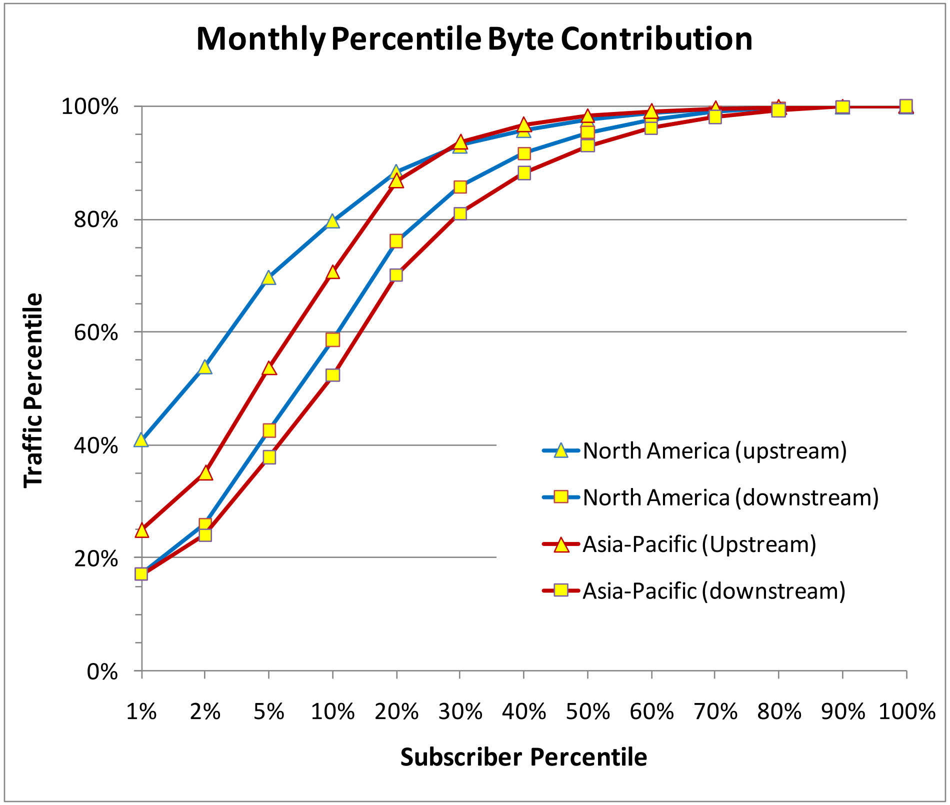
Resource Sharing
or
Designing Access Network For Low Cost

What Drives Demand for Bandwidth?

- **Usage**
  - In North America, the median usage is 4 GB per month, while the mean is almost 15 GB. Top users consistently exceeded 5 TB of monthly usage.
    - 1% of heaviest upstream users account for 40% of upstream bytes.
  - Median monthly data consumption on fixed access networks in Asia-Pacific is roughly 12 GB, and a mean is more than 35 GB
  - The average user of a fixed access network in North America is active online for almost 97 hours per month, in Asia Pacific -- 164 hours/month.



Source: *Fall 2010 Global Internet Phenomena Report*, Sandvine, Inc. (www.sandvine.com)

