End-to-End Performance of Heterogeneous Multi-EPON/OBS Networks

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Outline

- Introduction
  - Optical Burst Switching
  - Ethernet Passive Optical Network
- EPON-OBS inter-working
- Investigated scenario
- Numerical results
  - TCP performance
  - Simulation through ns2
- Conclusions

Optical Networks: Evolution

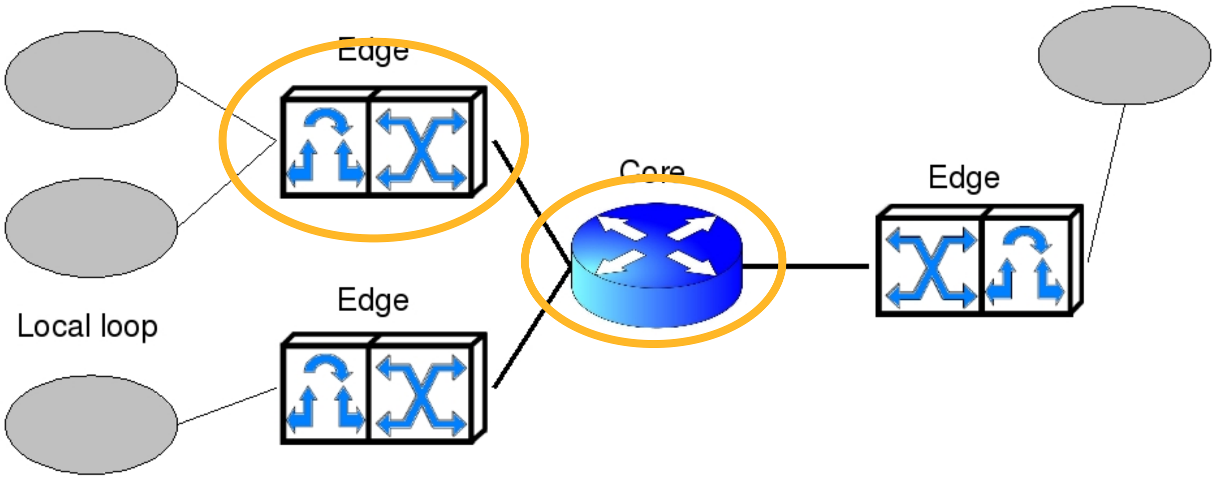
- DWDM technique
  - **Transmission rate in the range of Tbit/s**
- Architectural semplification
  - **From IP over ATM over SONET over WDM to IP over WDM**
- Need to exploit in an effective way the huge transmission bandwidth with IP traffic
  - **Wavelength Routing**
    - ✓ all-optical data network
    - ✓ Low flexibility for IP traffic
  - **Optical Packet Switching**
    - ✓ Ideal transfer mode for IP traffic
    - ✓ Severe technological constraints → not feasible in the short/middle term
      - Optical components immature

Optical Burst Switching

Goal: better sinergy between the mature electronic technologies and the new optical tecnologies (mid-term solutions)

- **Switching granularity between WR and OPS**
  - *Burst concept:* aggregation of IP packets with common features (e.g. destination and QoS), considered as the basic optical unit
- **Time and <u>space separation</u> of data and control (header) fields**
  - Control packet employs dedicated channel and precedes the relative data burst
    - ✓ All-optical network, buffer-less and data trasparent
    - ✓ Hybrid opto-electronic network for control signals (*out-of-band signaling*)
  - Simplification of the electronic processing of the control packets at intermediate nodes
  - Reduction of the opto-electronic functionalities required to router

