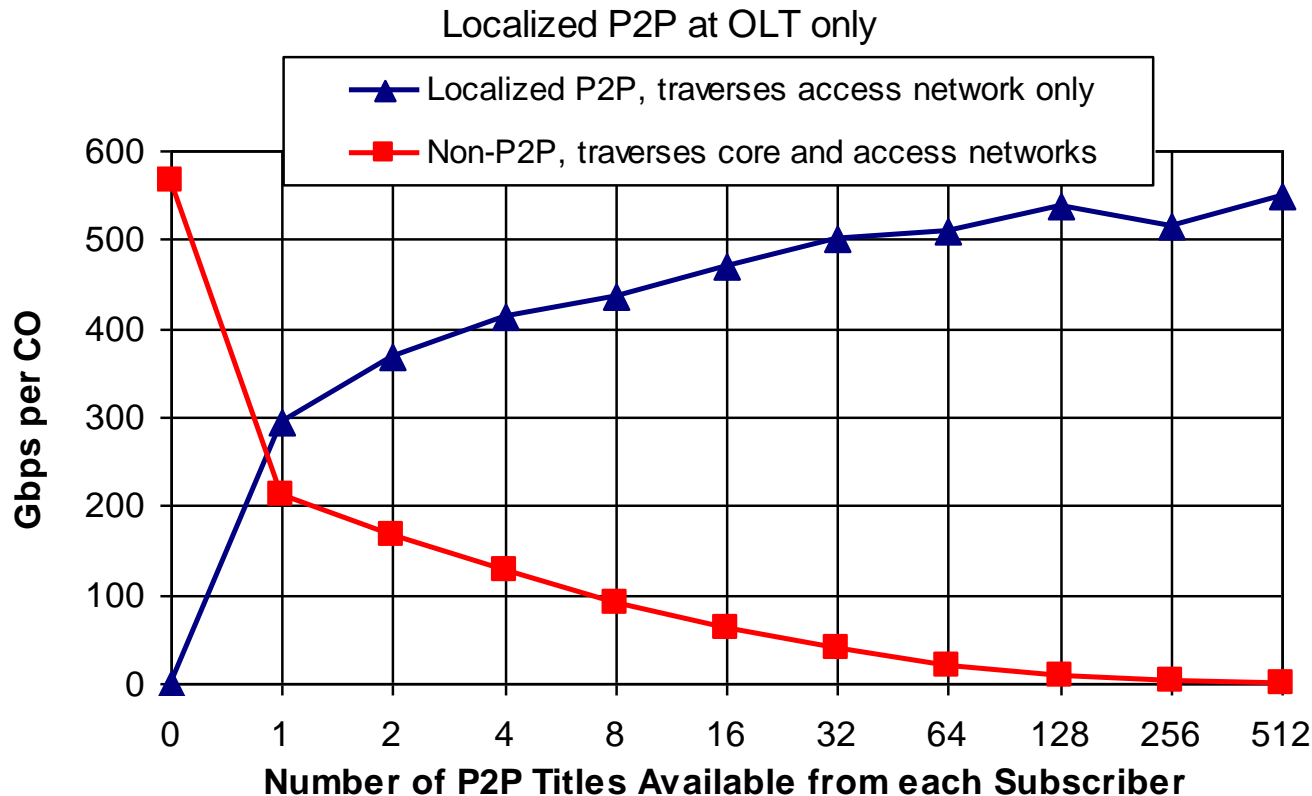
Detailed Results: Average Numbers of Streams

