An Optical-Header Processing and Access Control System for a Packet-Switched WDM Metro Ring Network

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Prof. Maria C. Yuang
Department of Computer Science and Information Engineering,
National Chiao Tung University, Taiwan

Outline

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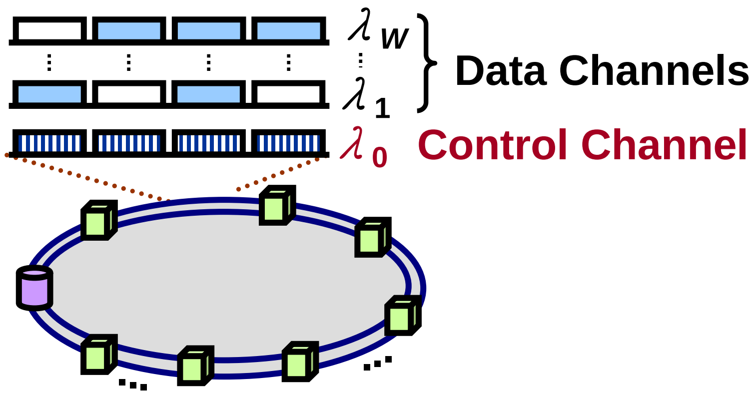
Introduction

- **Future optical metro networks are expected to cost-effectively satisfy a wide range of heterogeneous traffic with different time-varying and high bandwidth demand**
- **Optical Packet-Switching (OPS) employs statistical multiplexing to share wavelengths among multiple users**
- **Our work focuses on OPS-based access control system under slotted-ring-based optical WDM networks**
- **The OPS-based access control system includes:**
  - **Header processing/control (in-band-based)**
  - **Medium Access Control**
- **In-band-based header control differs from out-of-band header control**

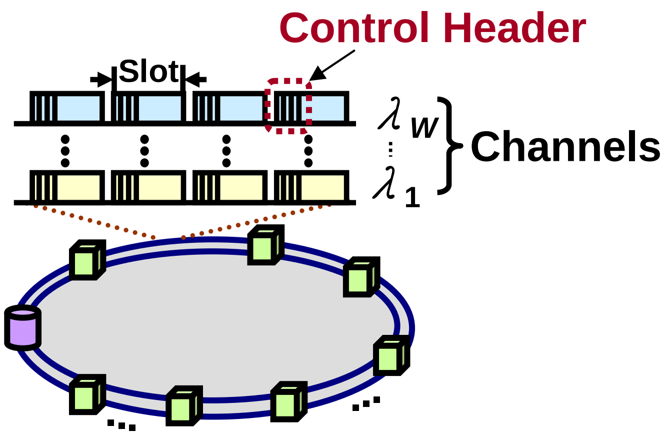
In-Band vs. Out-of-Band Header Control

- Out-of-Band Header Control



  – Requires an additional control channel
  – Drawbacks
    + Inefficiency
    + Low reliability
    + Low scalability

- In-Band Header Control



  – High efficiency and scalability
  – Prevailing approach: SubCarrier Multiplexed (SCM)
  – SCM drawbacks
    + Baseband expanding may overlap subcarrier frequency
    + Needs large # of O/E/O devices

Our Goal

To propose a system:

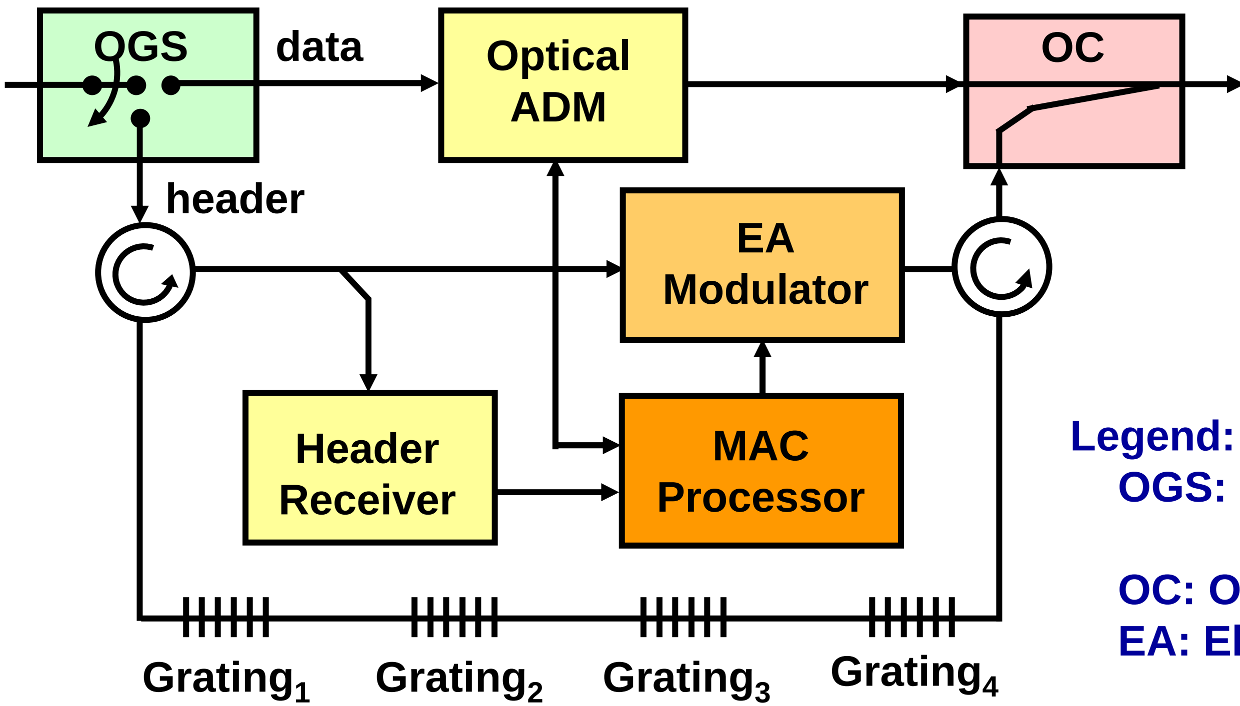
Optical-Header Processing and Access Control System (OPACS)

Achieving:

- **Efficient In-band header control**
  - **Header and payload are time division multiplexed**
  - **Optical headers are in parallel efficiently received, modified, and re-transmitted by wavelength/time conversion techniques**
- **High-performance MAC**
  - **Dynamic bandwidth allocation**
  - **High performance on delay, throughput, and fairness**
    - **Low load $\rightarrow$ random access, low delay and jitter**
    - **High load $\rightarrow$ guaranteed per-user bandwidth**
  - **High scalability and modularity**