Optical Burst Switching



Burst

- Variable length
- All-optical domain for data

Header

- Out-of-band transmission
- O/E/O in core nodes

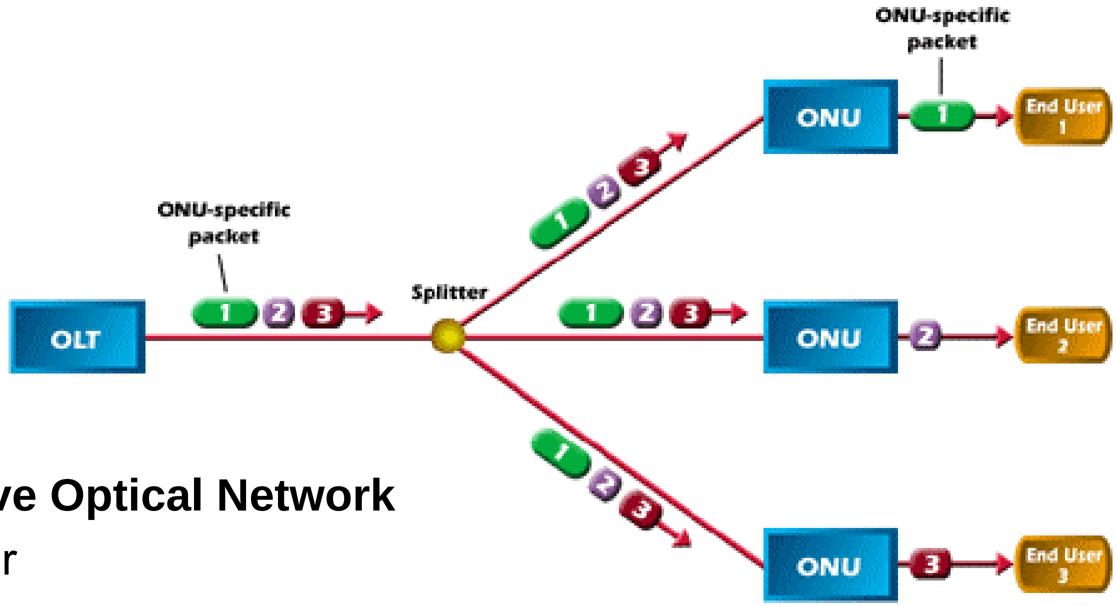
Edge node

- Burst Assembly
- Header generation

Core node

- Header processing
- Burst forwarding

Ethernet Passive Optical Network



Ethernet Passive Optical Network

- Optical fiber
- Passive components
- Ethernet protocol

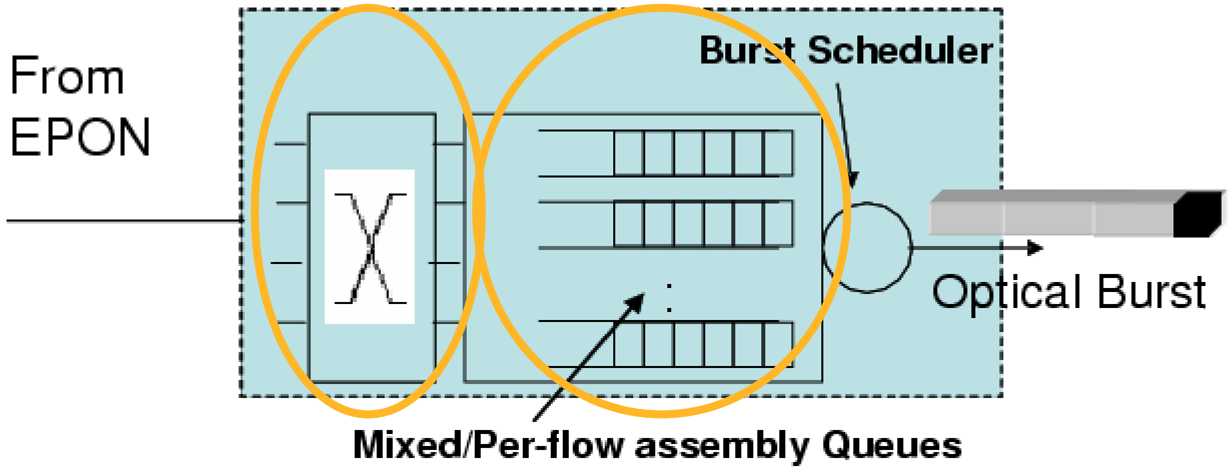
Downstream transmission

- Point-to-multipoint
- Each ONU selects its data

Upstream transmission

- Point-to-point
- Multiple Access → TDM
- Dynamic bandwidth assignement → IPACT
- Use of *grant* - *request* packets
- *Limited* discipline
- Cycle time: T_c