- 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

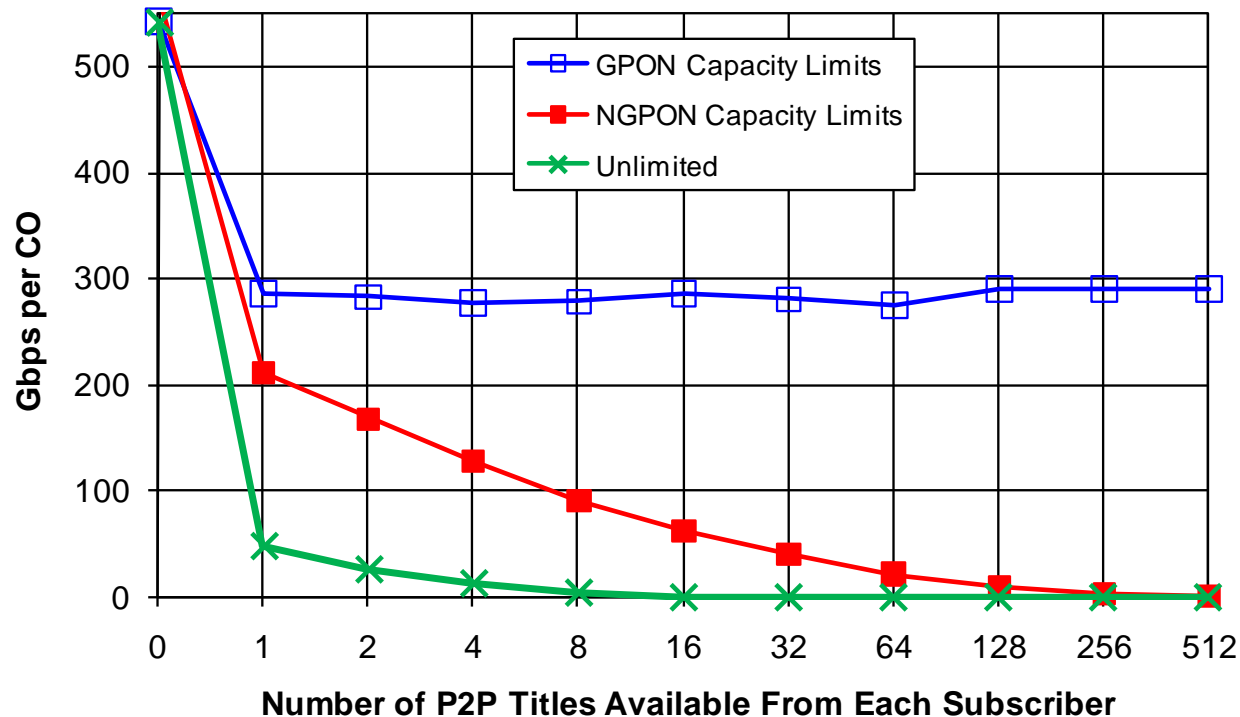
- Local P2P enabled by **OLT**, customers on the same OLT port or OLT chassis can share local P2P video, Unicast video only
 - P2P hairpins at OLT chassis or OLT port
 - NG-PON, 20 most popular titles reserved for broadcast/multicast



Impact of GPON and NG-PON Bandwidth Limitations

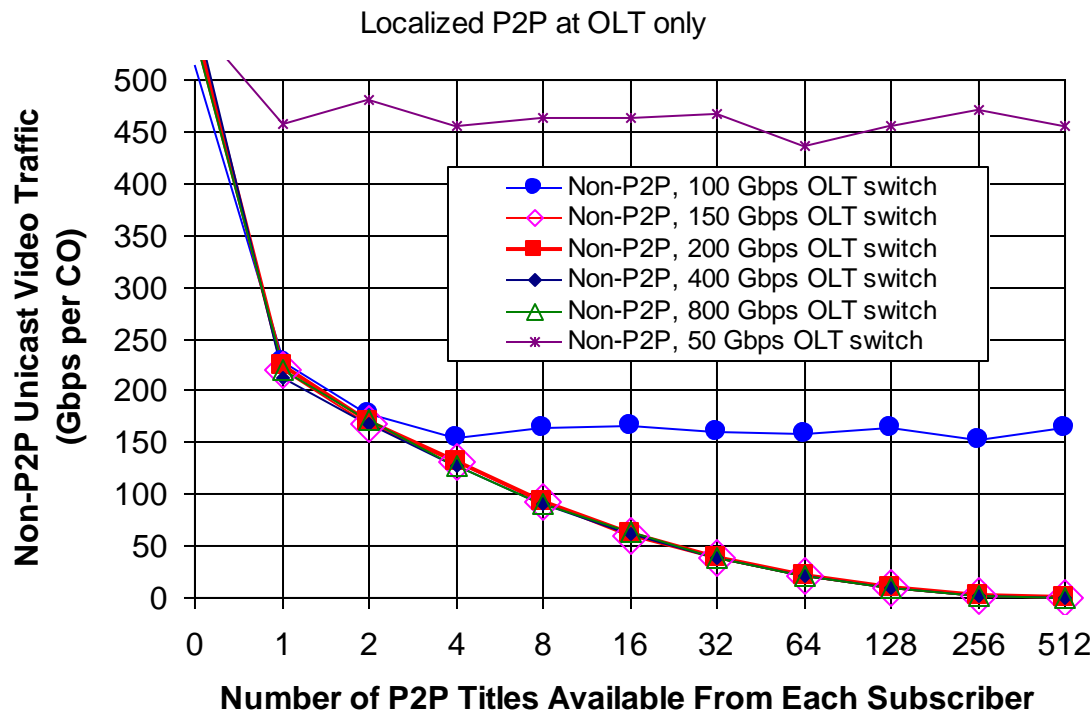
- NG-PON bandwidth imposes minor limits on P2P video
- GPON bandwidth limits P2P video bandwidth localization to about 1/2 of max

