Multiple Access Techniques for ePON

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ALLOPTIC

FIBEROPTIC ACCESS SOLUTIONS

"First Mile" ≠ LAN

HAVE

- Non-cooperative (independent) users
- Non-uniform traffic: most traffic flows between CO and customers, not much between customers

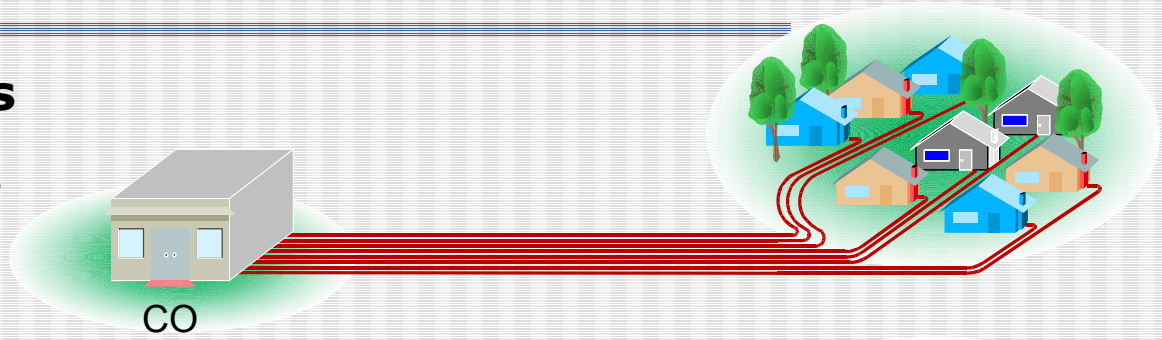
MUST

- Have SLA with every customer
- Not punish all for one misbehaving customer
- Guarantee security (privacy)

PON – a natural step in access evolution

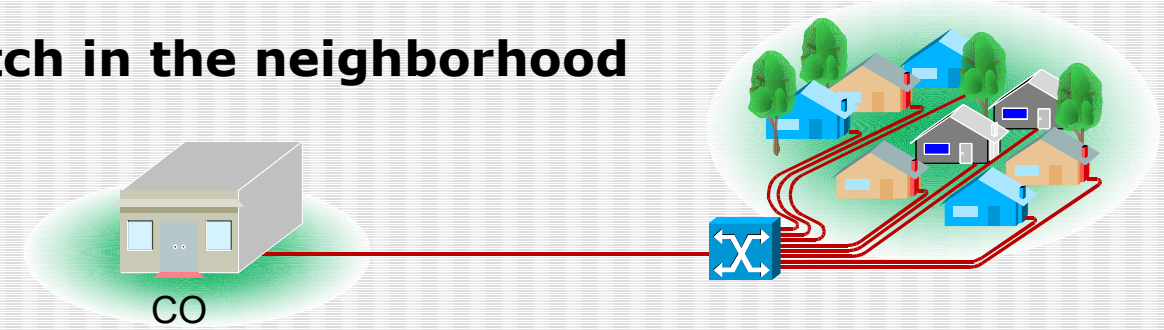
Point-to-point links

- Too many fiber lines
- 2*N* transceivers



Concentration switch in the neighborhood

- Power in the field
- 2*N* + 2 transceivers

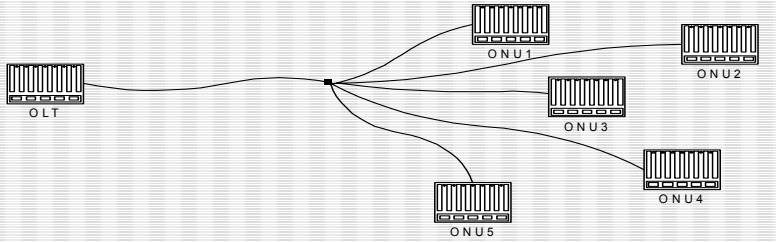


PON – a distributed switch

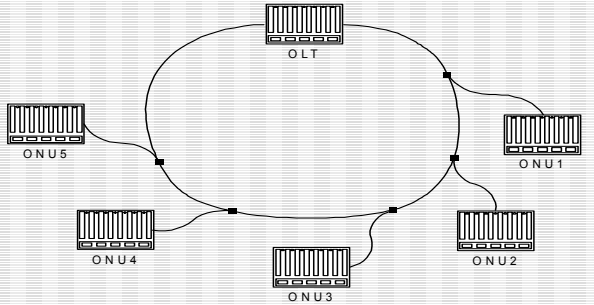
- Minimum fiber
- *N* + 1 transceivers
- Path transparency

What is Ethernet PON (ePON)?