EPON-OBS inter-working



IP look-up

Queues
- destination
- class-of-service

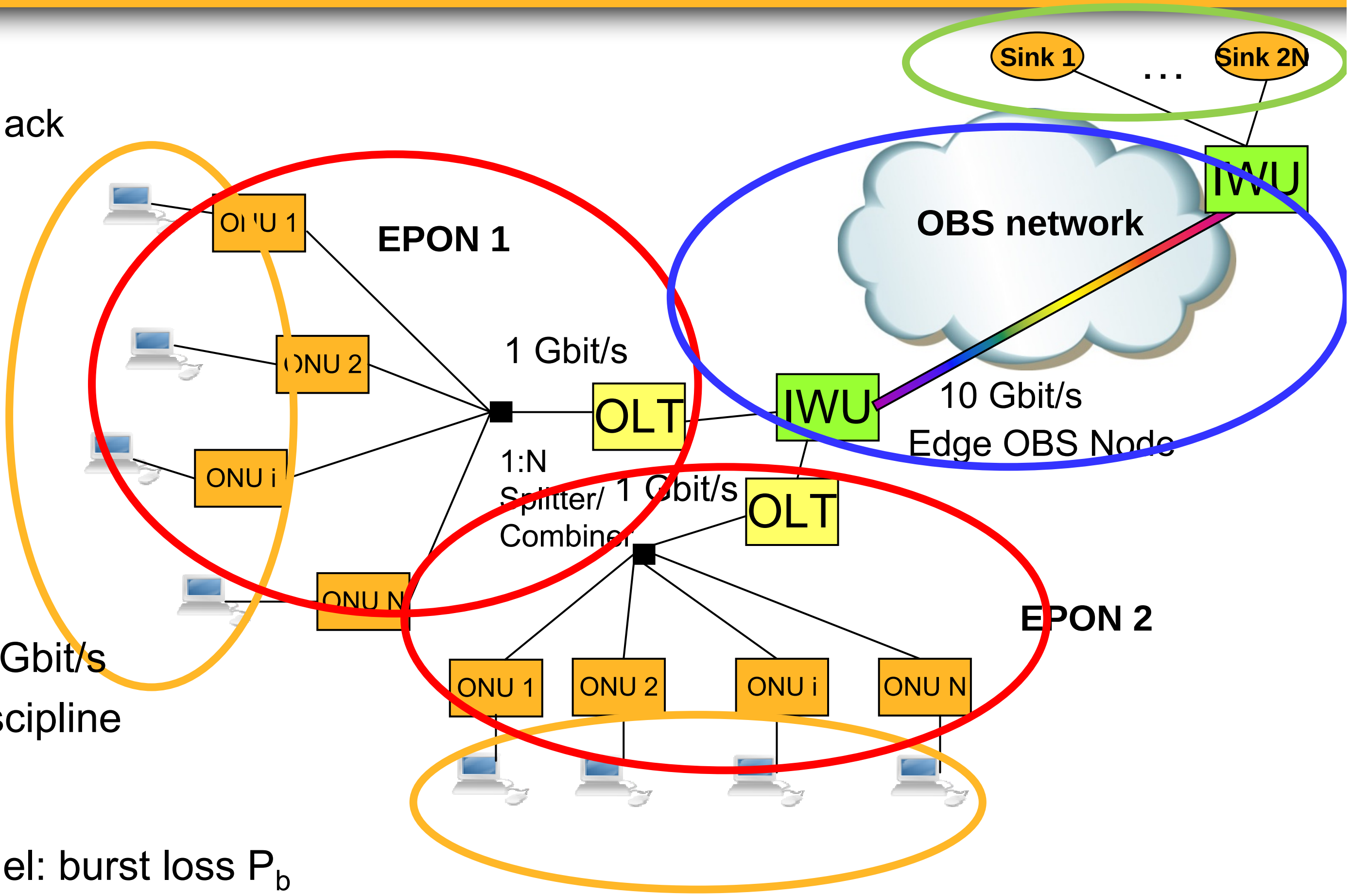
Assembly algorithm
- Timer based
- Length based
- ....

