Optical Coarse Packet Switched IP-over-WDM Network (OPSINET): Technologies and Experiments

Presentation for WOCC'2004

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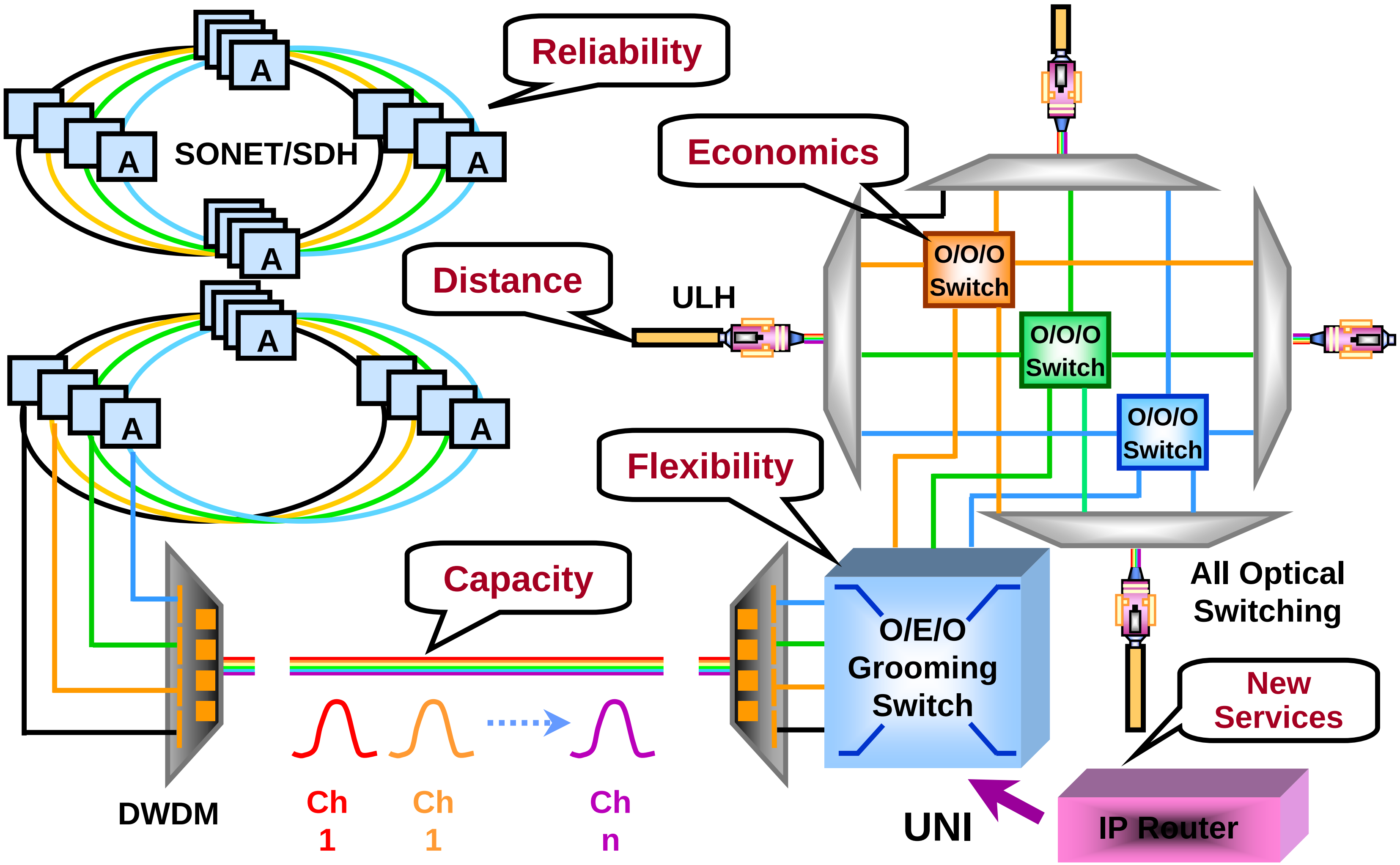
Outline

- Optical Networking- Introduction
- A New Paradigm- Optical Coarse Packet Switching (OCPS)
- *OPSINET-* An Overview
- System and Network Technologies
- Conclusions

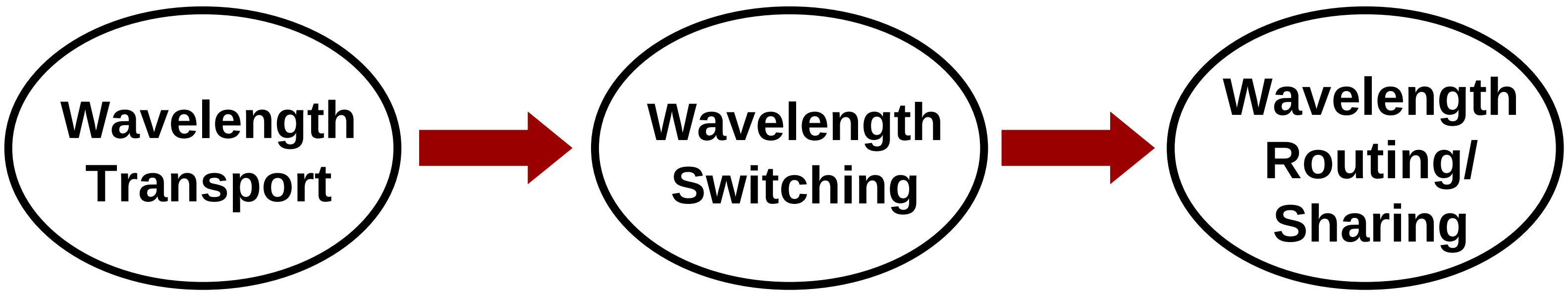
Why Optical Networking?



Source: Dr. N. Patel Talk on NGN2002

Optical Networking Evolution

1st Generation — ***2nd Generation*** — ***3rd Generation***



1st Generation

- **Optical Transmission**
- **OEO Switching**
- **IP-over-ATM-over-SONET**

2nd Generation

- **Optical Transmission**
- **OOO Switching**
- **Circuit Switc. IP-over-WDM**

3rd Generation

- **Optical Transmission**
- **OOO Switching**
- **IP-over-WDM**
  - **Optical Packet Switching**
  - **Optical Burst Switching**
  - **Optical Coarse Packet Switching**
  - **Photonic Slot Routing**

Optical Networking Evolution (cont.)