System Architecture

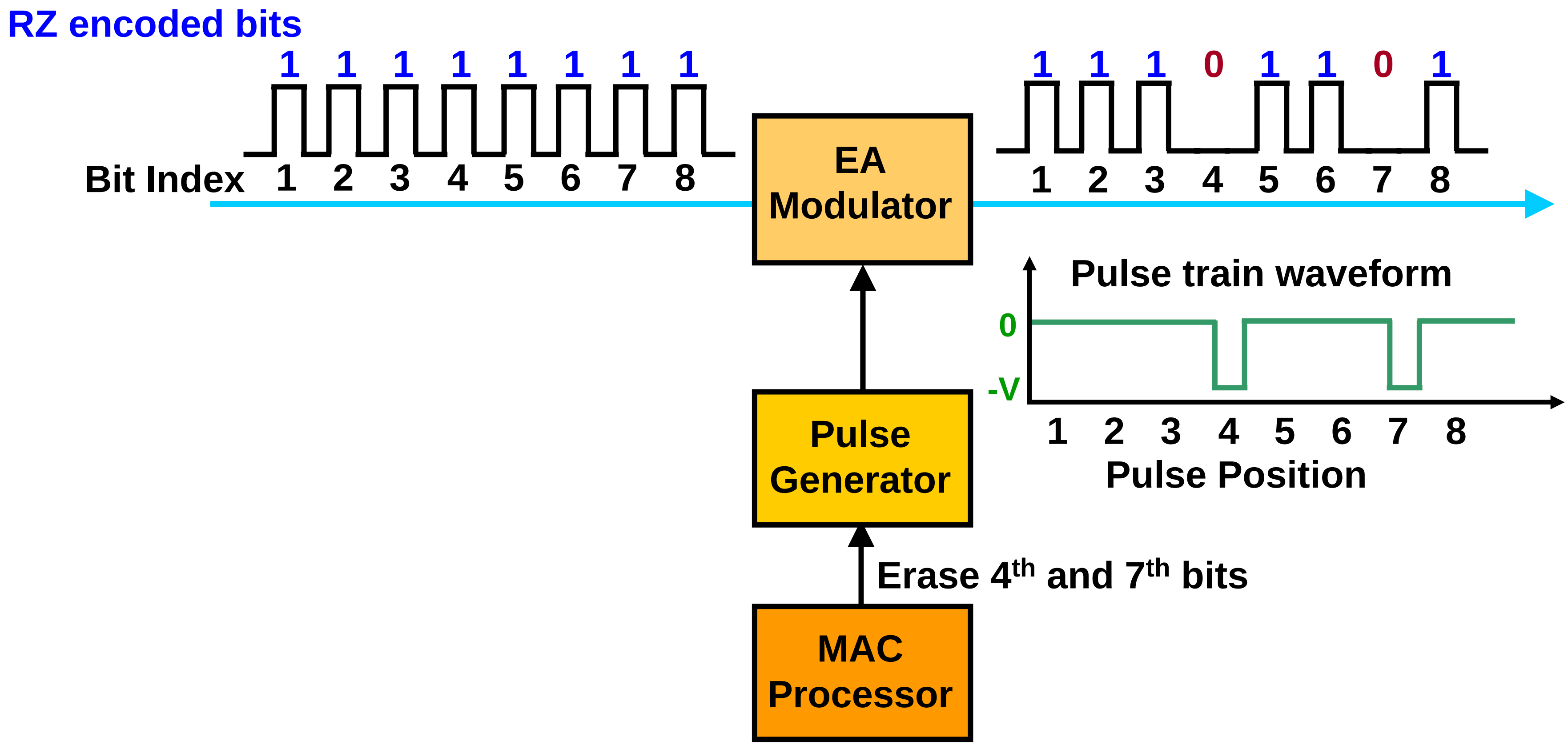
- Operates at nodes interconnected via dual unidirectional fiber ring
- Each node is equipped with one tunable transmitter and one tunable receiver for each ring
- System architecture



Legend:
- OGS: Optical Gate (1x2 Switch);
- OC: Optical Coupler;
- EA: Electro-Absorption;

