

EPoC Resource Allocation

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Presentation Outline

- Downstream resource allocation
- Upstream resource allocation
 - Applying MPCP across Optical and Coax Links
 - Separate MPCP for Optical and Coax Links
- Observations and Recommendations

Downstream Resource Allocation

- In the Downstream we have a point-to-multipoint transmission
 - In EPON: OLT transmits packets to all ONUs
 - No transmission “collision” problems -> no need to “schedule” transmissions for different ONUs
- With EPON + EPoC network there are opportunities to achieve traffic splitting gains and, hence, maximize the effective capacity of each of the links (optical/coax)
 - Packet filtering of traffic at OCUs (other than the one of interest)
 - OCU should have the capability to filter out the packets that are not meant for anyone in its network, including packets meant for any ONU
 - Can be based on LLID, forwarding only packets corresponding to LLIDs associated with CNU's connected to the particular OCU
- If no filtering mechanism is supported, the hybrid network is effectively run at the data rate of the slowest link (e.g. slowest coax link)

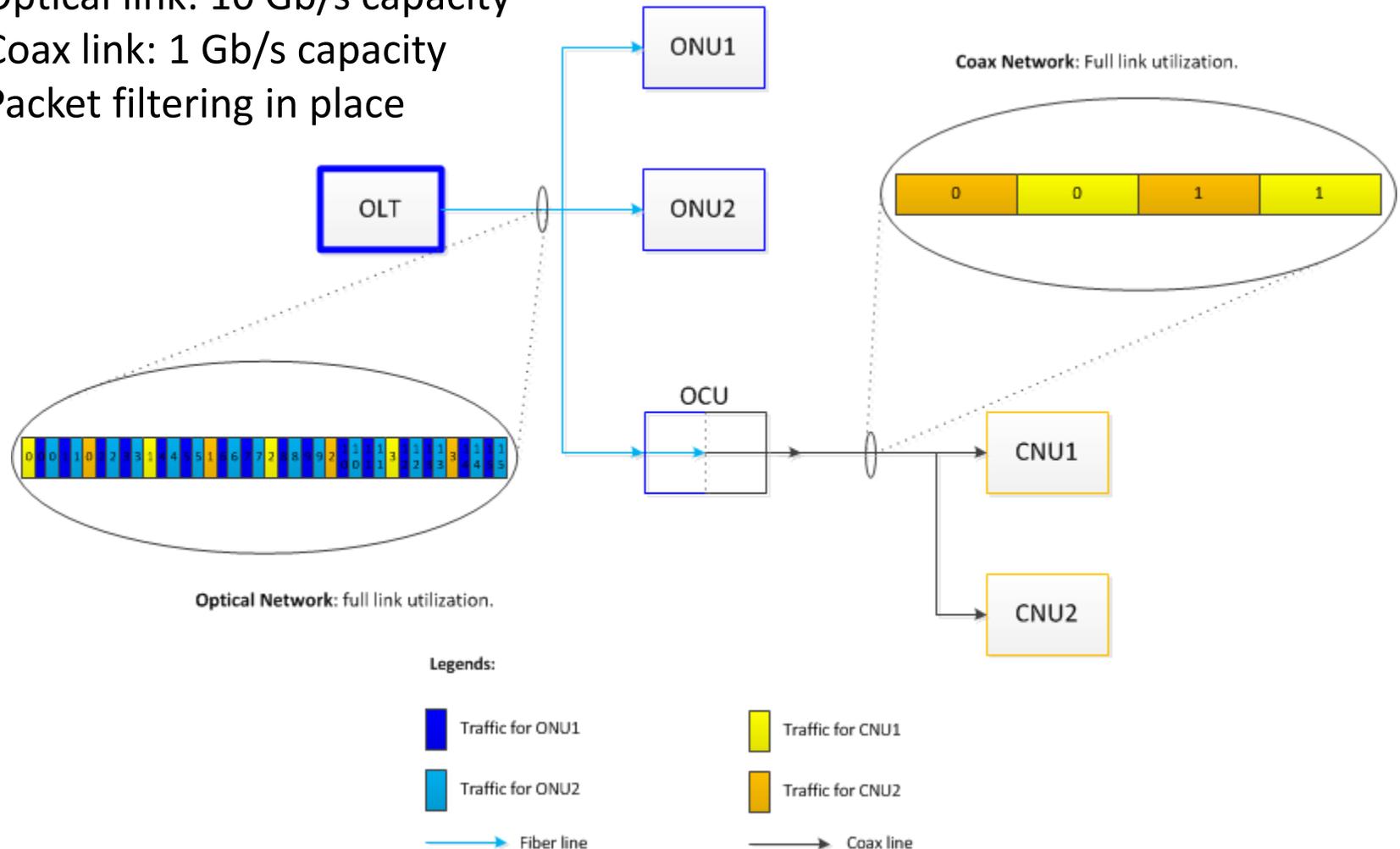
Transmission Characteristics Optical/Coax