- **Optical Circuit Switching (OCS)**
  - **Static utilization of WDM channels**
  - **Good to support stream traffic**
- **Optical Packet Switching (OPS)**
  - **All optical: transport, processing, and buffering**
  - **Fine-grained WDM channel allocation**
  - **An ultimate solution for data-centric Internet**
- **Current dilemma for OPS**
  - **Lack of optical signaling processing and optical RAM**
  - **Large switching overhead**

→ **Alternatives ?**

OPS Alternatives

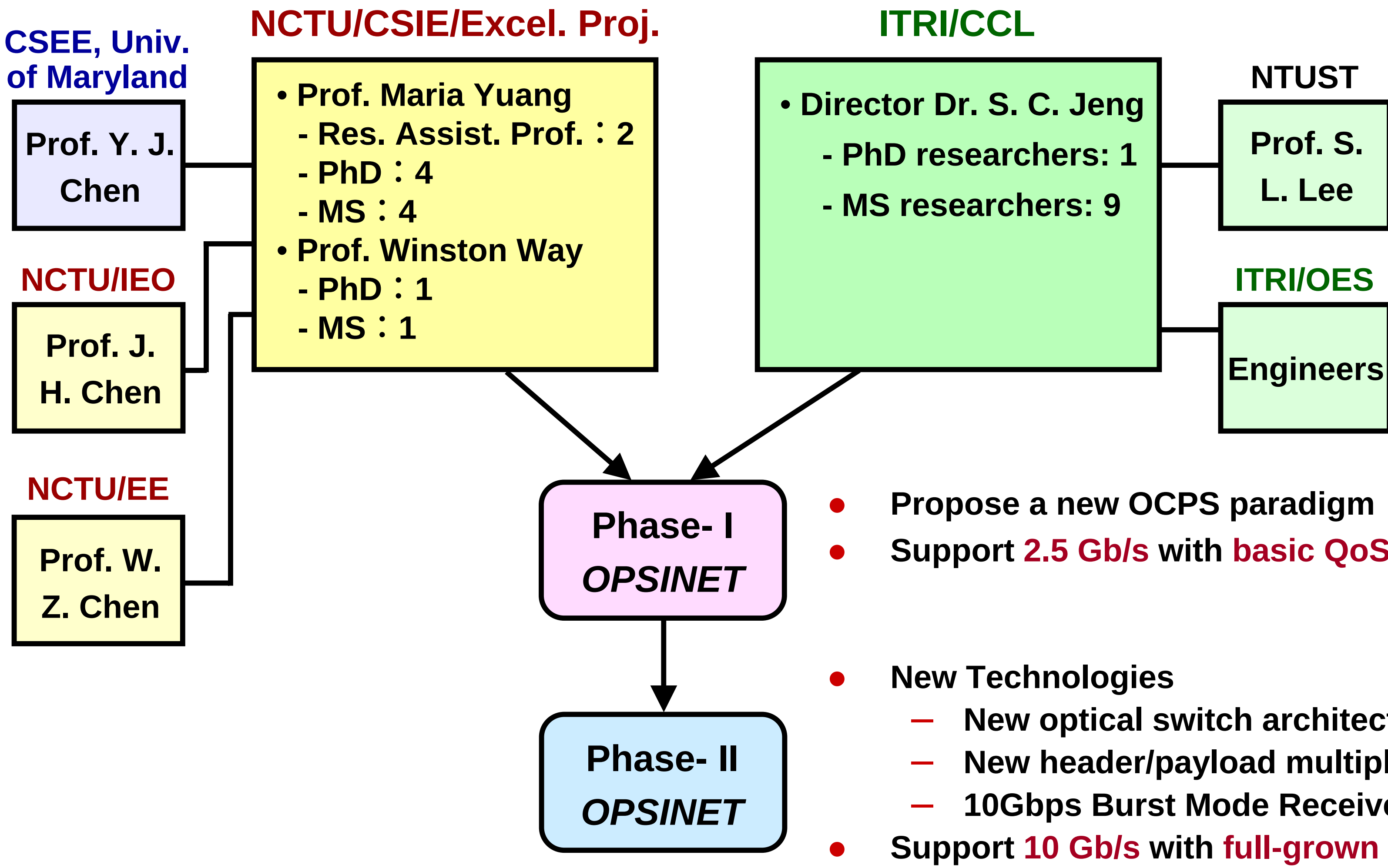
- **Optical Burst Switching (OBS)**
  - **Supports per-burst (rather than per-packet) switching**
  - **Focuses on out-of-band, one-way wavelength allocation**
    - **A control packet for each burst payload is first transmitted out-of-band, allowing each switch to perform just-in-time configuration before the burst arrives**
    - **Wavelength is reserved only for the duration of the burst**
    - **The burst payload follows its control packet immediately after a predetermined *offset time***
- **OBS can be viewed as a more efficient variant of OCS**

➡ **Our approach: *Optical Coarse Packet Switching (OCPS)***

A New Paradigm- OCPS

- **By "Coarse"**
  - **Per-burst switching (rather than per-packet switching)**
  - **Header is electronically processed while the payload remains in the optical domain**
- **By "Packet Switching"**
  - **Header is *in-band* modulated with payload and sent via one λ**
  - **Wavelengths are shared via wavelength converters**
  - **Enforcement of traffic control and traffic engineering to maximize *wavelength-dimension statistical multiplexing gain***
- **OCPS can be considered as a less stringent variant of OPS**
- **Based on OCPS, we have constructed an IP-over-WDM network, called OPSINET (Optical coarse Packet Switched IP-over-WDM Network)**