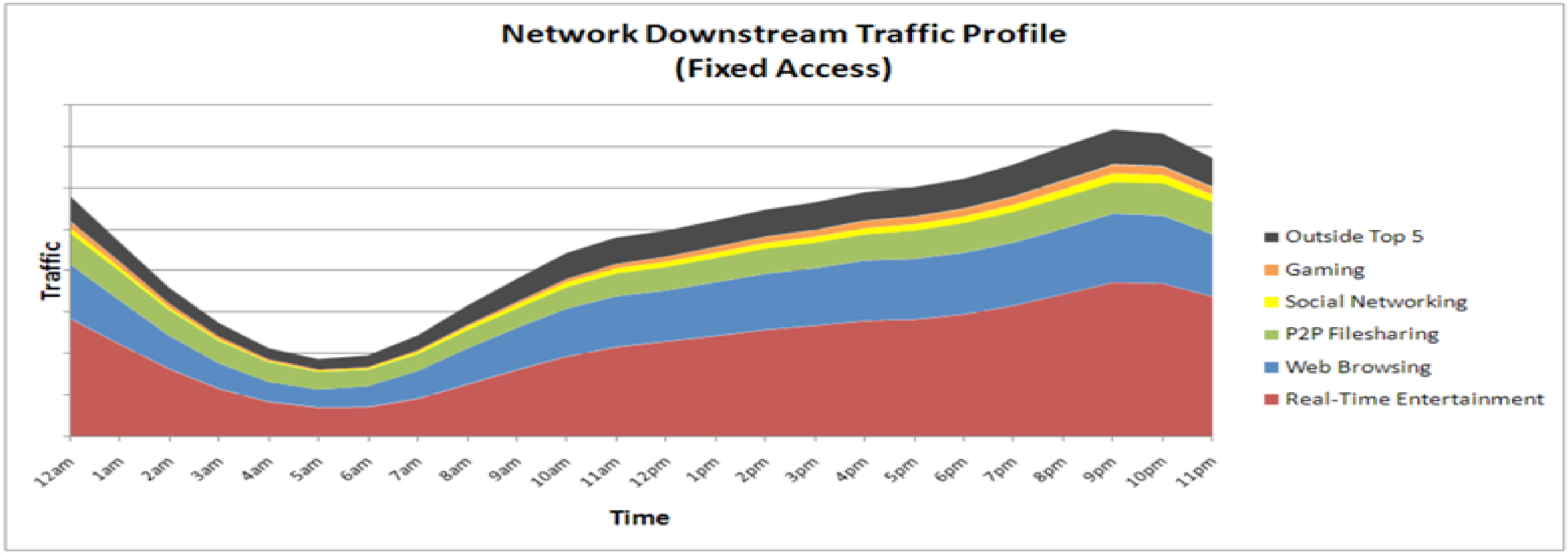
What Drives Demand for Bandwidth?

- **Applications**
  - 45.7: percent of downstream traffic on North American fixed access networks attributable to Real-Time Entertainment
    - SD IPTV: 2-4 Mb/s
    - HD IPTV: 8-12 Mb/s
    - 3D HD IPTV: 15-25 Mb/s

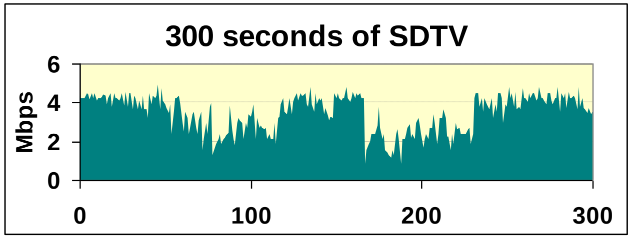
Source: *Fall 2010 Global Internet Phenomena Report*, Sandvine, Inc. (www.sandvine.com)

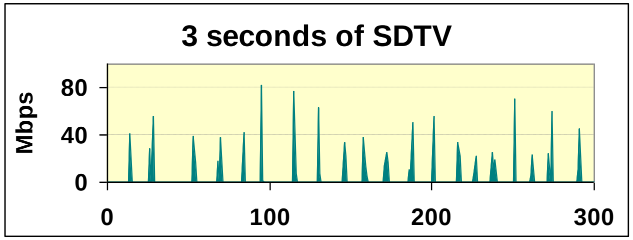
Traffic share by application (Peak Period)

Rank	Upstream		Downstream	
1	BitTorrent	34.31%	HTTP	22.70%
2	HTTP	12.36%	Netflix	20.61%
3	Gnutella	11.18%	YouTube	9.85%
4	Netflix	4.34%	BitTorrent	8.39%
5	Skype	3.28%	Flash Video	6.14%
6	SSL	2.99%	RTMP	6.13%
7	YouTube	2.47%	iTunes	2.58%
8	MGCP	2.46%	Facebook	2.44%
9	PPStream	2.41%	Gnutella	2.12%
10	Facebook	2.28%	Xbox Live	1.61%