- Optical transmissions use
 - OOK binary modulation – 1 bit at a time (0.1ns in 10 Gb/s EPON)
 - Time domain sequencing: one packet is transmitted after another
- Coax transmissions use
 - Higher order modulations – up to e.g. 12 bits per modulation symbol
 - Given the bandwidths that we are discussing to support Gbps for coax there are multiple modulation symbols per unit of time, e.g.,
 - OFDMA transmission with 7.5kHz subcarrier spacing (OFDM symbol length of ~135us): 16K modulation symbols per unit of time
 - Up to 24 KB per unit of time (135us)
- To convert from optical to coax domains:
 - Optical bits are encoded and modulated
 - Modulation bits are mapped onto the RF waveform and transmitted
 - Given the large number of bits available on each unit of time, it is desirable to multiplex in frequency multiple packet transmissions
 - The link capacity to different CNU's can be matched by the spectral efficiency of the transmission by selection of the appropriate modulation and coding scheme

Goal: Maximizing Downstream Utilization

Assumptions:

- Optical link: 10 Gb/s capacity
- Coax link: 1 Gb/s capacity
- Packet filtering in place

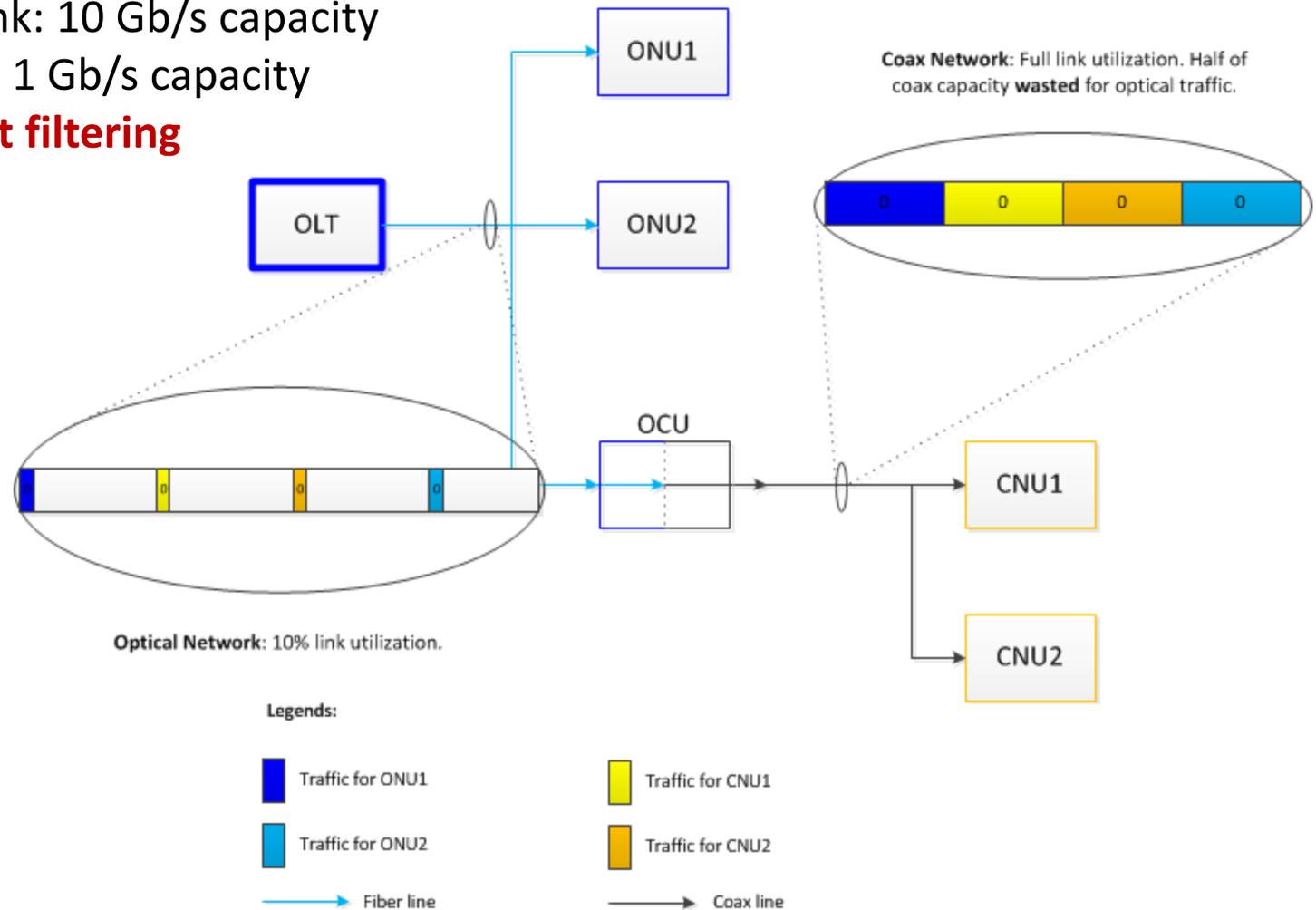


Optical link run at 10Gbps
Coax link run at 1Gbps effective data rate

What if there is no packet filtering at OCU?

Assumptions:

- Optical link: 10 Gb/s capacity
- Coax link: 1 Gb/s capacity
- **No packet filtering**



Double negative effect:

- 1) **Optical link run at 10% utilization (1 Gbps)**
- 2) **Coax capacity wasted with optical traffic (effective rate 500Mbps)**