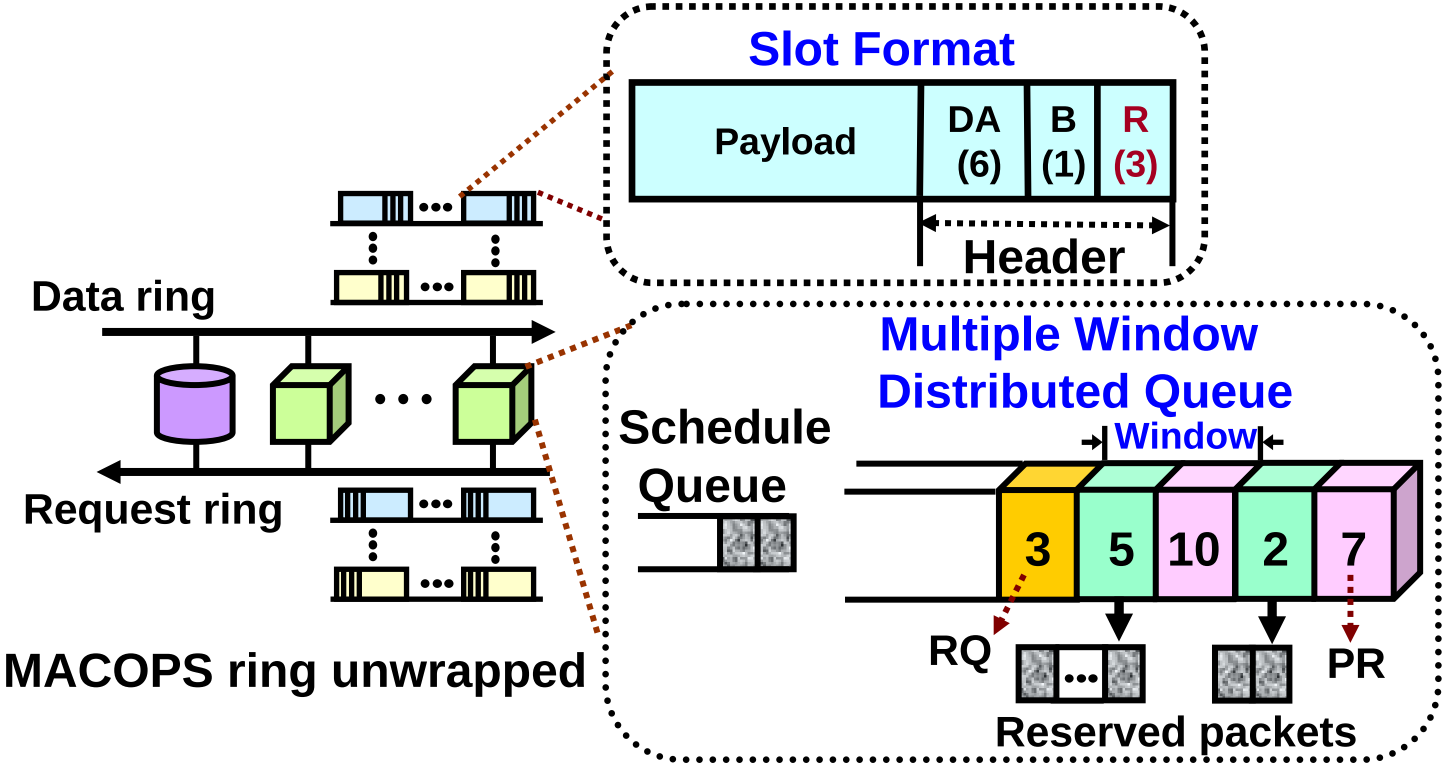
EA Modulator

- MAC processor determines certain bits to be updated
- MAC is specially designed so that header bits are always changed from 1 to 0
- EA Modulator simply attenuates those optical pulses to be updated