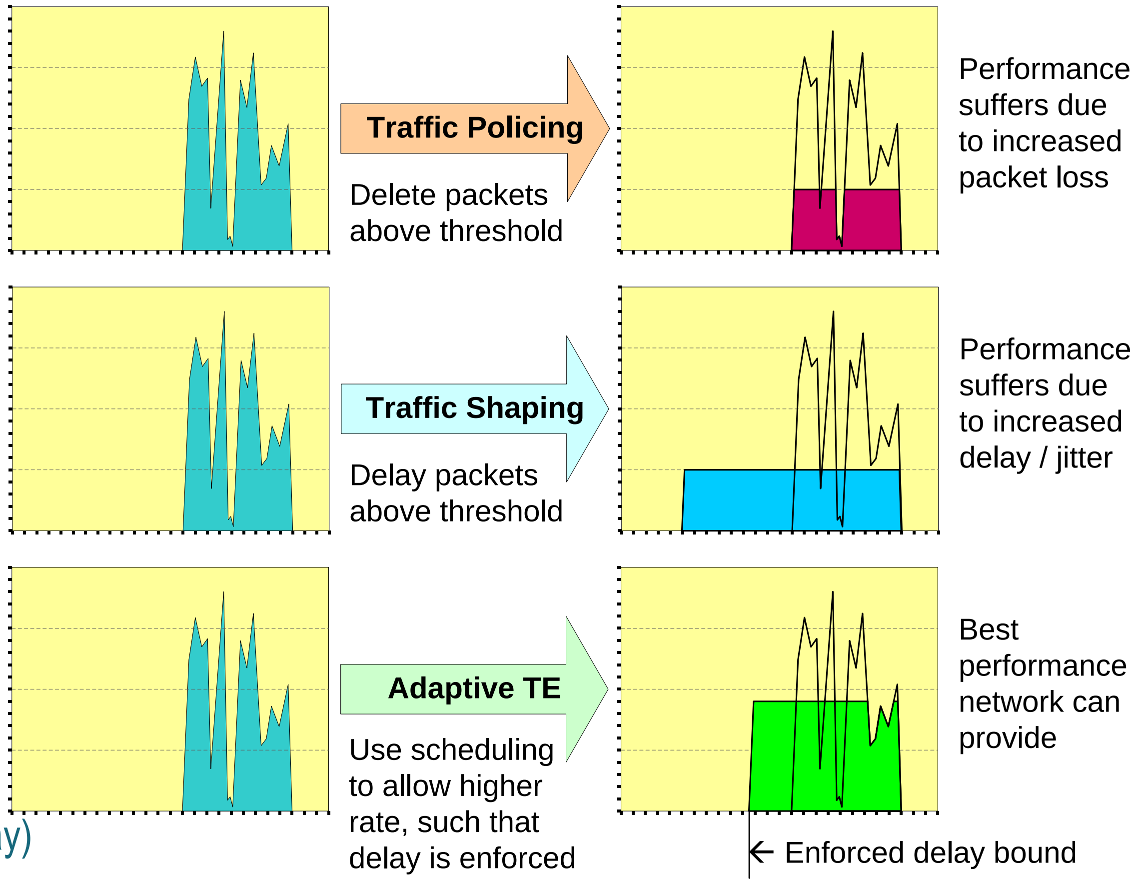


Engineering for IP Video





- **Video packets become useless after a certain delay**
  - It is better to drop packets earlier (and free some bandwidth) rather than deliver late (and drop at the destination anyway)



- **Need to intelligently combine scheduling, shaping and policing to accommodate busrty traffic**

Capacity Sharing is Crucial

- **Data/video traffic is bursty at many timescales (second-order self-similar).**
- **Burst size distribution is long-range dependant (heavy tailed):**
  most bursts are small, but most bytes arrive in large bursts.
  - From a data byte point of view, network is always busy!