Upstream Resource Allocation

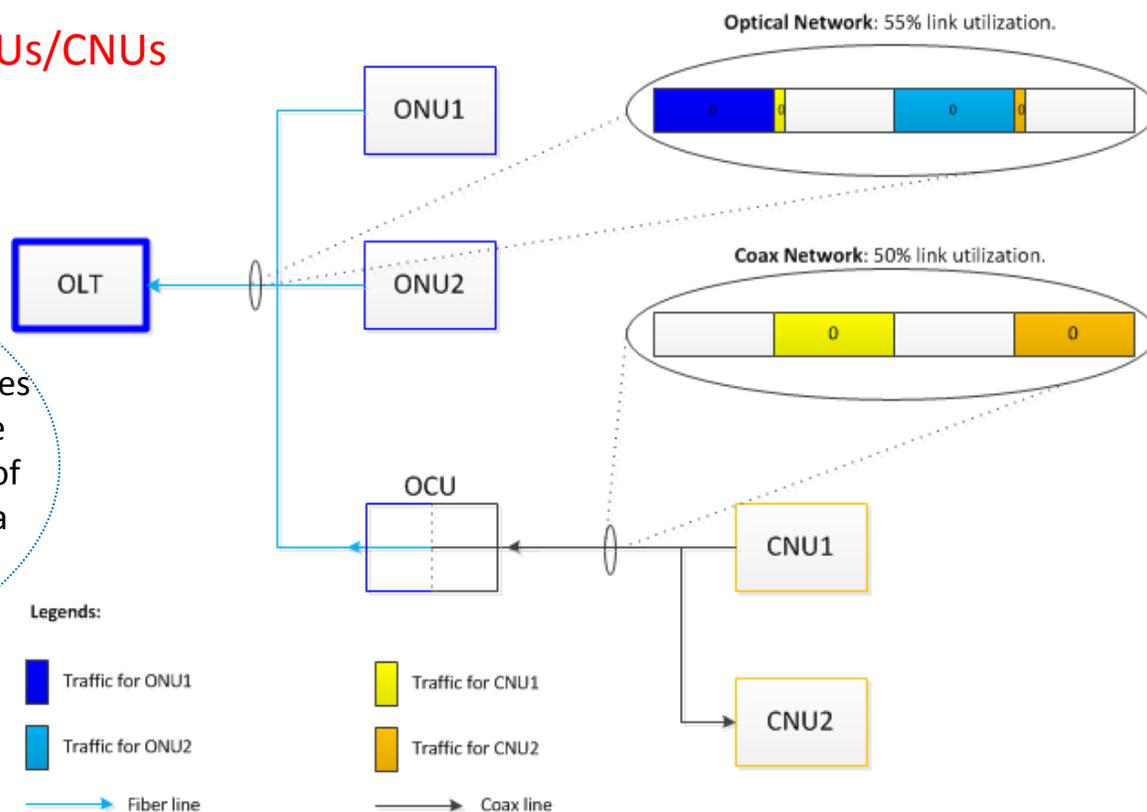
- In the Upstream we have a multipoint-to-point transmission
 - In EPON: different ONUs are time division multiplexed to avoid collisions of different LASER transmissions
 - Transmissions from different ONUs happen with pertinent time advances so that they do not collide in time at the OLT receiver
- The EPON upstream TDM scheme can be reused for EPoC
 - Reusing the existing MPCP protocol in a network with ONUs and CNU's to schedule Upstream transmissions will lead to high inefficiencies, primarily on the use of available fiber capacity
 - We look at two Examples to Illustrate Efficiency Issues
 - Equal (time) resources are allocated for each network unit (ONU/CNU)
 - Assuming all xNUs have plenty of data in their buffers, they will all request Upstream bandwidth
 - Equal data bandwidth allocated for each network unit (ONU/CNU)
 - Note that this requires OLT to have knowledge of the link capacity from each xNU (which might not be available when coax is added w/o OLT changes)

Applying MPCP across Optical and Coax Links

Assumptions:

- Optical link: 10 Gbps capacity
- Coax link: 1 Gbps capacity
- **Equal time allocation for ONUs/CNUs**

Translation of gate messages from time resources to time/frequency resources is not enough to make use of all available coax resources when the OLT is unaware of CNU supported rates. For that we need a separate resource management for the coax resources