Localized P2P at OLT only



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



■ ■ ■ What About the *Total* Amount of Traffic?

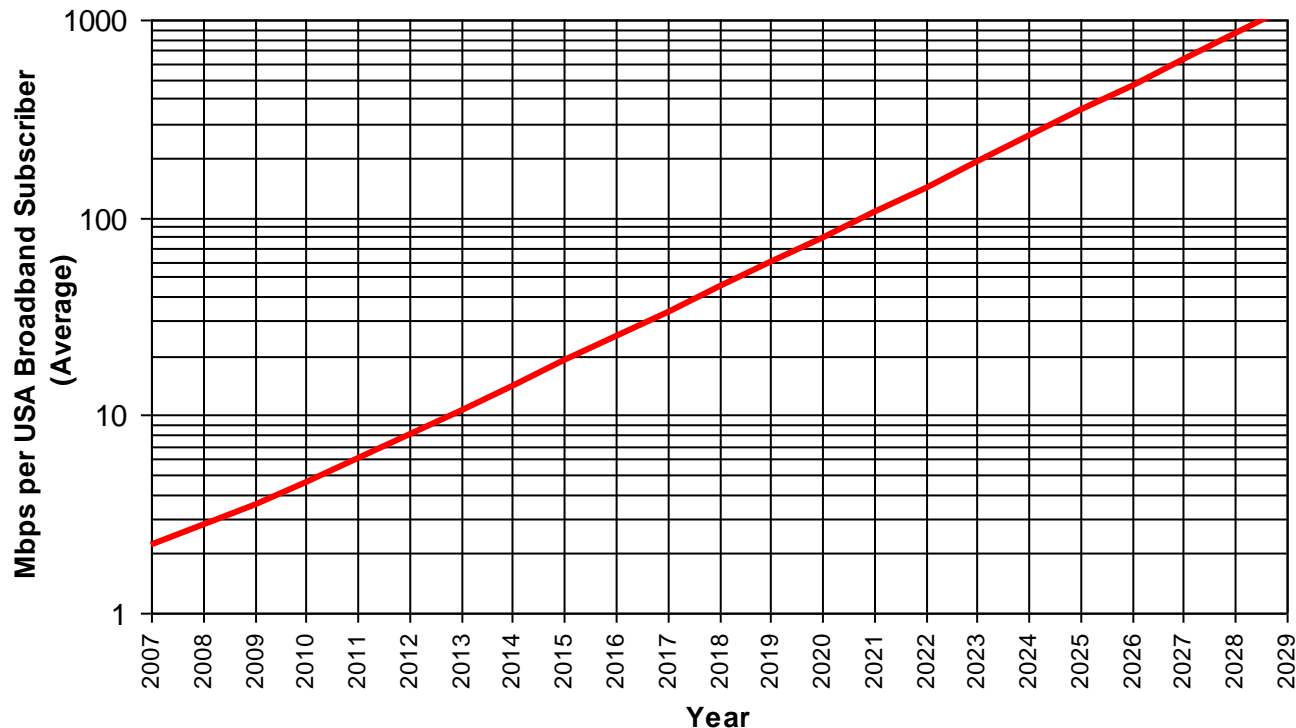
- Cisco, “Cisco Visual Networking Index – Forecast and Methodology, 2007-2012”
- All consumer IP traffic, including IPTV and Cable IP VOD
- Broadcast only predicted to be 0.02% of traffic
 - Due to multicasting
- Some portion of IPTV, P2P video, and Internet video may become localized