(!) Static bandwidth assignment is very inefficient

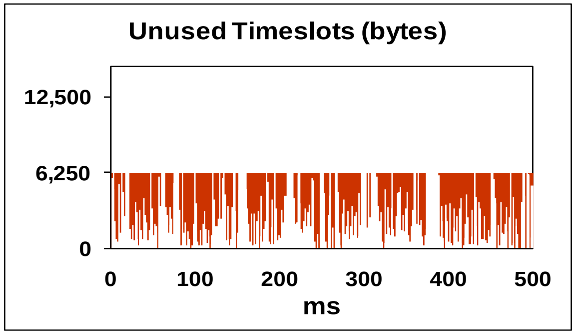
- Static slot size is not enough when a burst arrives
- Static slot size is underutilized between bursts

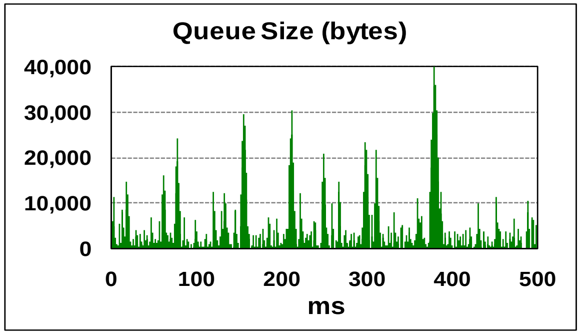
Output Stream

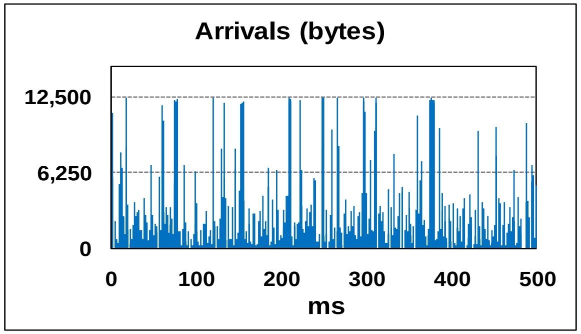
Input Stream

- Guaranteed fixed capacity = 50 Mbps (6250-byte slot / 1 ms)

- Link rate = 100 Mbps
- Average arrival rate = 20 Mbps





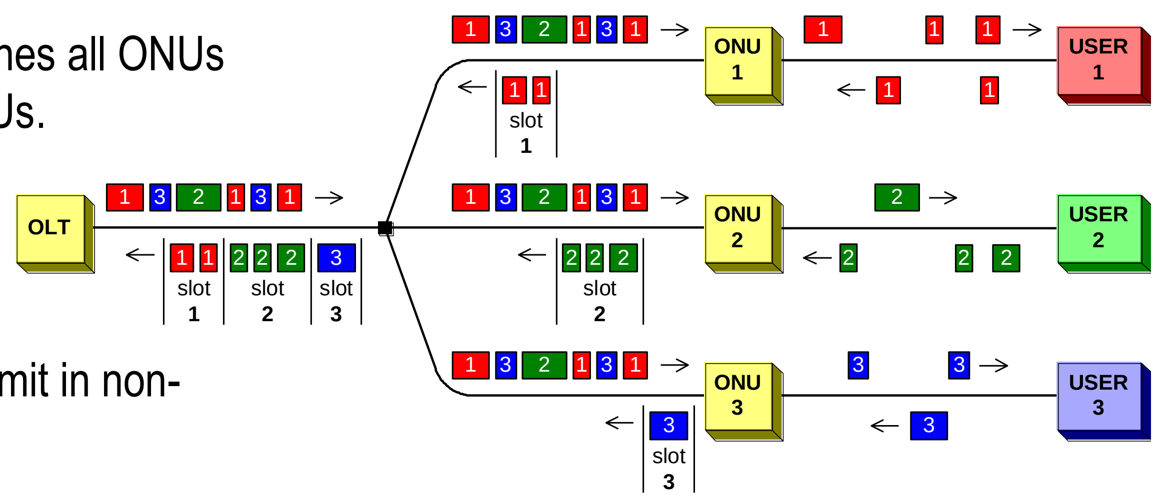


- **In this experiment, the egress capacity = 2.5 x ingress load. Still, the queue has grown to 40 Kbytes.**