Low utilization of Optical Medium

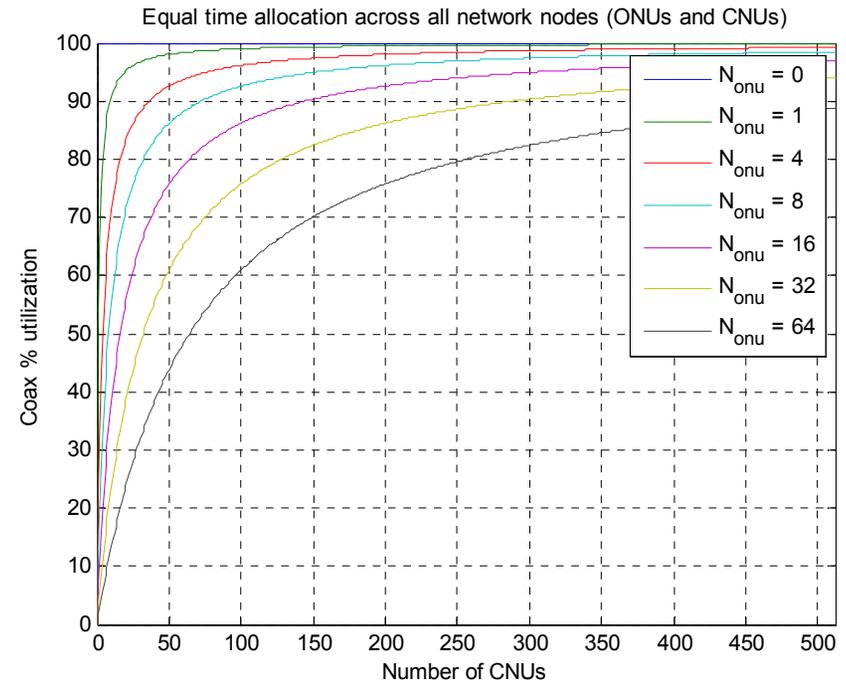
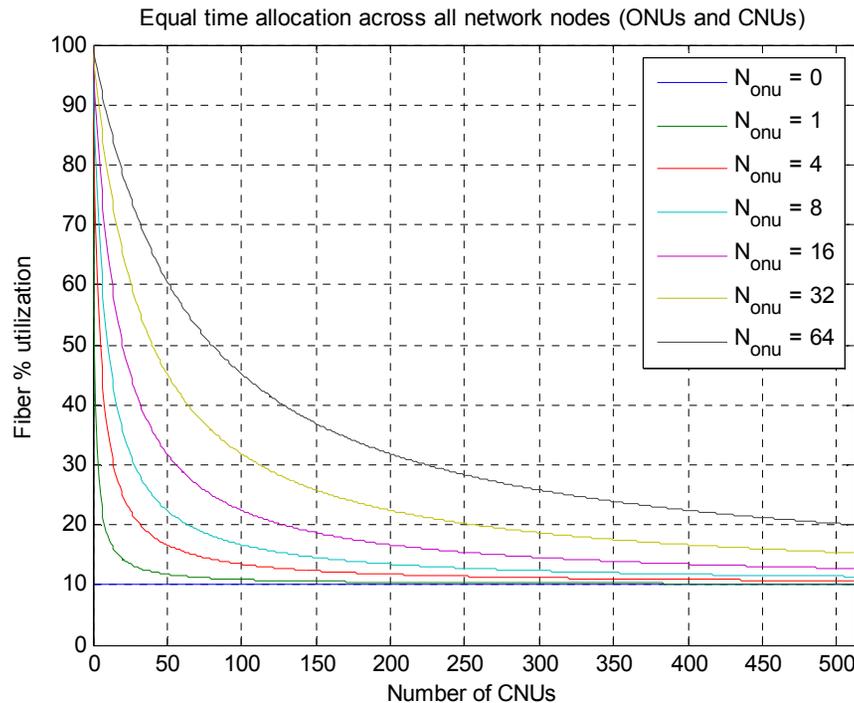
Fair utilization of Coax Medium

$$\text{Fiber Utilization} \approx (N_{\text{ONU}} + 0.1 * N_{\text{CNU}}) / N_{\text{TOT}}$$