Category	Video?
Web, email, data	No
P2P	65%
Gaming	No
Video communications	No
VoIP	No
Internet Video to PC	Yes
Internet Video to TV	Yes
Cable VoD	No
Cable IP VoD	Yes
IPTV VoD	Yes
Broadcast	Yes

■ ■ ■ Bandwidth Trends:

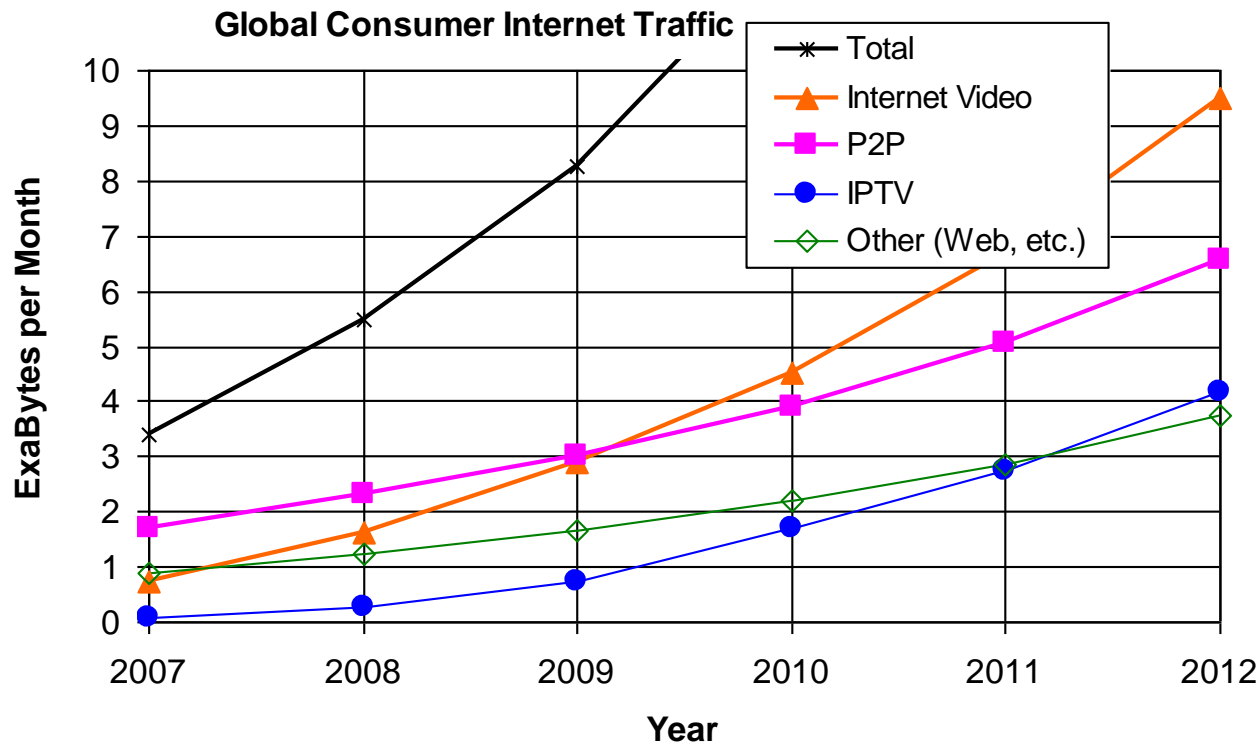
Actual consumed bandwidth, not maximum rate