EPON is Designed for Dynamic Sharing

Downstream

– Data stream from the OLT reaches all ONUs
– 802.3 Frames extracted by ONUs.



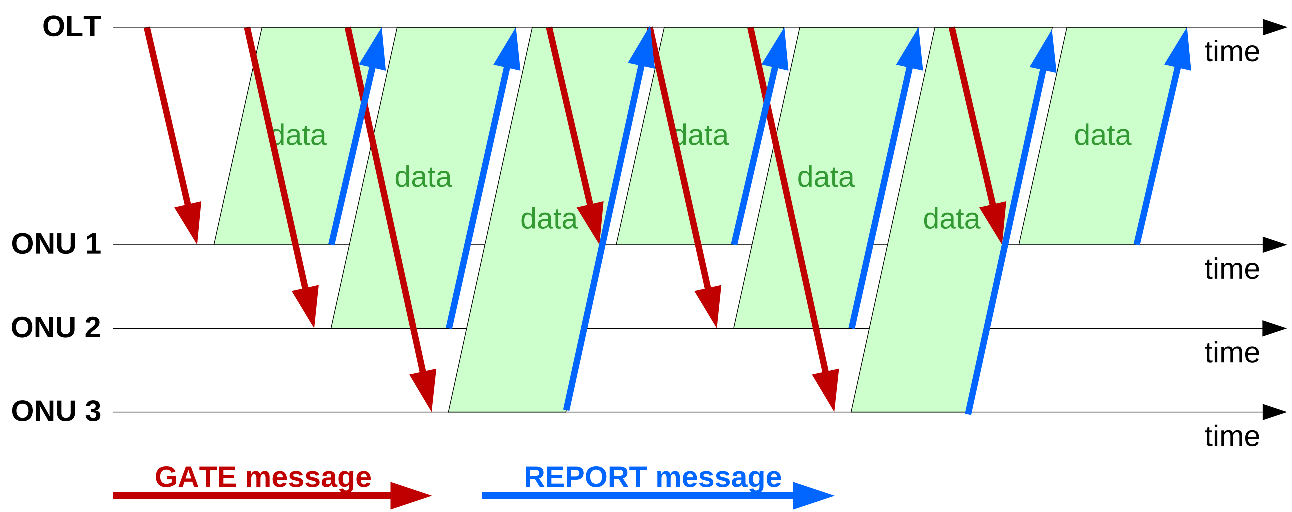
Upstream

– To avoid collisions, ONUs transmit in non-overlapping timeslots

– No packet fragmentation

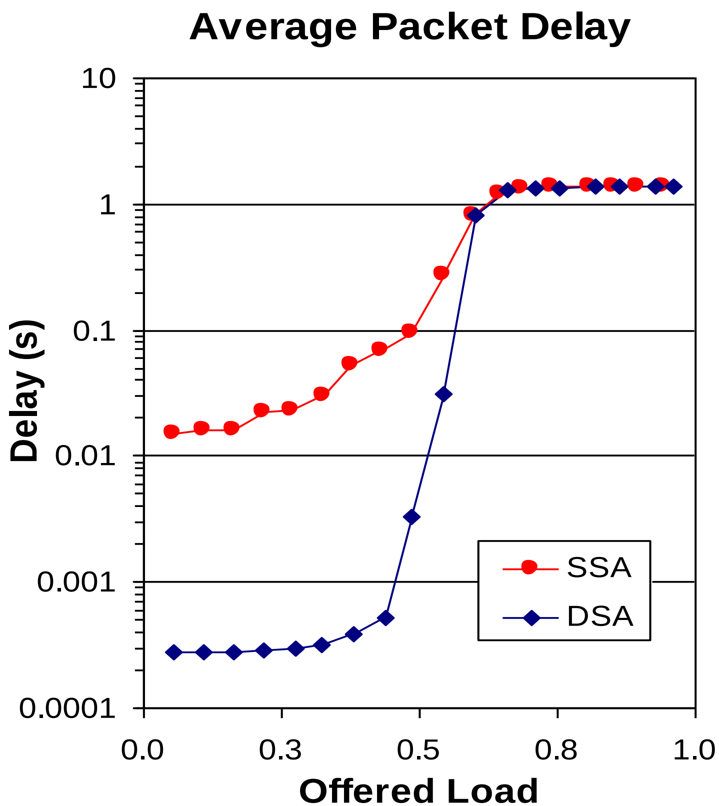
– Bandwidth assignment is done using GATE and REPORT messages

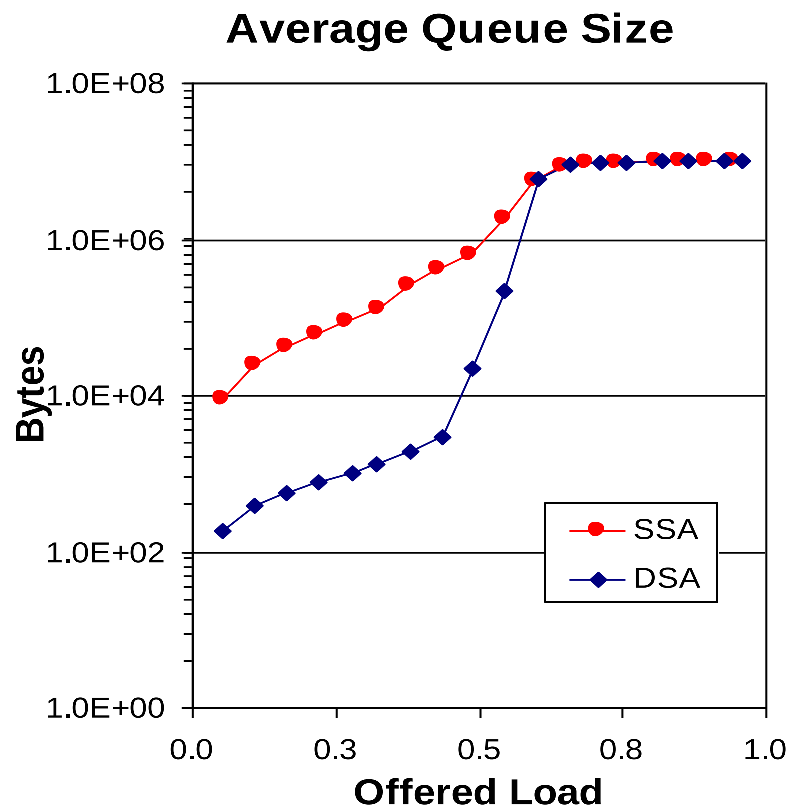
- **REPORT** tells OLT how many bytes are waiting in ONU's queues
- **GATE** tells ONU when and for how long it may transmit.