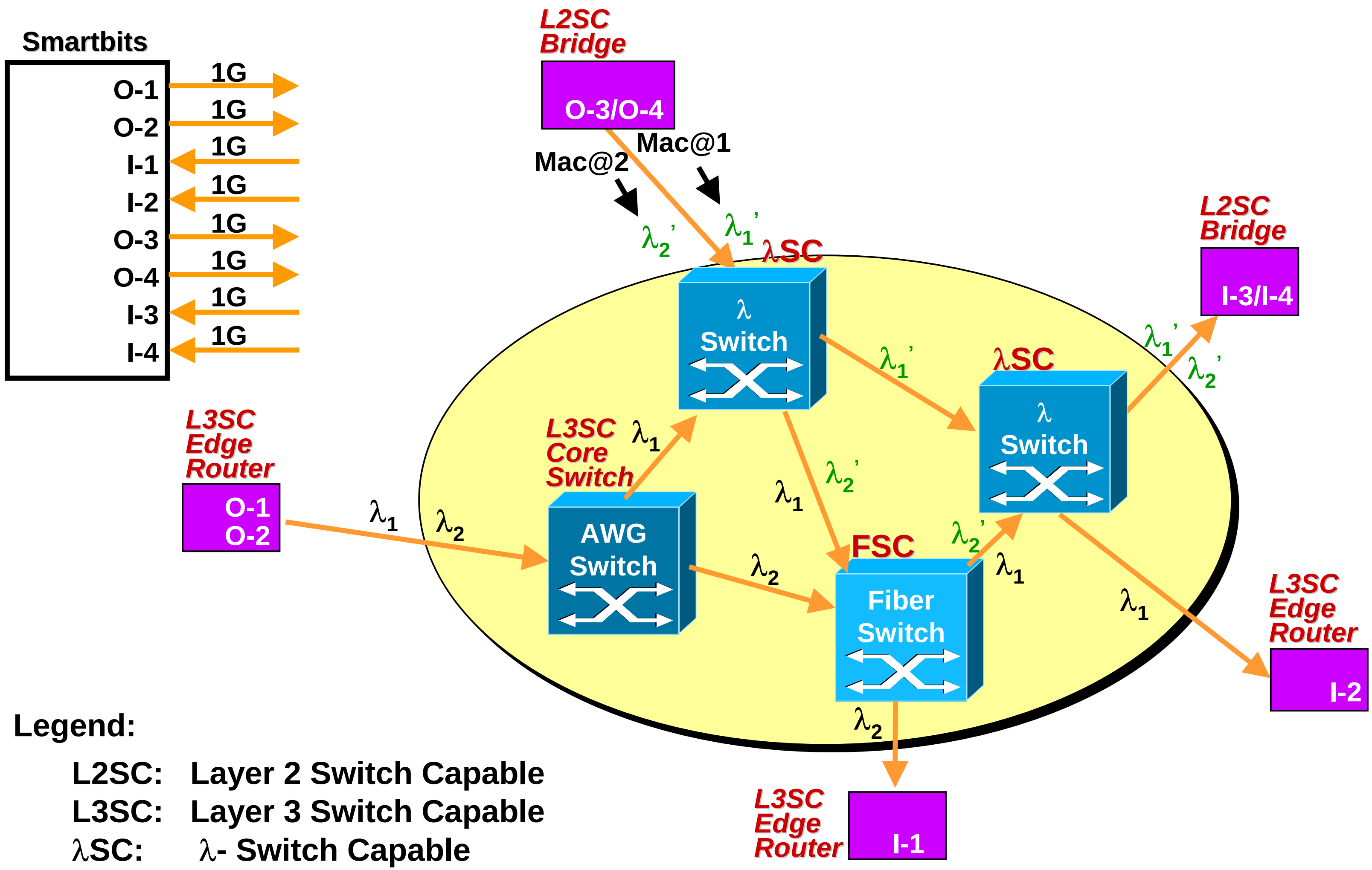
Project at a Glance



- Propose a new OCPS paradigm
- Support 2.5 Gb/s with basic QoS

- New Technologies
  - New optical switch architecture
  - New header/payload multiplexing
  - 10Gbps Burst Mode Receiver
- Support 10 Gb/s with full-grown QoS

OPSINET: All-Optical Experimental Network



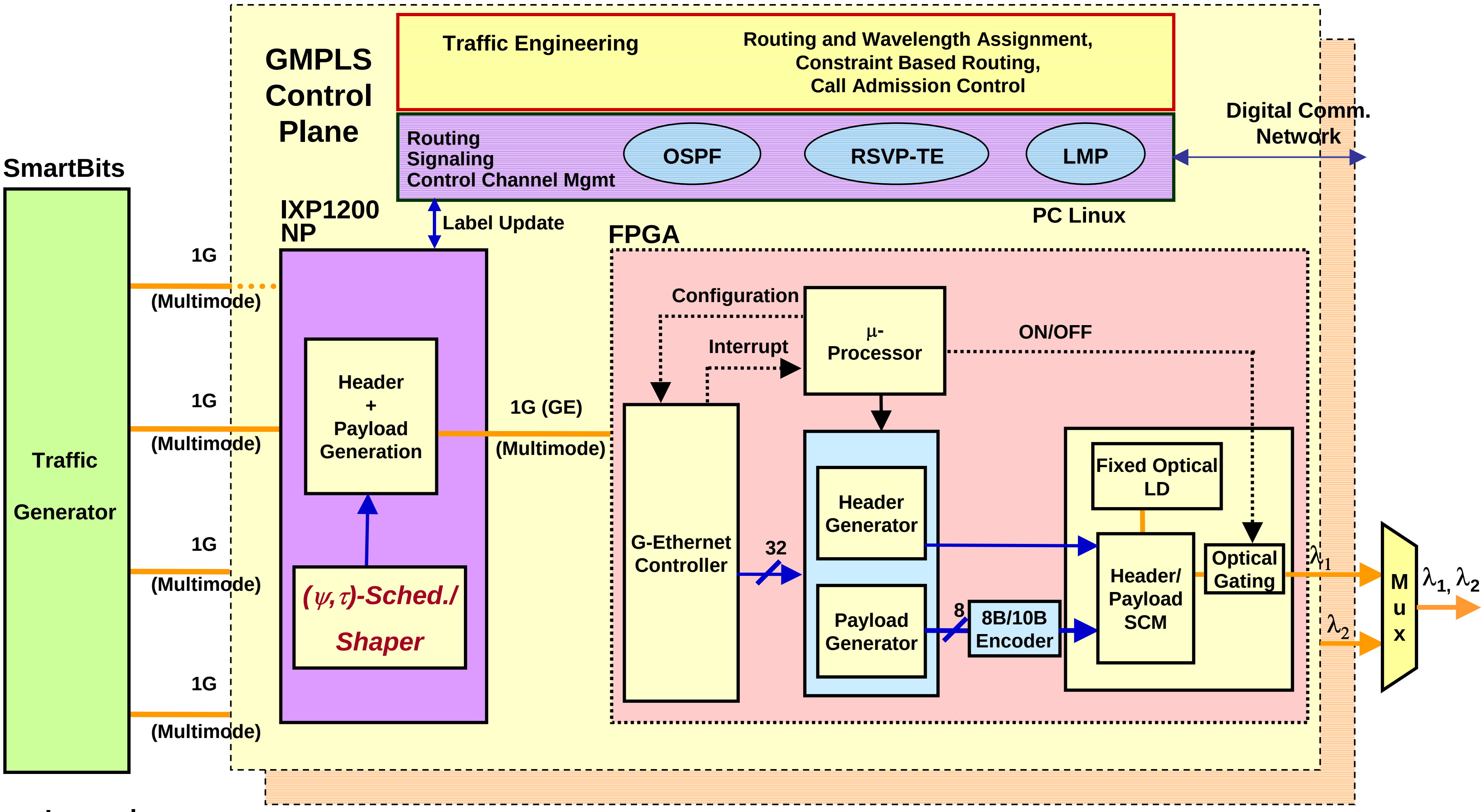
Legend:

L2SC: Layer 2 Switch Capable
L3SC: Layer 3 Switch Capable
λSC: λ- Switch Capable
FSC: Fiber Switch Capable

OPSINET- Phase I

- **Ingress and Egress Edge routers**
- **Optical Label Switched Routers (OLSRs)**
- **Fiber/Lambda Switches**

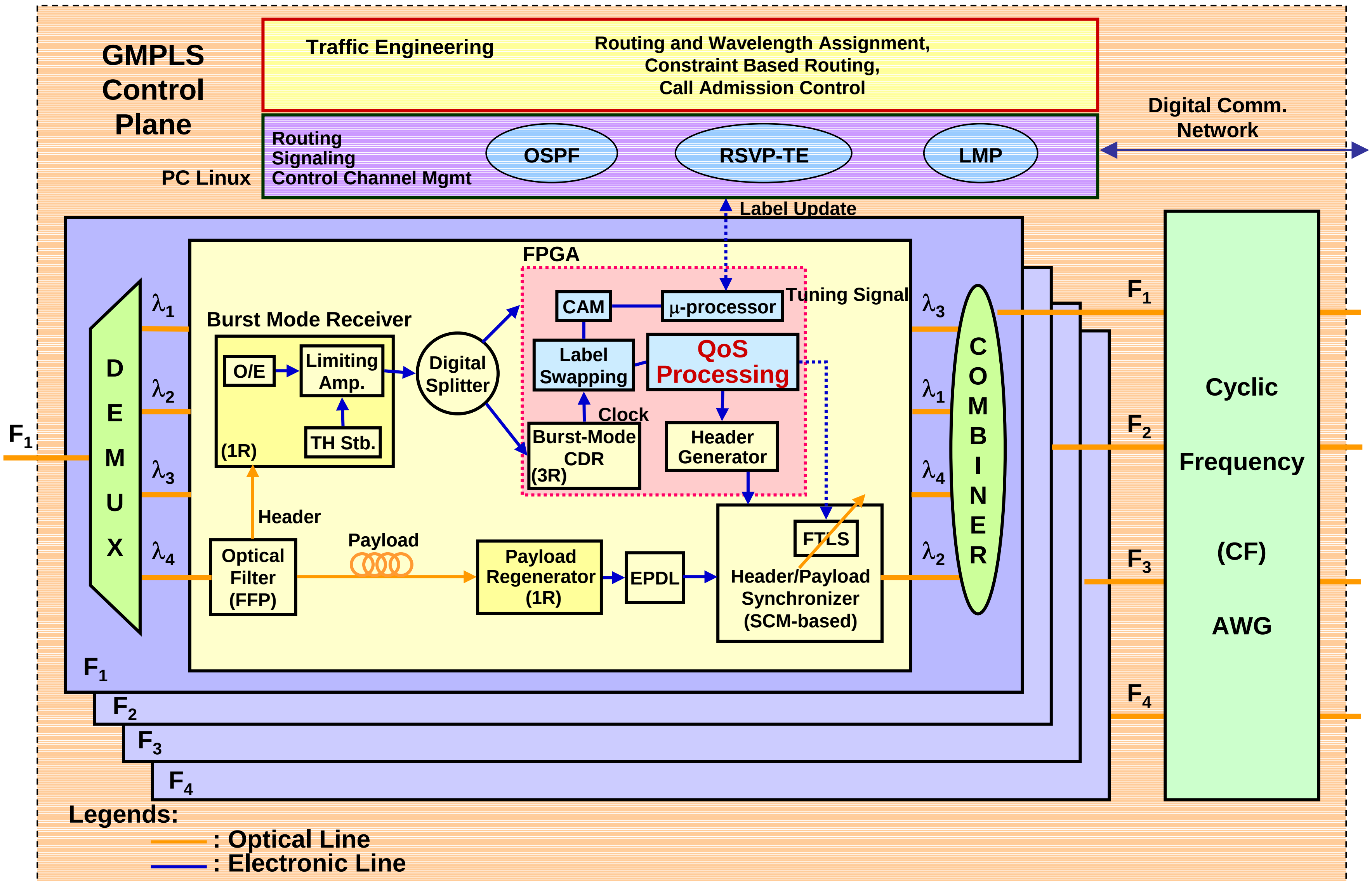
Ingress Edge Router Architecture



Legend:

: Optical Line
: Electronic Line

Optical Label Switched Router Architecture



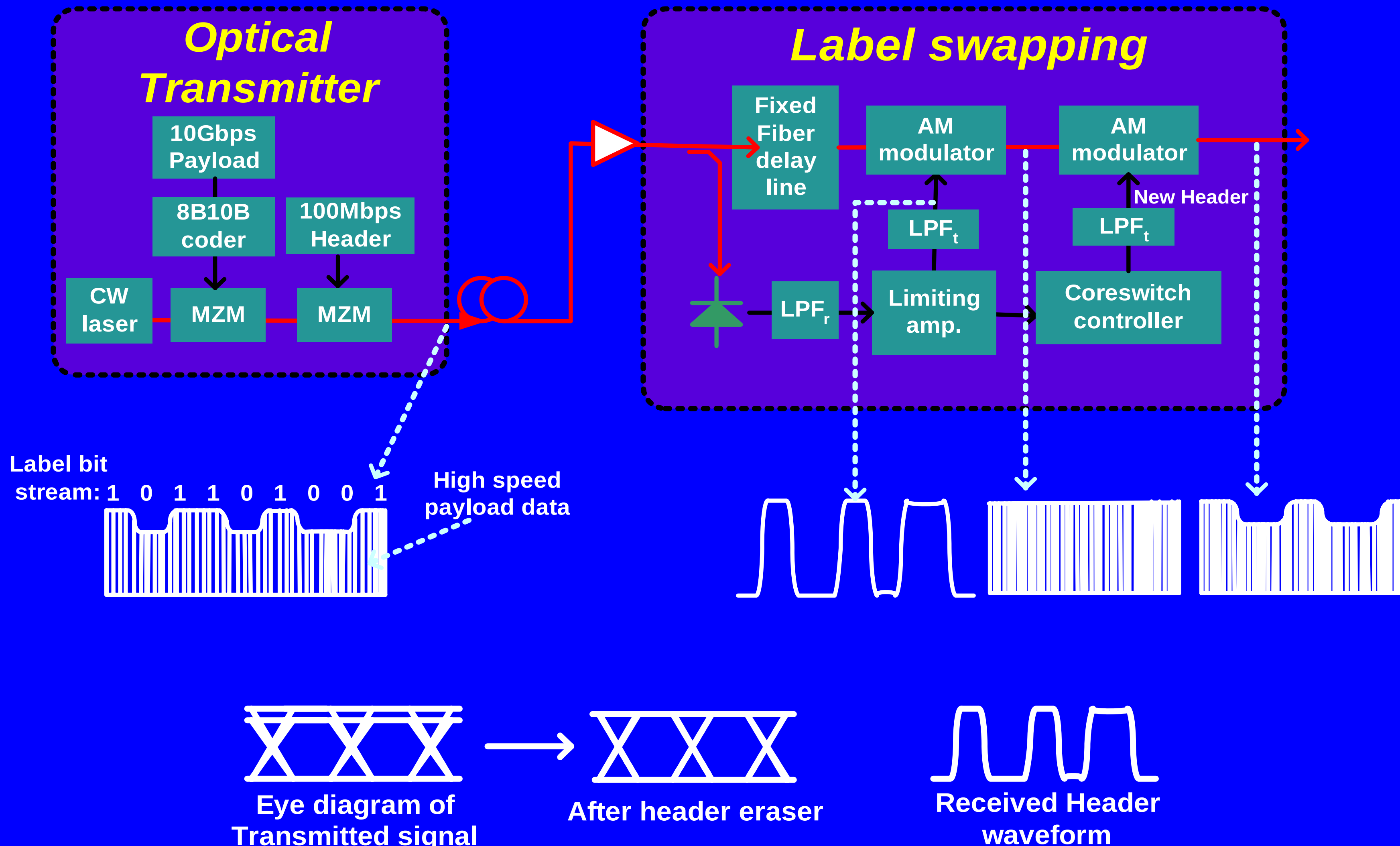
System and Network Technologies

- **Label multiplexing and swapping**
- **Traffic control at edge routers**
- **Traffic control at core switch routers: λ contention resolution**
- **Traffic engineering: Optical Tunnel Allocation**
- **Optical switch architecture with partial λ-sharing and limited optical buffers**

Label Multiplexing and Swapping

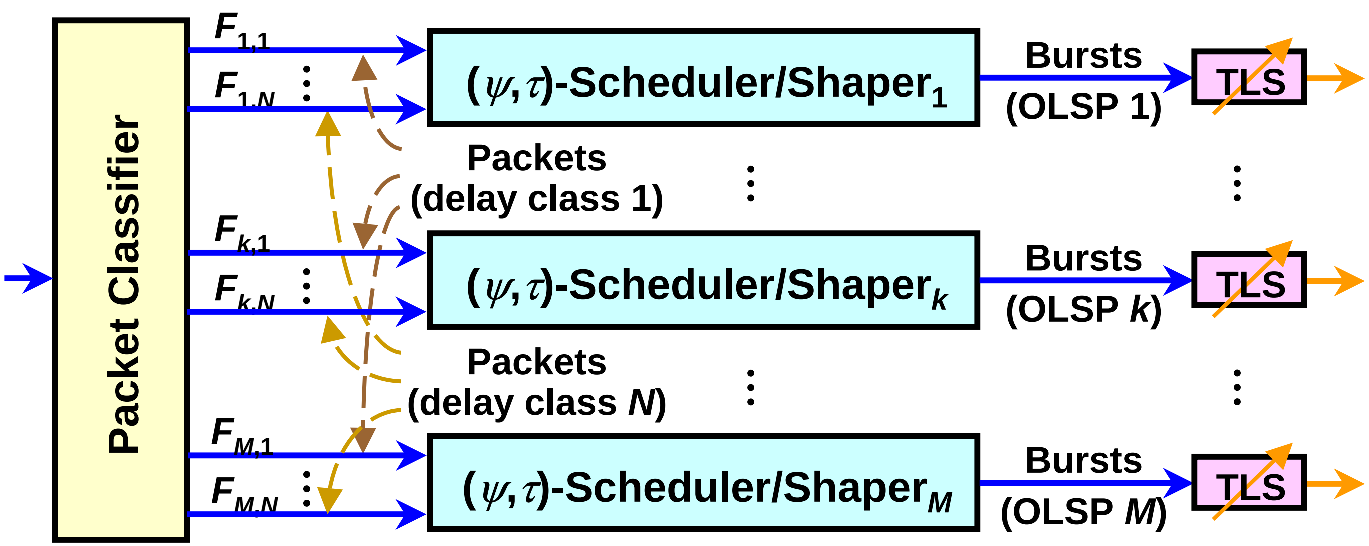
- **Existing Method: Sub-Carrier Multiplexing (SCM)**
  - **Payload and label are carried at different frequencies**
  - **Payload is carried at low band**
  - **Label is carried around 7.9 GHz**
  - **Advantage: Simple**
  - **Disadvantage: Fail to support 10Gbps payload transport**
- **Our Innovative Method: *Superimposed ASK-based Label Multiplexing and Swapping***

All optical label swapping technique -
Superimposed ASK label



Traffic Control at Edge: (ψ,τ)-Scheduler/Shaper

- For a (ψ,τ)-Scheduler/Shaper$_K$
  - It is a scheduler for packets of different delay classes
  - It is a shaper for bursts of the same loss class



Legend:

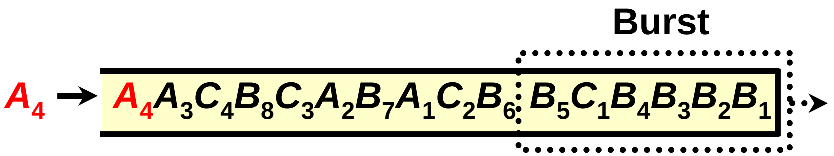
$F_{d,y}$: Packet flow of destination/loss class d and of delay class y;

OLSP : Optical Label Switched Path;

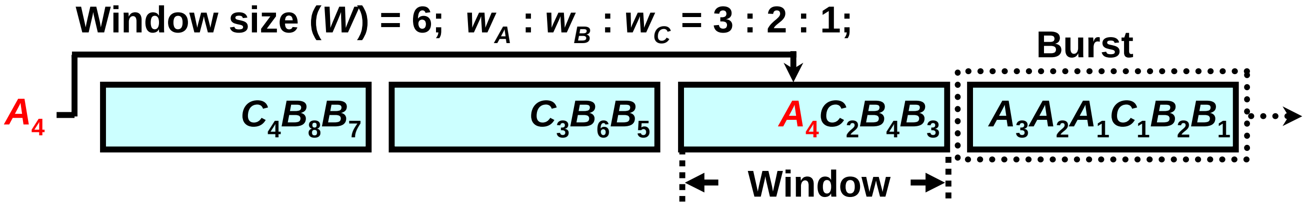
TLS : Tunable Laser Source;

(ψ, τ)-Scheduler: Concept

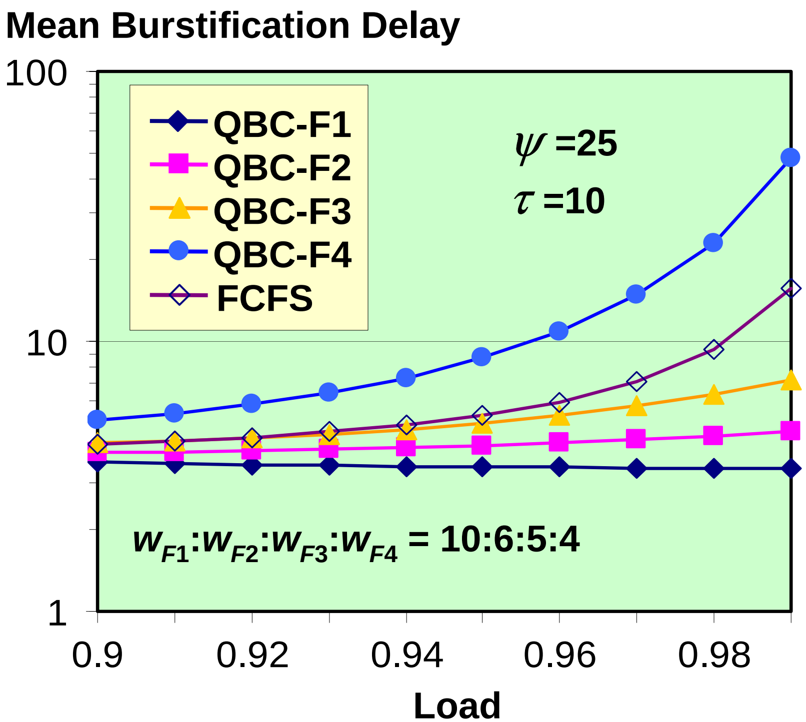
- **FCFS-based burstification**

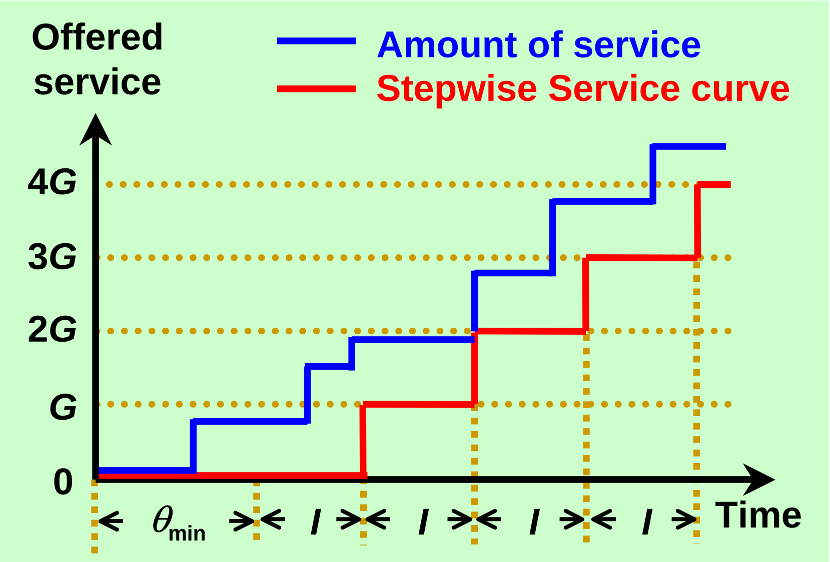


- **(ψ, τ)-Scheduler (ψ = 6, τ = ∞)**



(ψ, τ)-Scheduler: Delay Guarantee





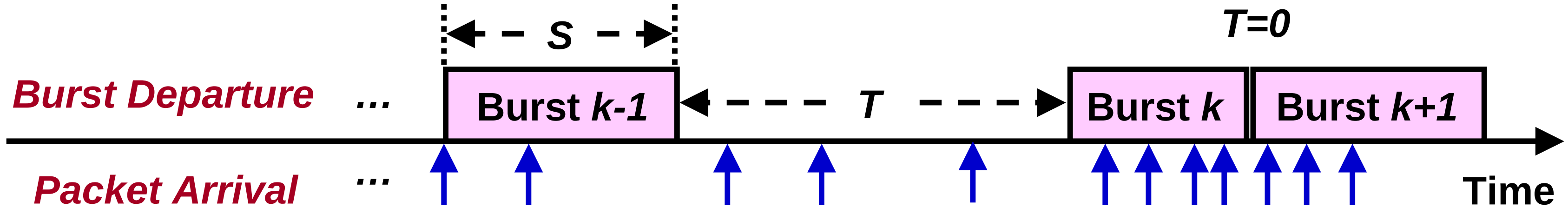
Legend:

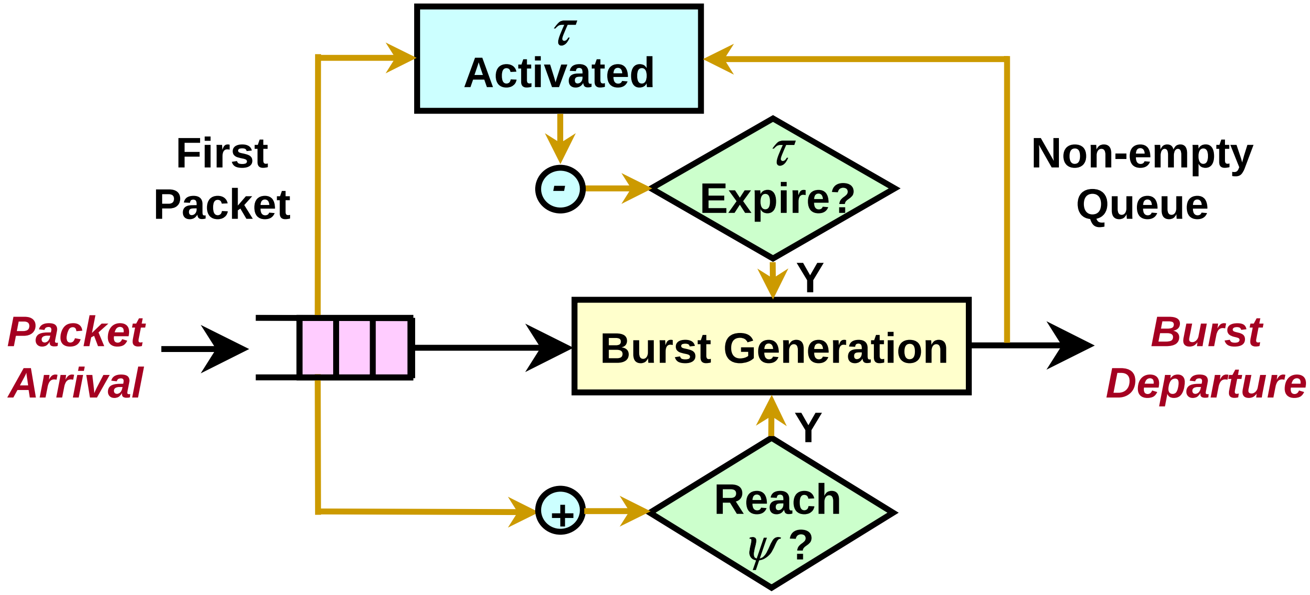
G : Bandwidth granularity;

I : Incremental Interval;

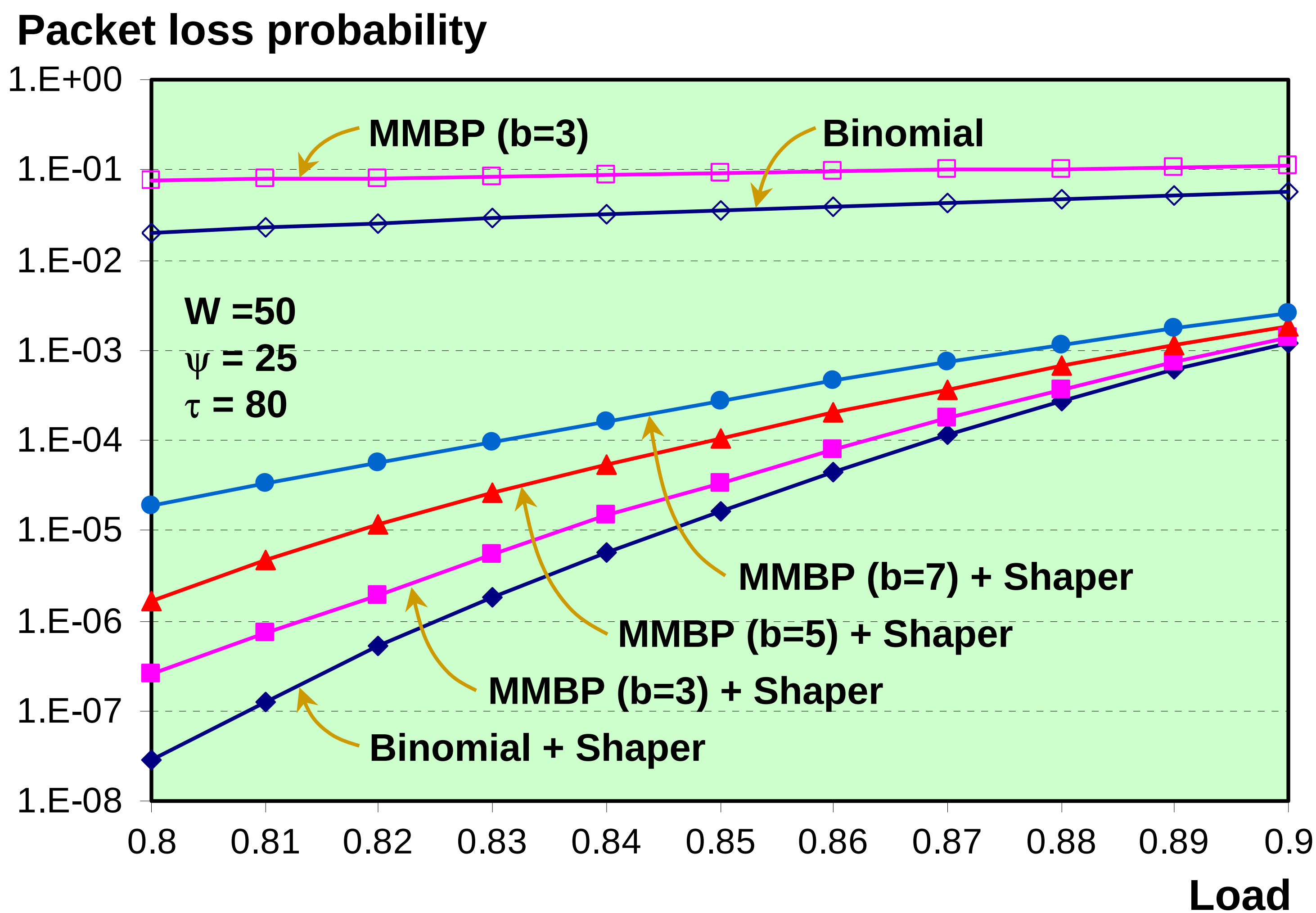
(ψ, τ)-Shaper: Concept

- Departure Process contains burst inter-departure time (*T*) and burst size (*S*) distribution