- mixed flow
- per -flow

Investigated Scenario

Sources

- TCP Reno with selective ack
- Segment size: 512 byte
- CBR at 100 Mbit/s



EPON

- 10 ONUs
- Shared access bw: 1 Gbit/s
- IPACT with limited discipline

OBS network

- Link with error-model: burst loss P_b
- Bandwidth: 10 Gbit/s
- Burst assembly: *timer based* T_{max}
- Queueing: *mixed flow*

Sinks

- ack transmissions

Performance Evaluation: Metrics

Throughput

- Measure of the variability of the bandwidth usage over a given time-scale
- Average throughput: amount of successfully transmitted bytes in a given time interval (e.g. (0,t])

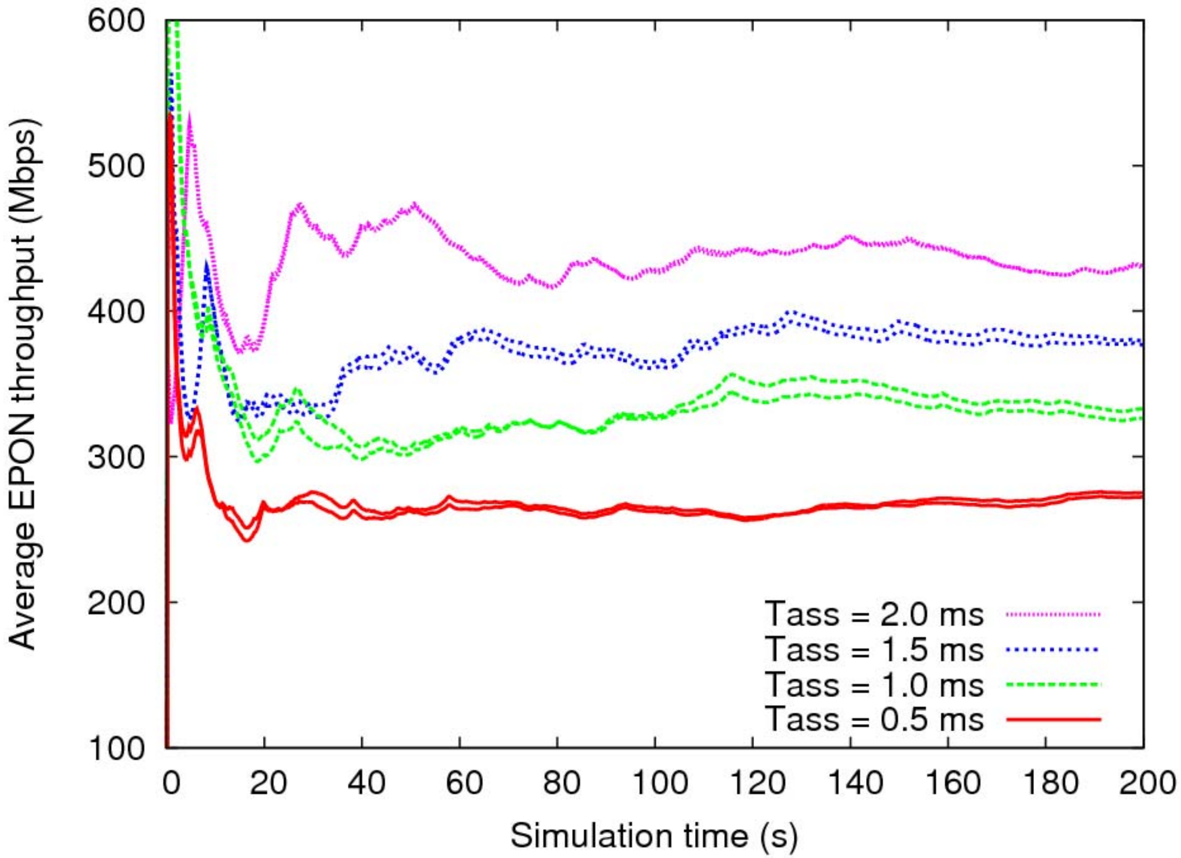
Fairness

- Chiu/Jain's Fairness Index
- Intra-fairness index
- Best intra-fairness => F=1

$$F_{\text{intra}} = \frac{B_{P,\min}}{B_{P,\max}}$$