- MINTS data <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



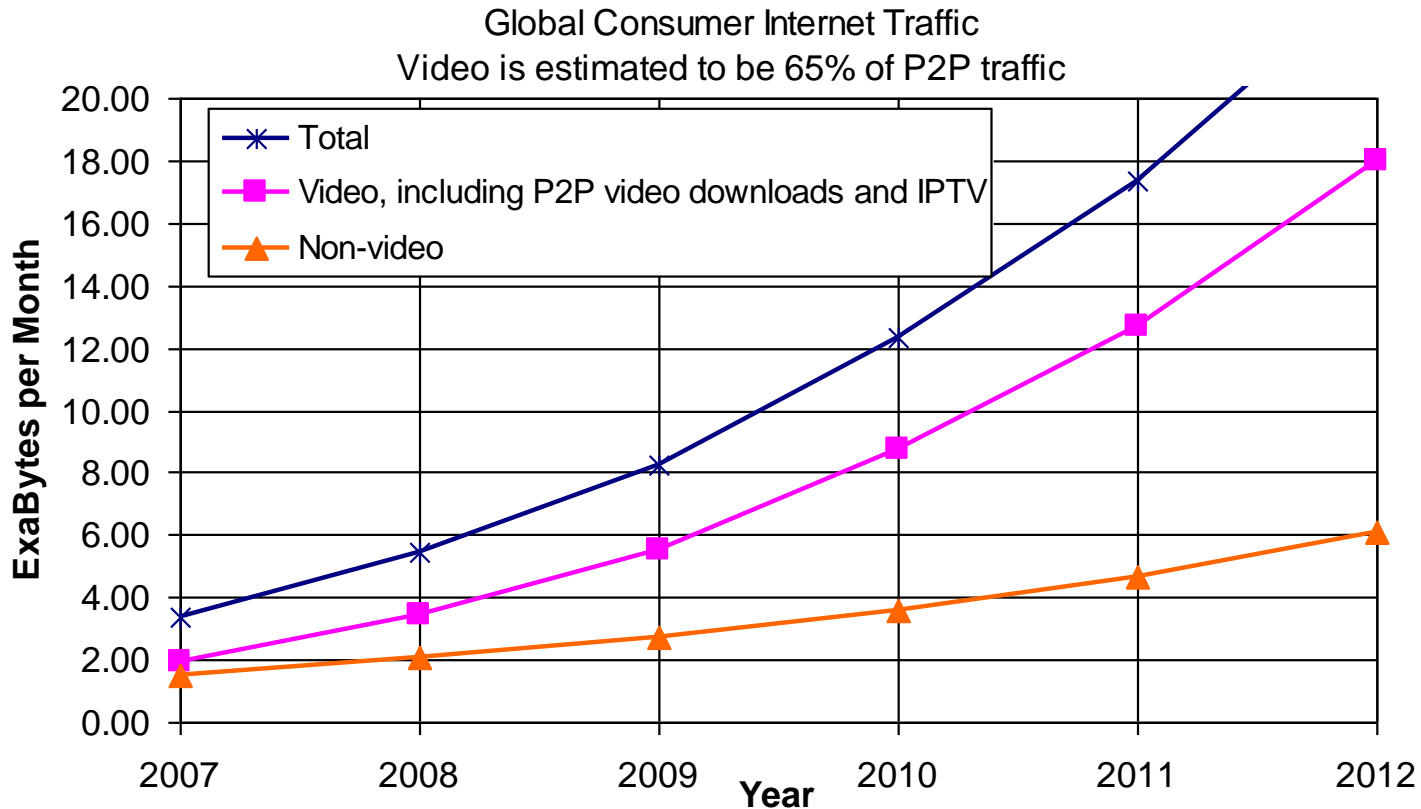
Cisco, “Cisco Visual Networking Index – Forecast and Methodology, 2007-2012”

- 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...