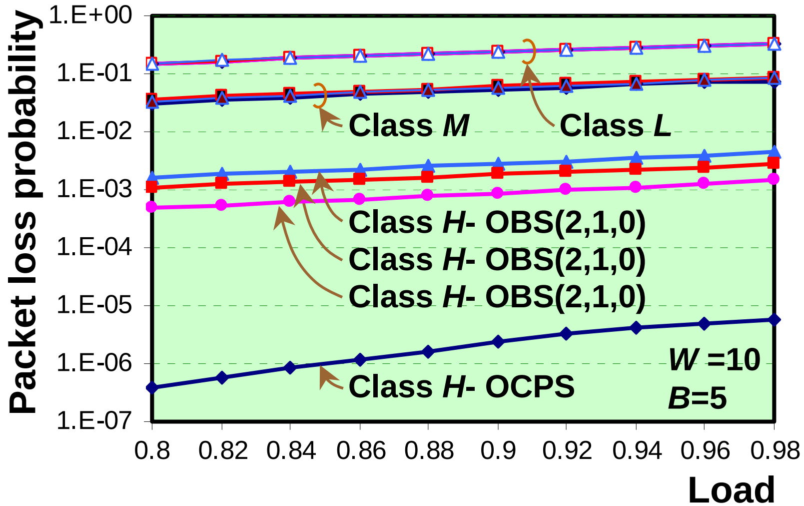




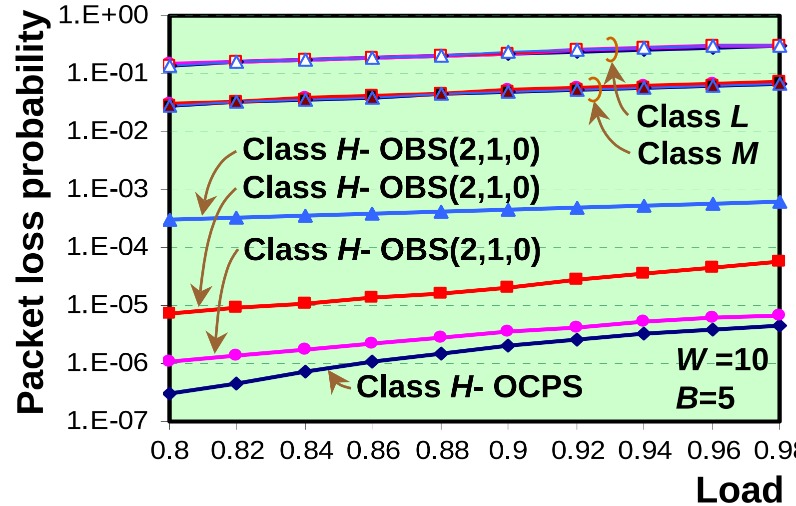
Effectiveness of (ψ, τ)-Shaper (ψ=25)



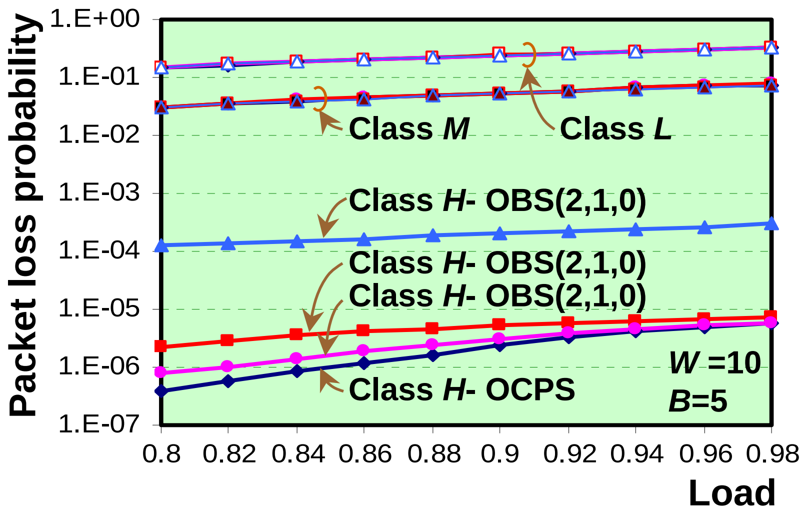
Performance Comparison: OCPS and OBS



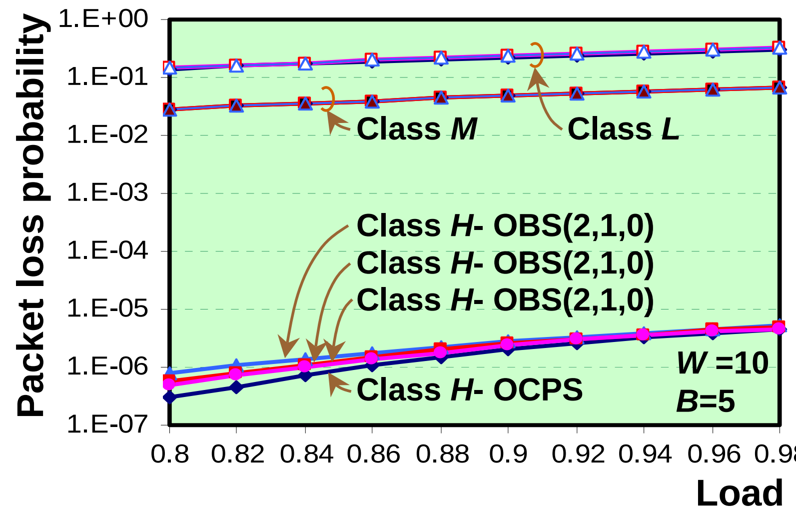
$\psi_H = \psi_M = \psi_L = 25$, $\delta = 48\mu s$



$\psi_H = \psi_M = \psi_L = 100$, $\delta = 48\mu s$



$\psi_H = \psi_M = \psi_L = 25$, $\delta = 9.6\mu s$



$\psi_H = \psi_M = \psi_L = 100$, $\delta = 9.6\mu s$

Conclusions

- **OCPS is a relaxed OPS paradigm by exploiting coarse switching granularity (burst vs packet)**
- **OCPS is a viable paradigm making all-optical networks a cost-effective reality within three to five years**
- **OCPS can be applied to metro core networks**
  - **Mesh topology: wavelength contention resolution**
  - **Ring/Bus topology: Medium Access Control**