Average throughput per EPON vs. Time

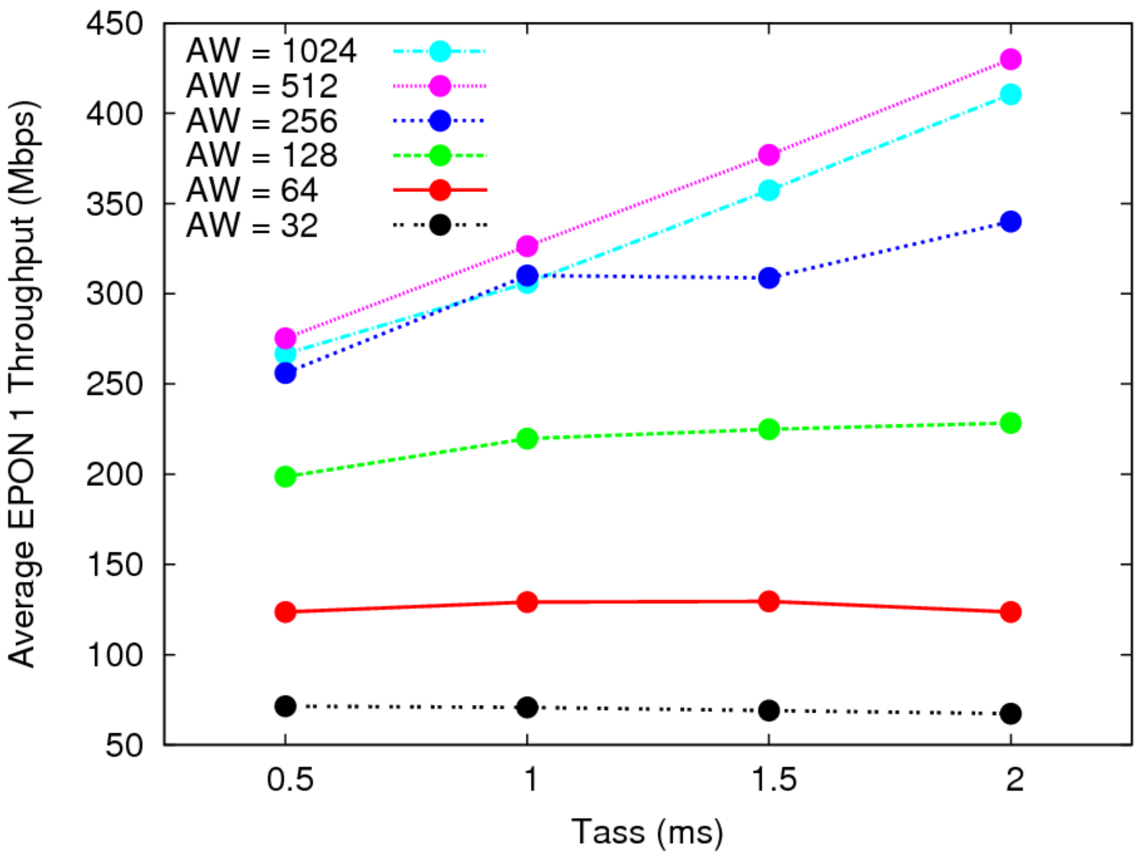
- Cycle time: $T_{c1} = T_{c2} = 2$ ms
- $T_a = 0.5 - 2$ ms
- TCP segment = 512 bytes
- AWND = 512 segments
- Burst loss = 10^{-3}



1. EPON show same performance
2. Fairness close to 0.9
3. Increasing T_a, throughput increases: correlation benefit

Average EPON1-2 throughput vs. T_a

- Cycle time: $T_{c1} = T_{c2} = 2$ ms
- $T_a = 0.5 - 2$ ms
- TCP segment = 512 bytes
- AWND = 32-1024 segments
- BWxRTT gives 400 segments as ideal TCP tx window
- Burst loss = 10^{-3}



1. AW = 512 provides best results
2. Correlation benefit is reduced by increasing Ta , in particular for low AW values, for longer RTTs

Fairness vs. T_a and AW

Behaviour

- Generally high values
- Improvements for higher T_a (correlation benefit)
- Worse for larger W_{max}