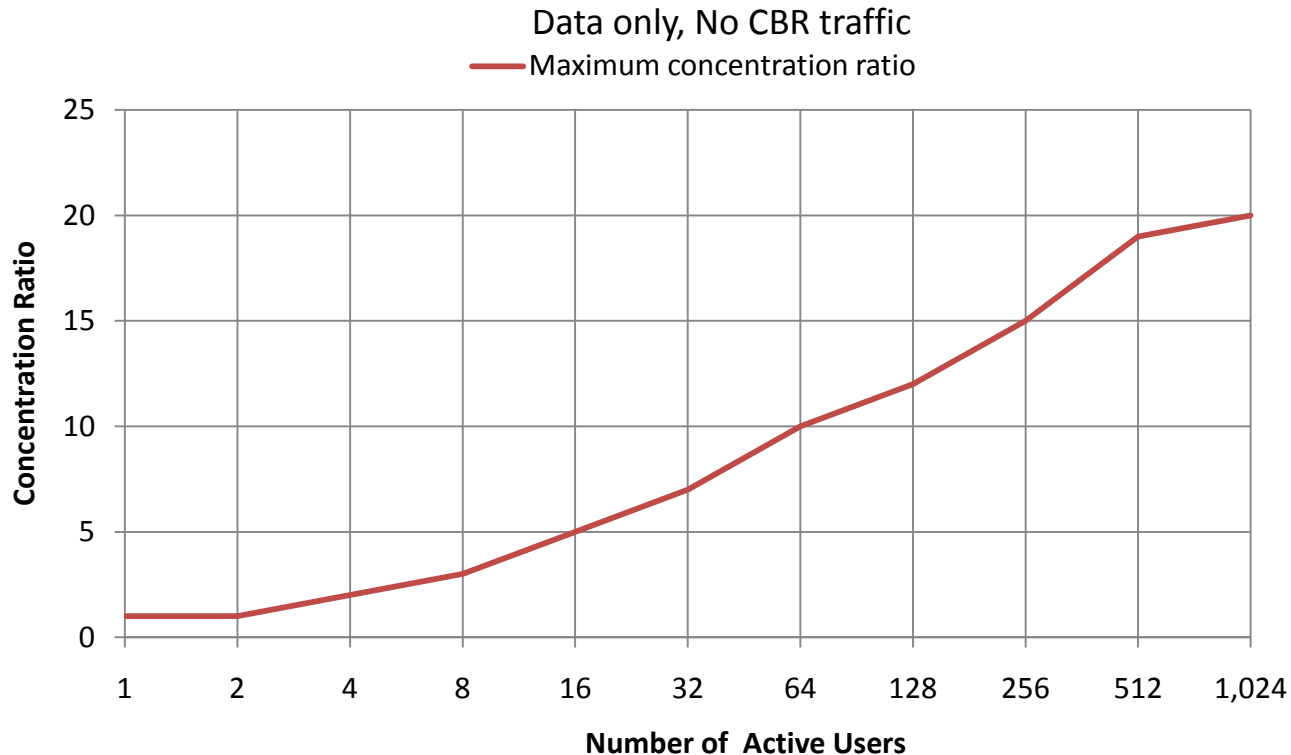


Broadband Video Traffic

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



Internet Concentration Ratios

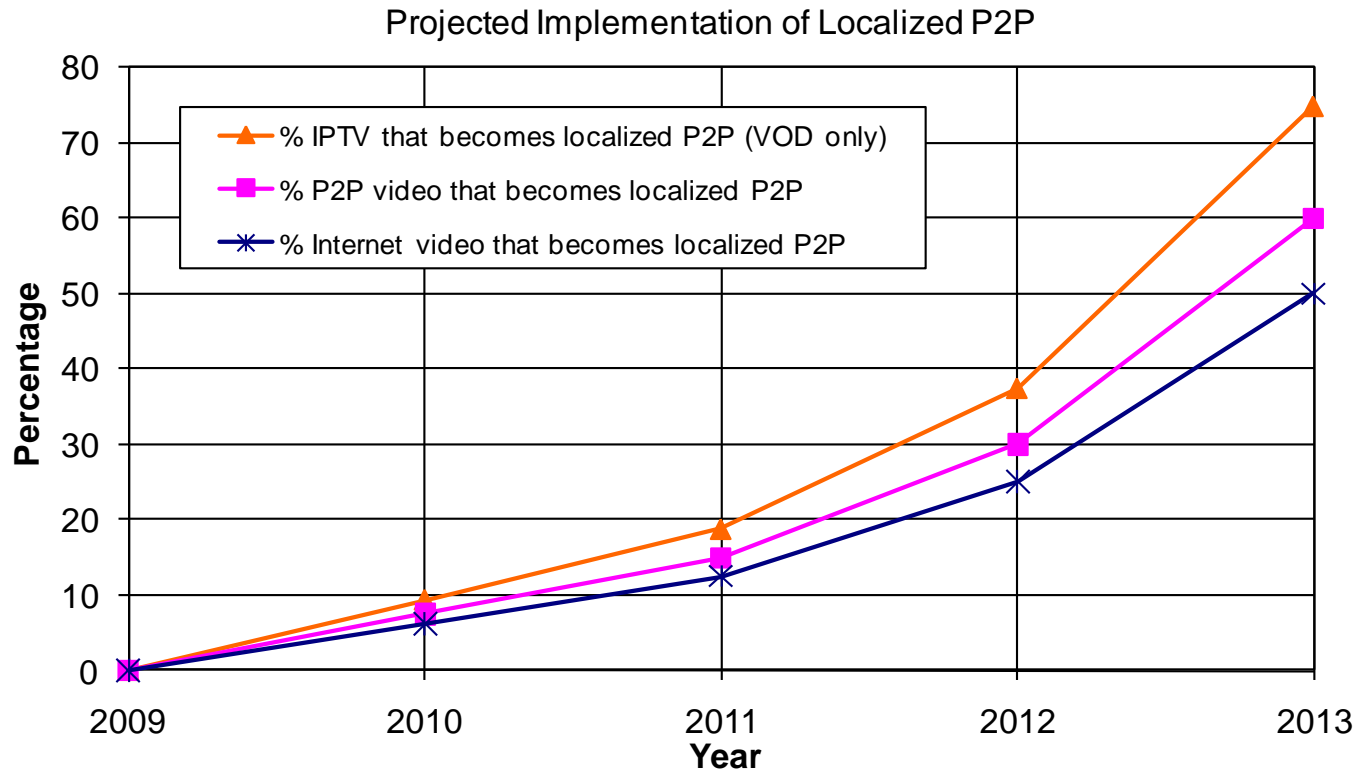