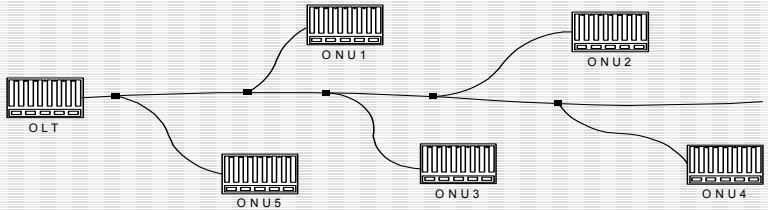
- ePON MAC uses Ethernet framing and line coding.
- Downstream channel uses true broadcast. Packets extracted by the MAC addresses.
- Upstream transmission uses multiple access. Which multiple access scheme?



(a) Tree topology

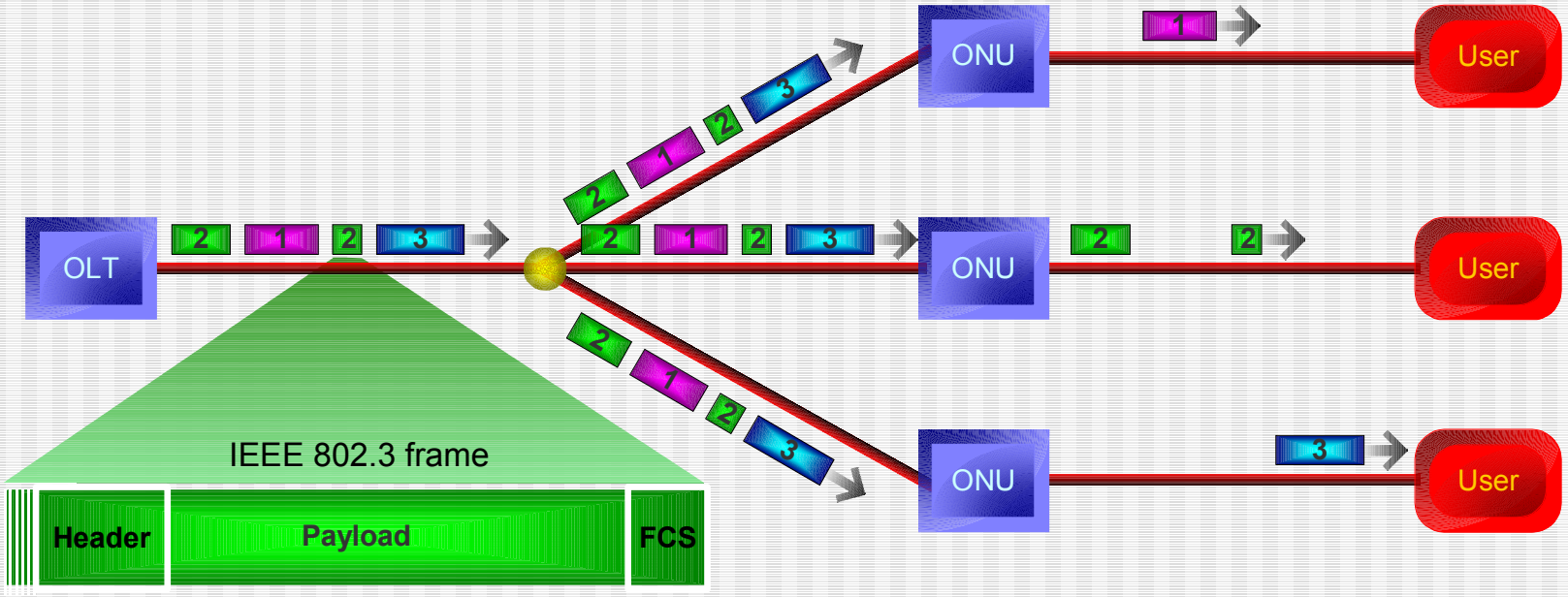


(c) Ring topology



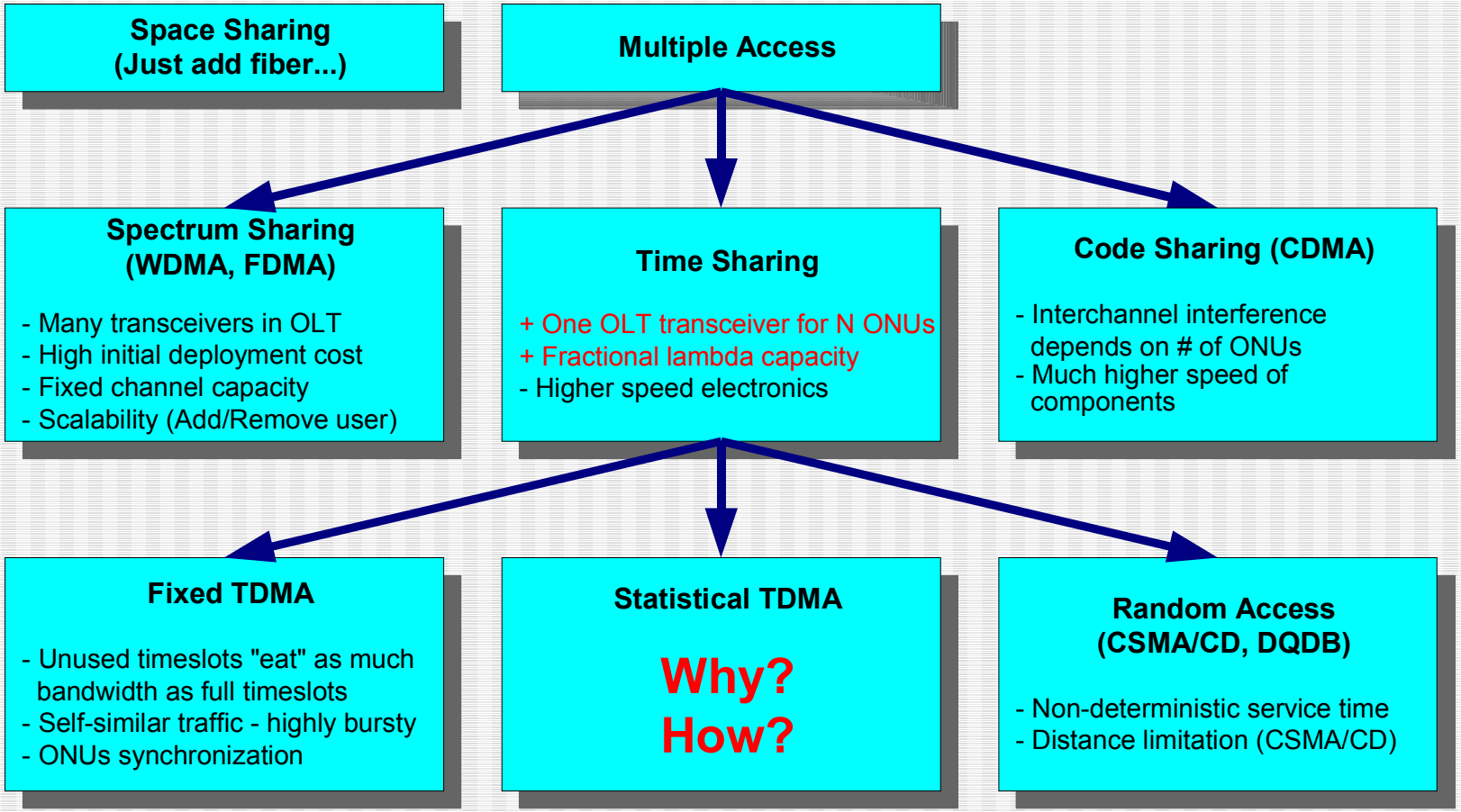
(b) Bus topology

Why is it Ethernet PON?