Because

- Different burst composition

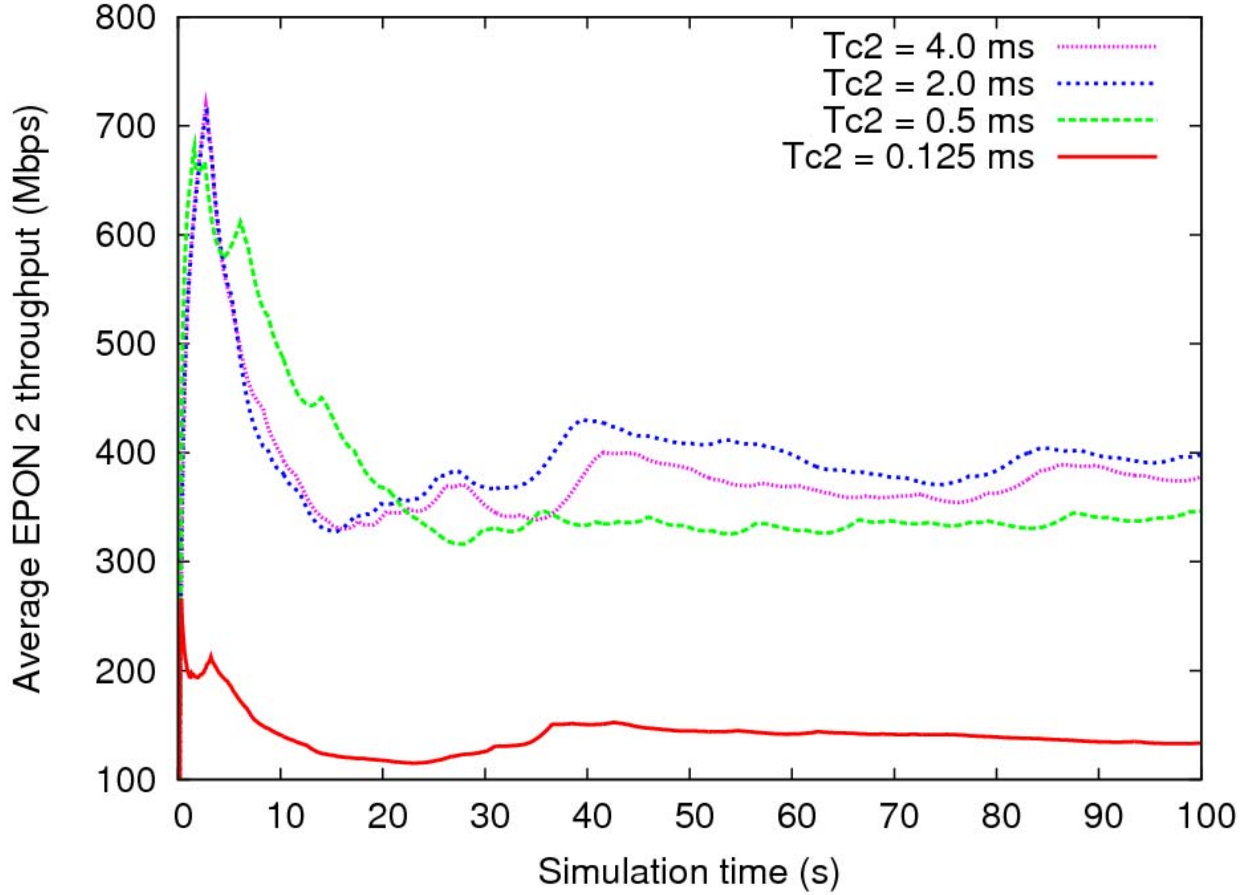
- High T_a and small AW → many TCP flows

	T_{ass}	0.5 ms	1 ms	1.5 ms	2 ms
$AW = 32$	EPON 1	0.992	0.993	0.991	0.989
	EPON 2	0.991	0.994	0.992	0.990
$AW = 64$	EPON 1	0.975	0.987	0.989	0.989
	EPON 2	0.986	0.987	0.993	0.993
$AW = 128$	EPON 1	0.932	0.979	0.987	0.978
	EPON 2	0.964	0.971	0.979	0.978
$AW = 256$	EPON 1	0.901	0.889	0.936	0.942
	EPON 2	0.940	0.897	0.941	0.964
$AW = 512$	EPON 1	0.853	0.911	0.951	0.883
	EPON 2	0.879	0.901	0.893	0.903
$AW = 1024$	EPON 1	0.878	0.865	0.889	0.924
	EPON 2	0.902	0.880	0.934	0.900