$$\text{Coax Utilization} \approx N_{\text{CNU}} / N_{\text{TOT}}$$

Applying MPCP across Optical and Coax Links

Equal Time Allocation: Links utilizations



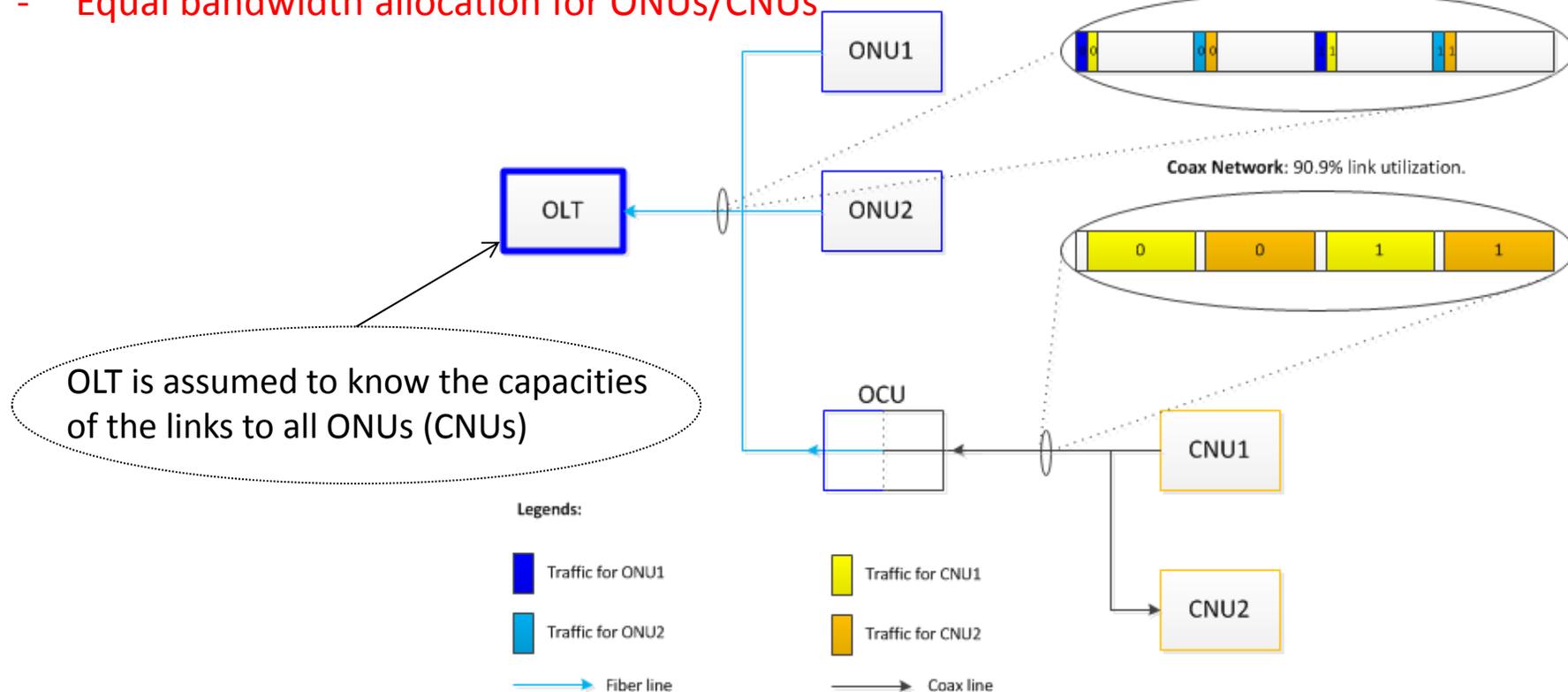
Observations:

- In this example, fiber utilization goes to 10% (1Gbps) as we increase the number of CNU, if the rate mismatch is not taken care properly
- For the sample point of 32 ONUs and 256 CNU we get:
 - Fiber utilization: 20%
 - Coax utilization: 89%
- There is no reason for not having 100% utilization of both links

Applying MPCP across Optical and Coax Links

Assumptions:

- Optical link: 10 Gbps capacity
- Coax link: 1 Gbps capacity
- **Equal bandwidth allocation for ONUs/CNUs**