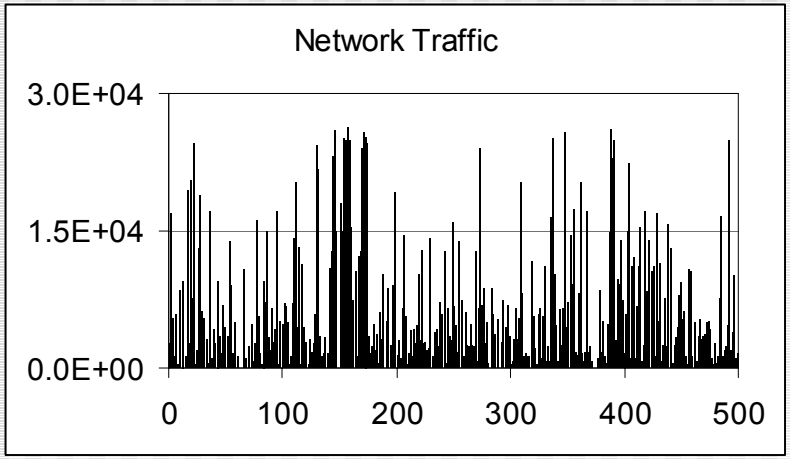
Downstream channel uses true broadcast.
Packets extracted by the MAC addresses.
Not different from any shared-medium Ethernet LAN.

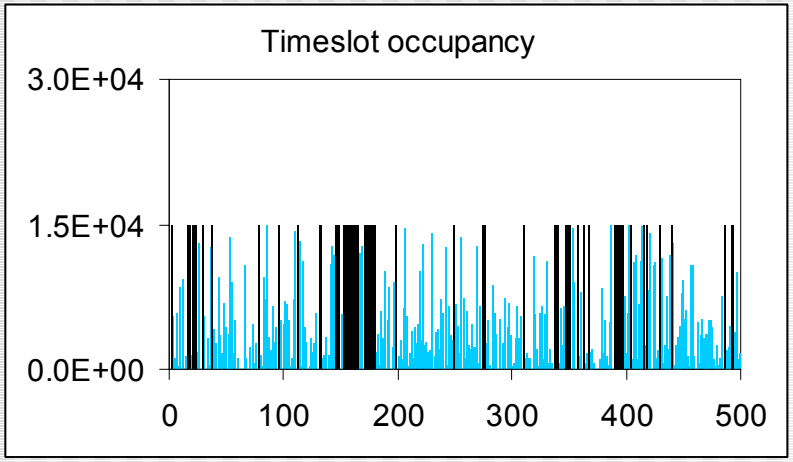
Multiple Access Schemes



Why statistical multiplexing is important?

- Data/video traffic is self-similar, i.e., bursty at many timescales. Flow aggregation doesn't help, i.e., no optimal fixed timeslot size exist.
- Burst size distribution is Long-Range Dependant (heavy tailed): most bursts are small, but most bytes arrive in large bursts.