- Short T_a and large AW → very few TCP flows

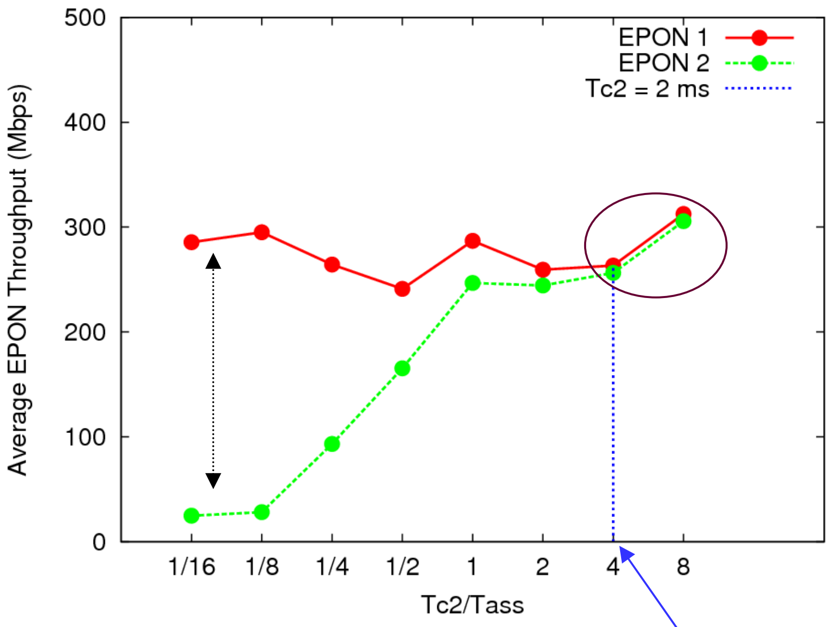
Average EPON2 throughput vs. time

- EPON1 T_{c1} = 2 ms
- T_a = 2 ms
- TCP segment = 512 bytes
- AWND = 512 segments

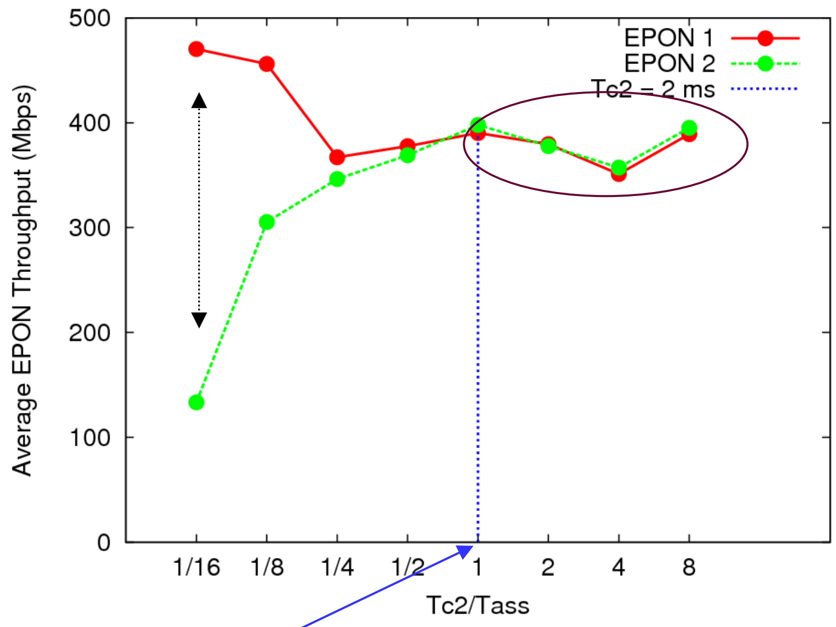


1. Best performance for $T_{c2} = T_a$ = 2 ms

Average EPON1-2 throughput vs. T_{c2}/T_a



T_a = 0.5 ms



T_a = 2 ms

$T_{c2} = T_{c1}$

- EPON1 T_{c1} = 2 ms
- AWND = 512 segments

Better performance for higher T_c values

EPON 1 performs better for lower T_{c2}

Conclusions

- Performance of TCP in a hybrid multi-EPON\OBS optical network
- Focus on the IWU or edge router between EPONs and OBS network
- Numerical investigation has revealed:

1. A remarkable role for TCP performance by cycle time and burst assembly time
2. In particular, T_a properly set to maximize performance
3. Then, T_c has to be set accordingly for the best EPON\OBS internetworking (e.g. $T_c = T_a$) for end-to-end performance
4. With a proper parameter setting, fairness is good as well

Current and Future Work

- Heterogeneous traffic (UDP and TCP sources)
- More than two EPONs with larger number of ONUs
- Service differentiation schemes in IPACT and/or assembly
- Impact on performance of long-range PONs

THANK YOU FOR YOUR ATTENTION

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… suggestions are very very welcome