Static vs. Dynamic Bandwidth Assignment

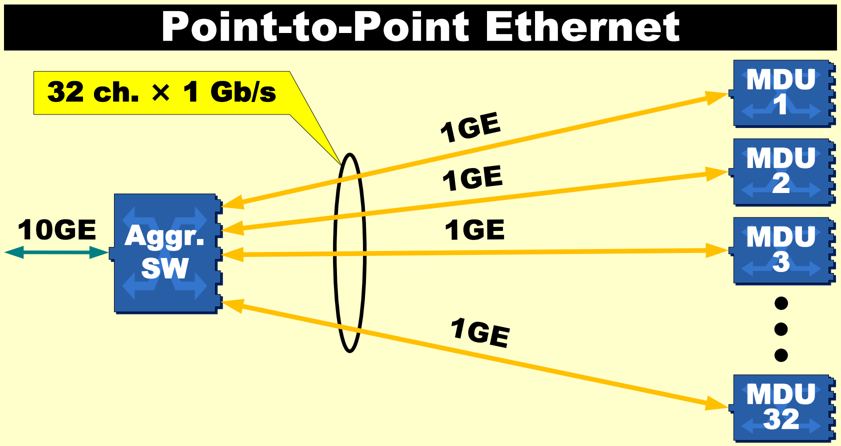
- Comparison of Static Slot Assignment (SSA) with Dynamic Slot Assignment (DSA) in a PON
  - Under SSA, avg. delay and avg. queue size ~ 50-100 times exceeds those under DSA