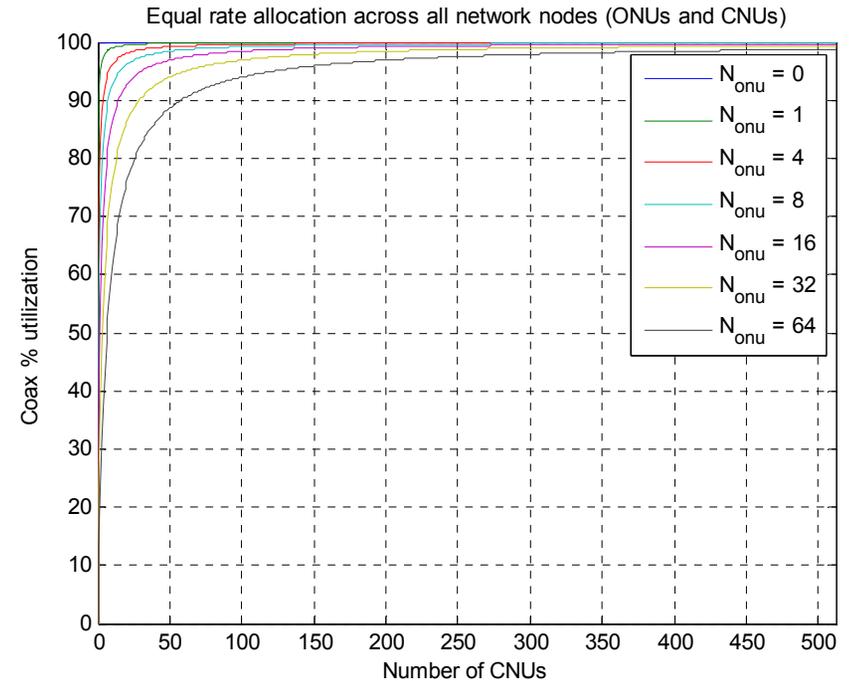
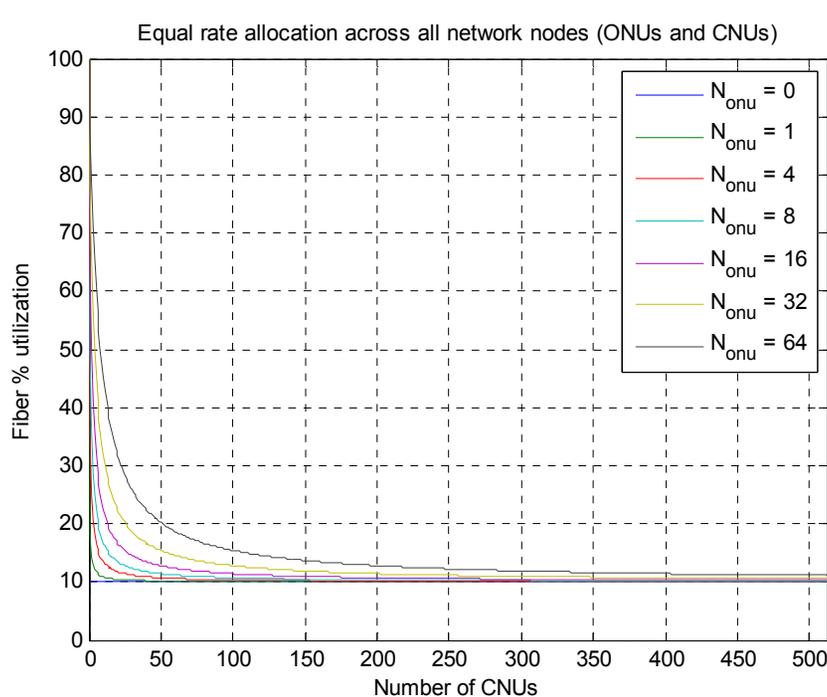
Very Low utilization of Optical Medium

High utilization of Coax Medium

Fiber Utilization $\approx N_{TOT} / (N_{ONU} + 10 * N_{CNU})$ Coax Utilization $\approx N_{CNU} / (N_{CNU} + 0.1 * N_{ONU})$

Applying MPCP across Optical and Coax Links

Equal bandwidth Allocation: Links utilizations



Observations:

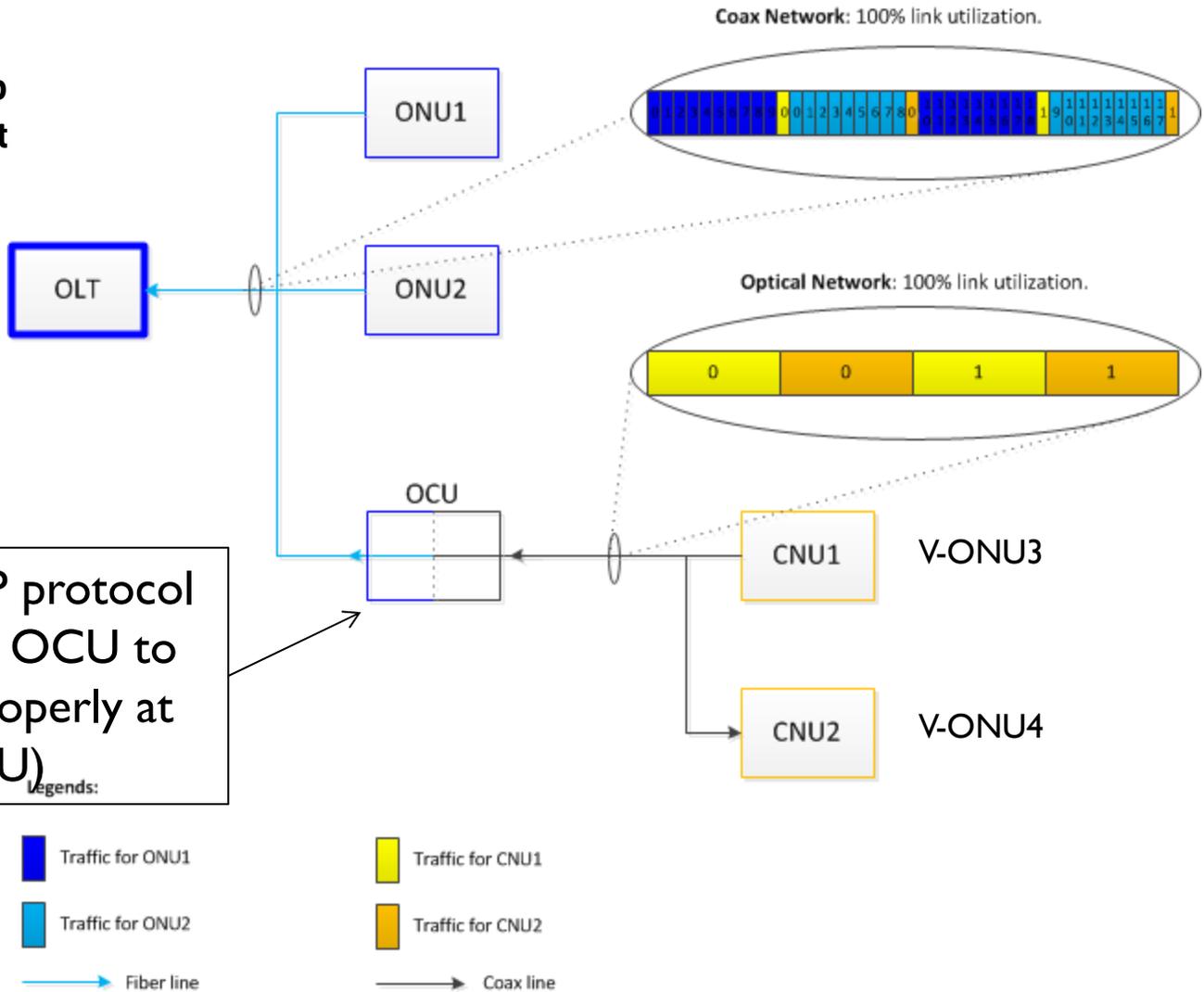
- Fiber utilization goes down very rapidly to 10% (1Gbps) as we increase the number of CNU, if the rate mismatch is not taken care properly
- For the sample point of 32 ONUs and 256 CNU we get:
 - Fiber utilization: 11%
 - Coax utilization: 99%
- There is no reason for not having 100% utilization of both links

Augmented MPCP for EPoC

Assumptions:

- Optical link: 10 Gbps cap
- Coax link: 1 Gbps capacit

An augmented MPCP protocol could be used by the OCU to manage resources properly at coax side (OCU/CNU).



Full utilization of both Coax and Optical Media

Observations and Conclusions

- Using MPCP protocol “as is” in OLT to manage resources on both optical and coax links means:
 - Single resource allocation and management for coax and optical link
 - Leads to low utilization of optical link as we increase the number of CNU, as OLT is not aware of the precise CNU rate capabilities
 - In the worst limit 10% fiber utilization in a 10 Gb/s EPON connected to 1 Gb/s coax (or whatever the slowest coax link data rate is)
 - Possibly low utilization of coax link when equal time allocations
- Using augmented MPCP protocol for coax resource management (at OCU):
 - Allows separate resource allocation and management for coax and optical links, without changes in the OLT
 - Leads to full utilization of optical and coax link capacities
 - Future proof: could be possibly integrated in an upgraded OLT

Recommendation

- As a result, we recommend having separate resource allocation to manage coax resources (from OCU to CNU) with augmented MPCP protocol and packet filtering
 - Ensure high utilization at both fiber and coax portion
 - Maintain single scheduler at OLT for both ONUs and CNU
 - Backward compatible