$$\text{Concentration ratio} = \frac{\sum_{\text{all users}} \text{peak bit rate}}{\text{aggregated bit rate}}$$

But no statistical concentration for video!

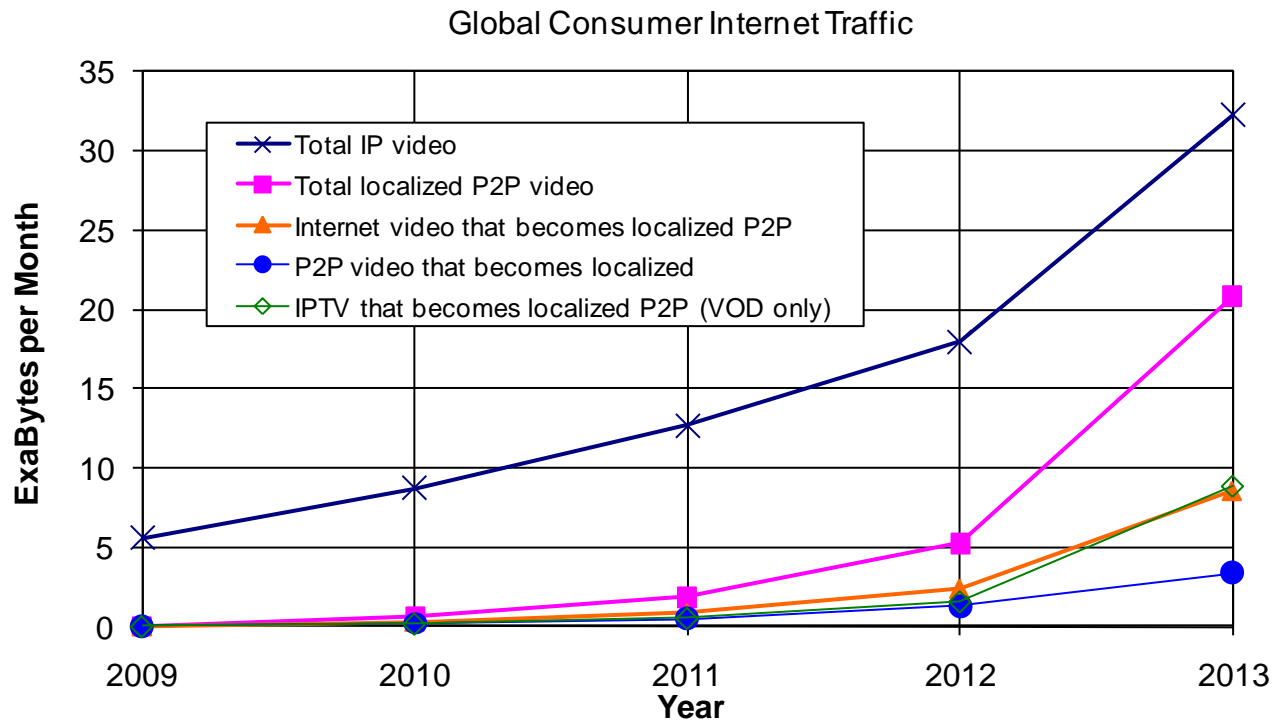
Projected Localized P2P Growth (Intermediate variable)