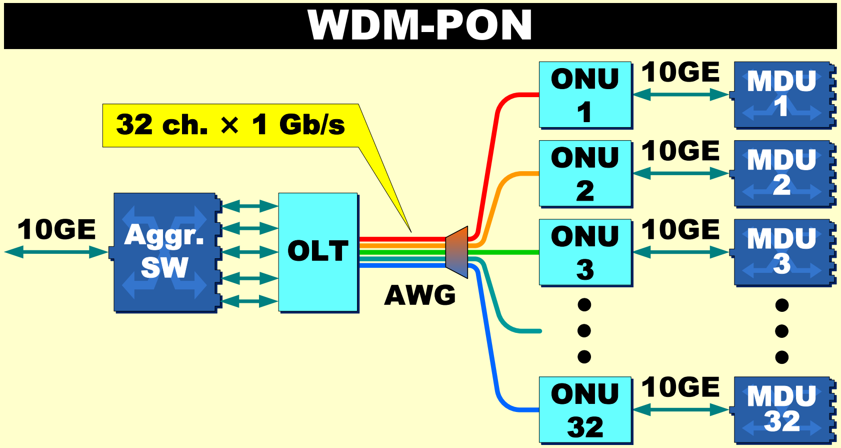




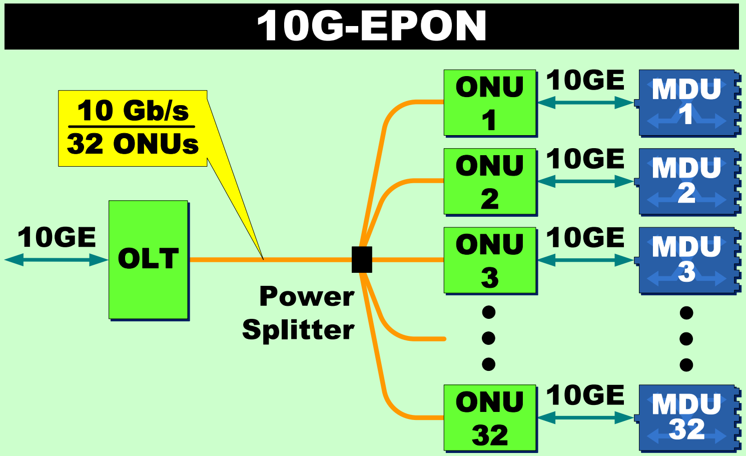
Shared vs. Dedicated Capacity

Dedicated (Fixed) Capacity



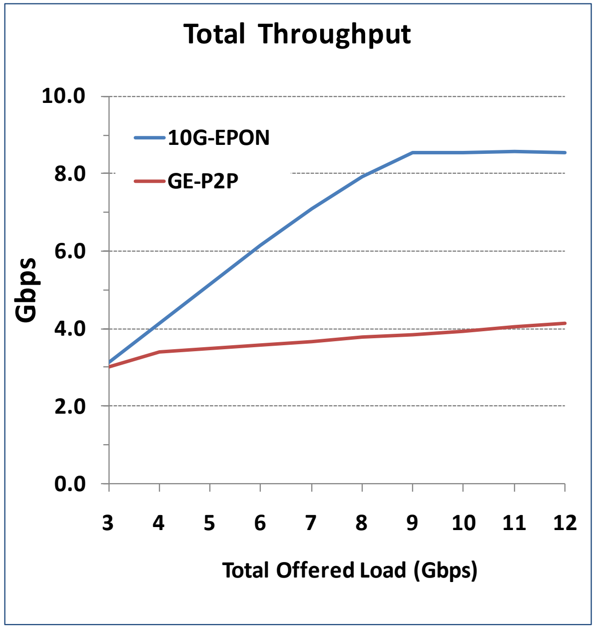


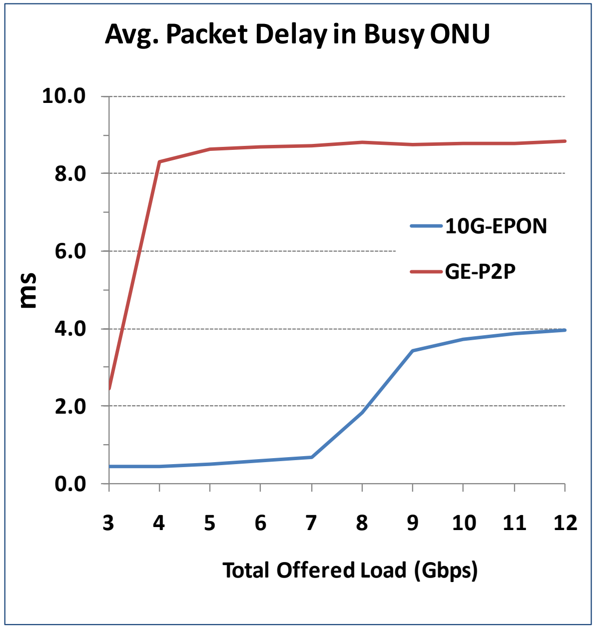
Shared (Variable) Capacity

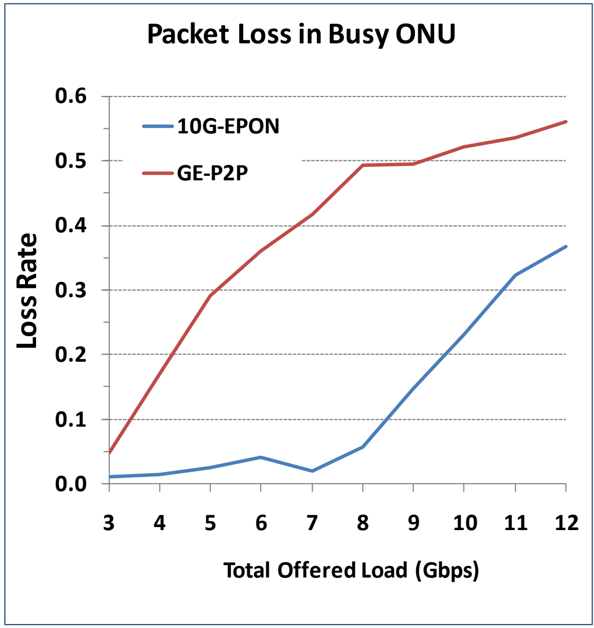


- Let's compare performance of three access architectures:
  - Point-to-point GE (32 GE ports)
  - WDM-PON (32 1Gb/s channels)
  - 10G-EPON (10Gb/s shared among 32 channels)
- Run simulation tests with bursty traffic and non-uniform load (10% of users generate 80% of traffic)

Sharing Is Good







(!) EPON with 10 Gb/s of aggregated capacity outperforms P2P Ethernet or WDM-PON with 32 Gb/s of aggregated capacity

- Ability to instantaneously redistribute capacity among busy users is the main advantage of TDMA-PONs (EPON and GPON)
- In P2P Ethernet case (or in WDM-PON), each MDU switch is confined to its fixed pipe.

Thank You