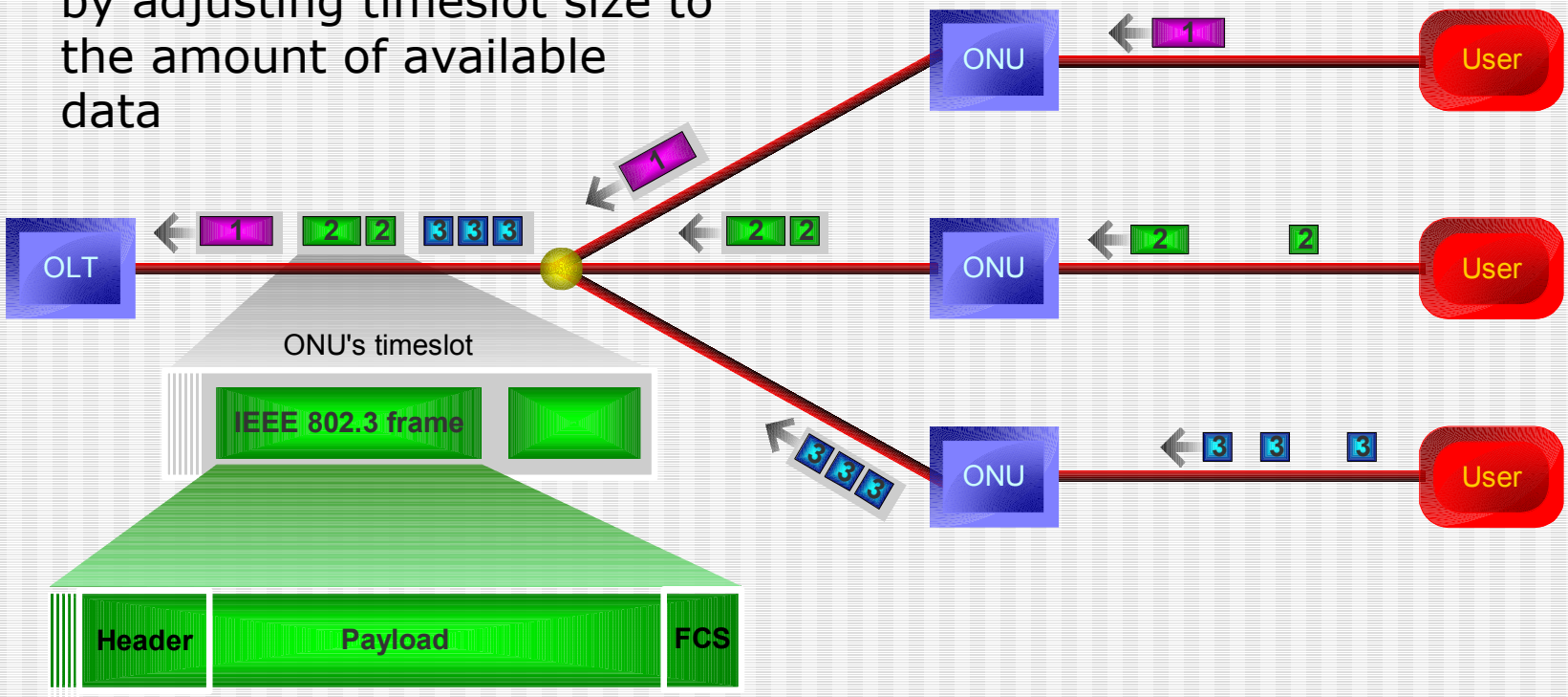
▲ **Overutilized** ▼ **Underutilized**

Statistical multiplexing schemes

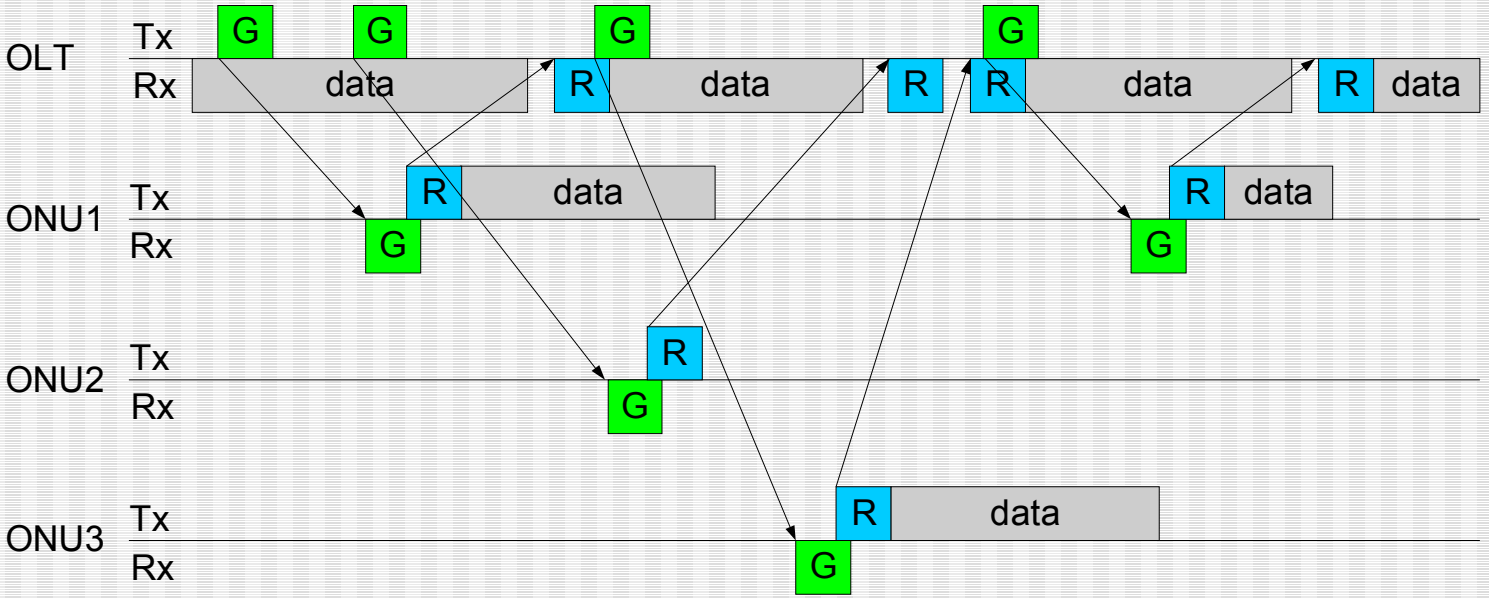
- Burst time and size are hard to predict => must use schemes with feedback (like polling).
- Roll-call polling is nice, but requires ONUs to listen to each other, i.e., PON should be deployed as a broadcasting star or passive ring (too restrictive).
- Hub polling could work, but walk times are very large.
- Solution: Interleave polling routines in time.