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



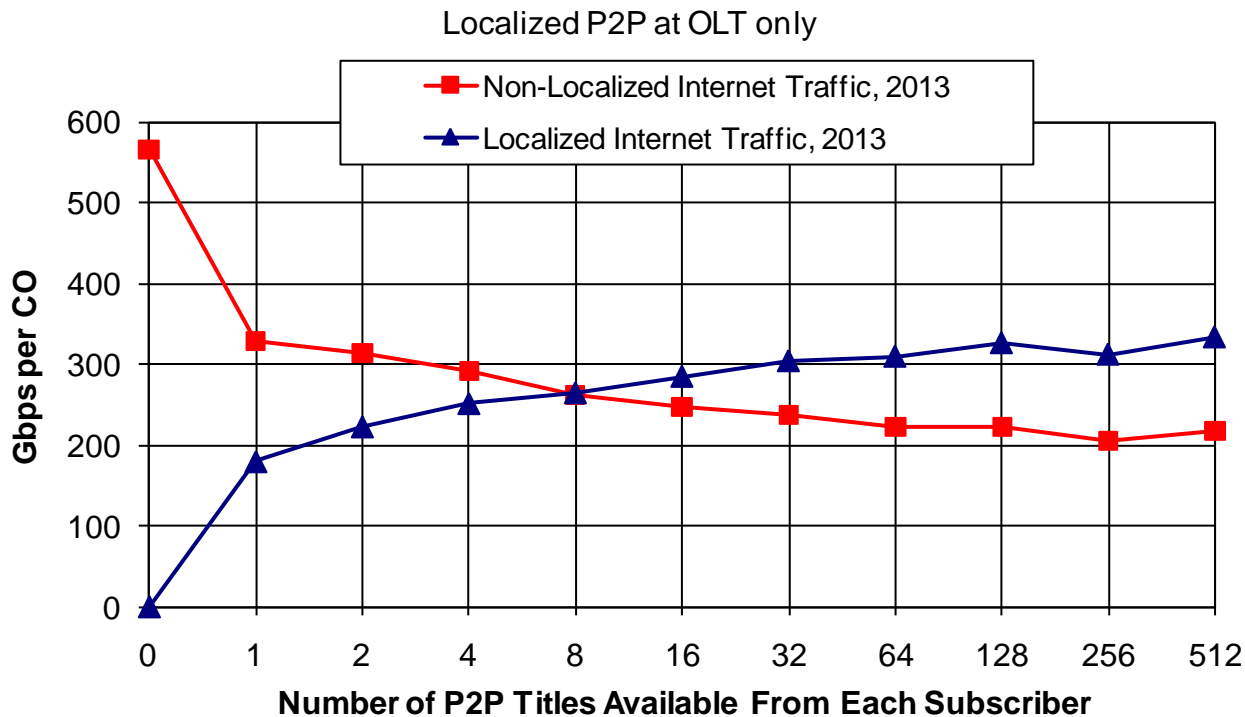
■ ■ ■ Combined Projection: Localized P2P Growth (Previous Slide) and Cisco Forecast

- 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