Upstream transmission

- ONU sends Ethernet frames within assigned timeslot
- Statistical multiplexing is achieved by adjusting timeslot size to the amount of available data



Interleaved polling scheme



SLA/Bandwidth provisioning

- Maximum Transmission Window (MTW) determines the guaranteed bandwidth provisioned to ONU.
- MTW may be different for different ONUs.

Example:

1 Gbps ePON; 16 ONUs with equal MTW

	Guaranteed bandwidth	**Best-case bandwidth** (only one ONU has data to send)
Guard Band = 5 μs MTW = 15000 bytes	60 Mbps	600 Mbps
Guard Band = 8 μs MTW = 14625 bytes	58.5 Mbps	478 Mbps

Disconnected ONU

- May happen often (especially in FTTH systems).
- Disconnected ONU should not use network resources.

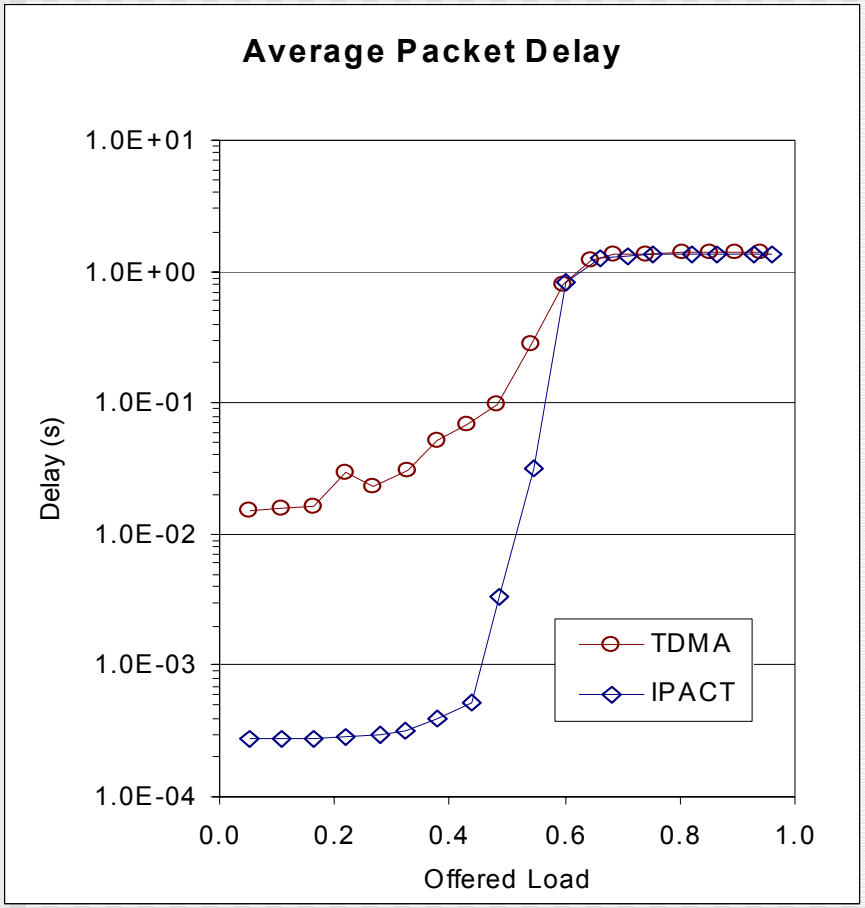
Solution:

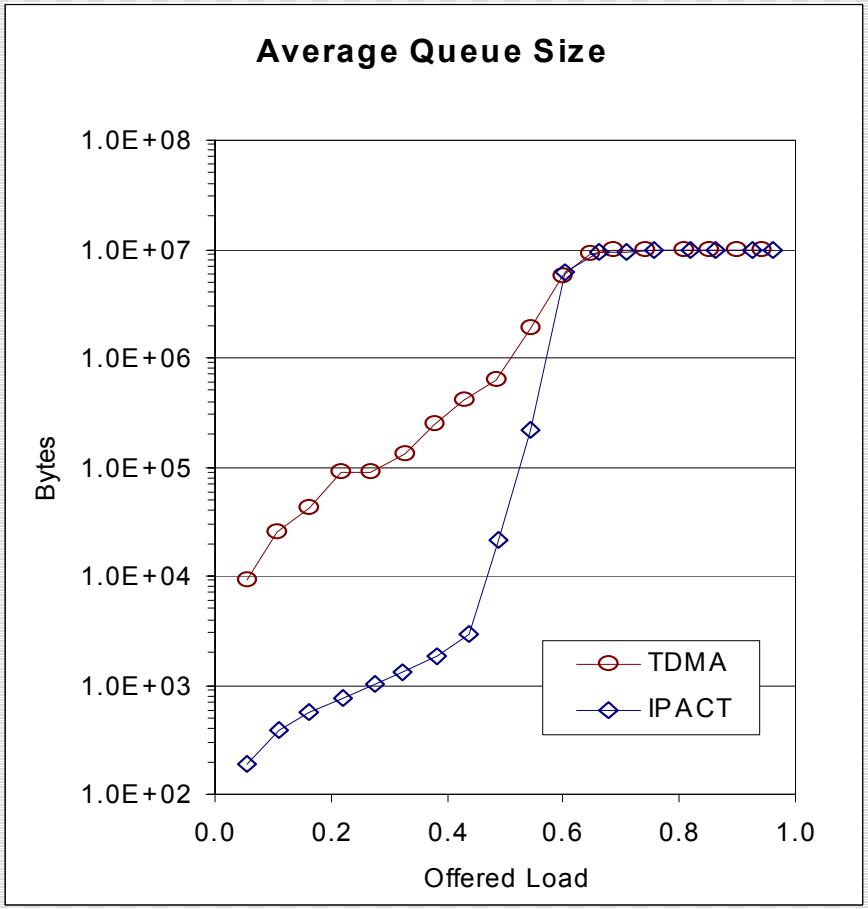
- New Request should arrive within RTT + Δt after the Grant
- Missing Request (*k* Requsts) means ONU is disconnected
- Wait 1 minute before querying this ONU again.
- Disconnected ONU consumes only ~0.0005% of PON bandwidth.

Important:

- Make no assumptions about RTT of disconnected ONU.

Simulation results (uniform load)





Advantages of Interleaved Polling Scheme

- **Bandwidth utilization.** If only one ONU is active, it can use up to **600 Mbps** (with 5 μs guard band).
- **Lower delay**. Delay is bounded by RTT, not frame time. Under maximum load behaves like TDMA system.
- **No ONU's synchronization necessary**. ONU sends data immediately on receiving (processing) the control message (Grant). No centralized framing necessary.
- **All "smarts" are in OLT**. OLT may use various scheduling algorithms based on SLA, type of traffic, etc.
- **Fast detection of disconnected ONU**. Disconnected ONU "consumes" only **~0.0005%** of PON bandwidth.

Summary

ePON-based "First Mile"...

- Minimizes fiber deployment
- Uses minimum number of transceivers
- Allows for downstream video broadcasting (analog overlay?)
- Eliminates electronic equipment in the outside plant
- Utilizes bandwidth efficiently (with right protocol)

Need to study

- Grant/Request scheduling approaches
- Upgrade scenarios
- Security/Privacy issues