MAC Scheme- DQMGW

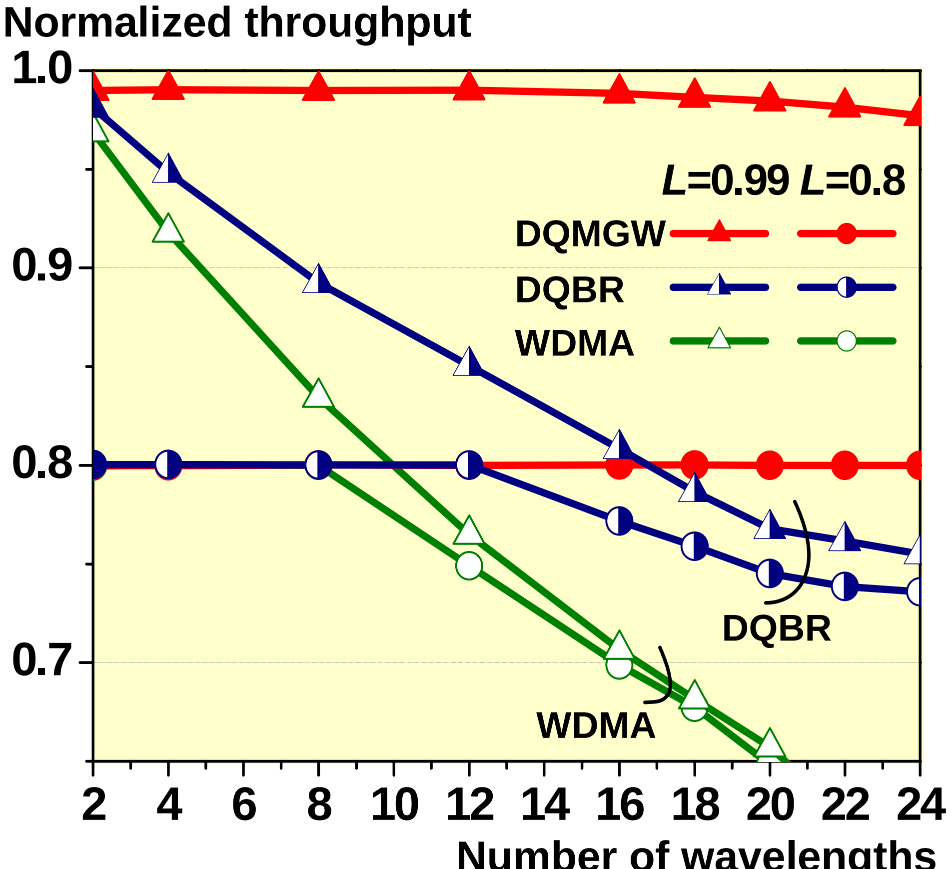
- DQMGW= Distributed Queue with Multi-Granularity and Multi-Window
- DQMGW enables dynamic bandwidth reservation in space (granularity) and in time (window)
  - Multi-Granularity: allows to reserve different # of slots in a request
  - Multi-Window: permits multiple reservation requests



Legend:
- R: Request;
- B: Busy;
- DA: Destination Address;
- PR: Prior Reservation counter;
- RQ: ReQuest counter;

Performance on Normalized Throughput

- DQBR & WDMA: poor statistical multiplexing gain (throughput deterioration)
- DQMGW achieves the same degree of bandwidth efficiency irrespective of the wavelength number and load



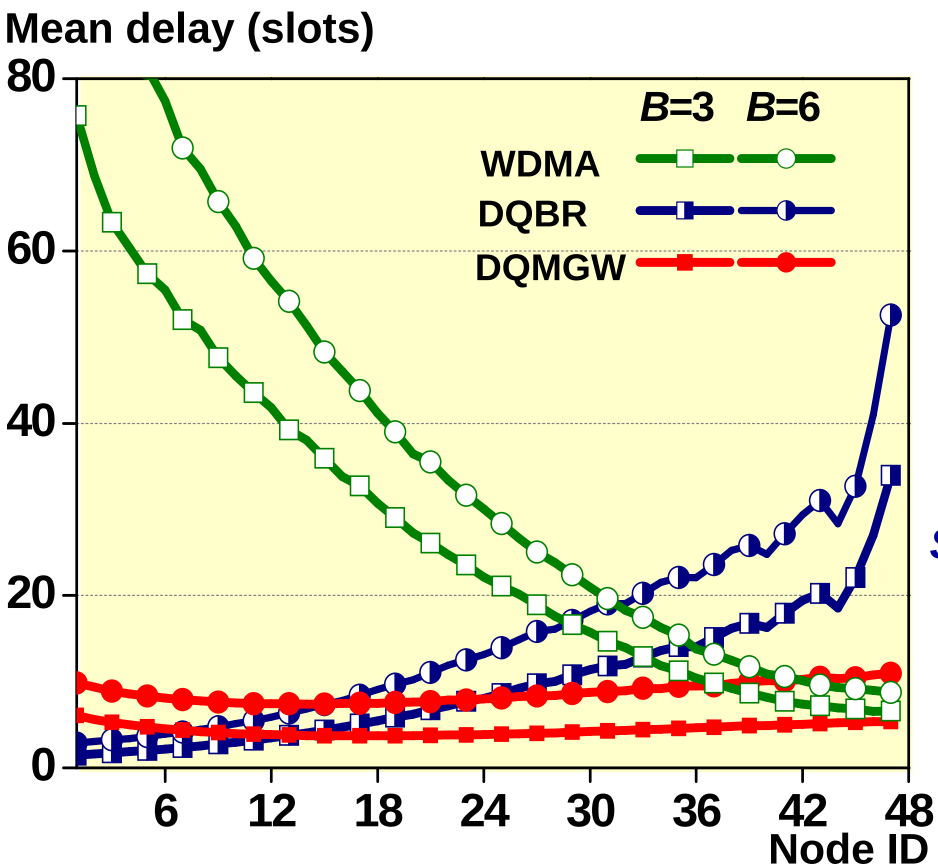
Simulation parameters:

Number of nodes = 48

Inter node distance (D) = 10 slots

Performance on Access Fairness

- **Under different burstiness settings**
  - **Delay unfairness is manifested in both DQBR and WDMA**
  - **DQMGW guarantees delay fairness due to the multi-window design**



Simulation parameters:

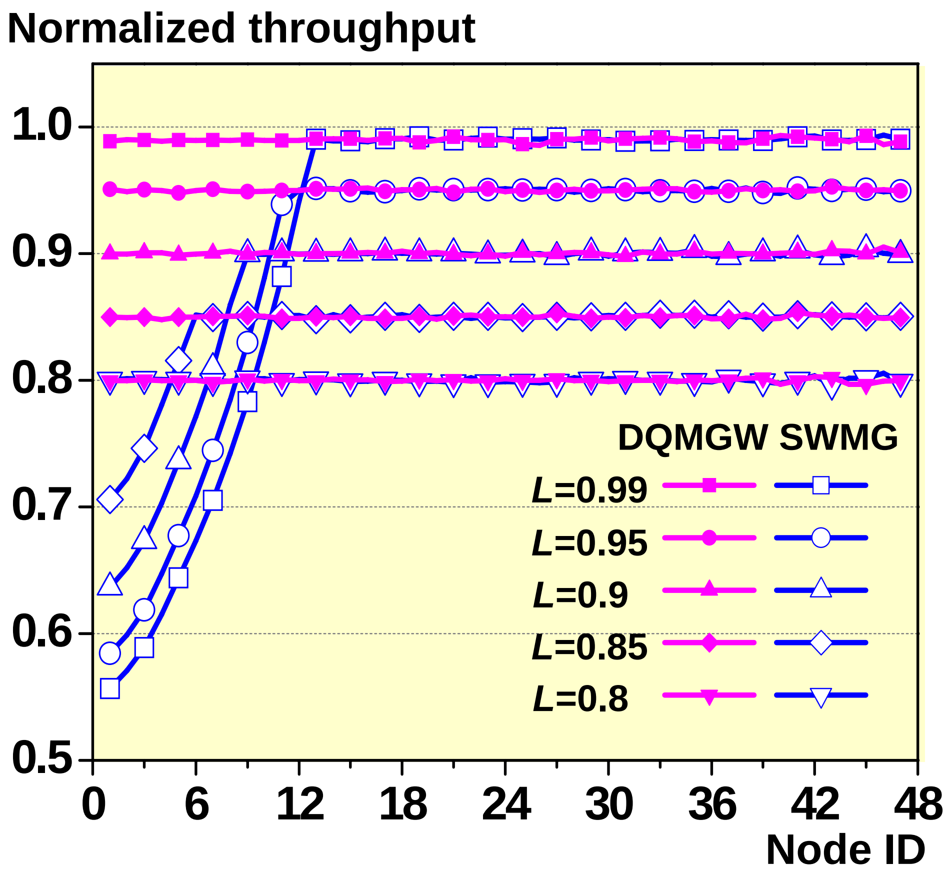
Number of nodes = 48

Number of wavelengths = 4

Load (L) = 0.85

The Impact of Multi-Window Design

- **Single Window Multiple Granularity (SWMG): DQMGW with window size=1**
- **SWMG suffers throughput unfairness as the load is above 0.8, DQMGW guarantees fairness under all loads**



Simulation parameters:

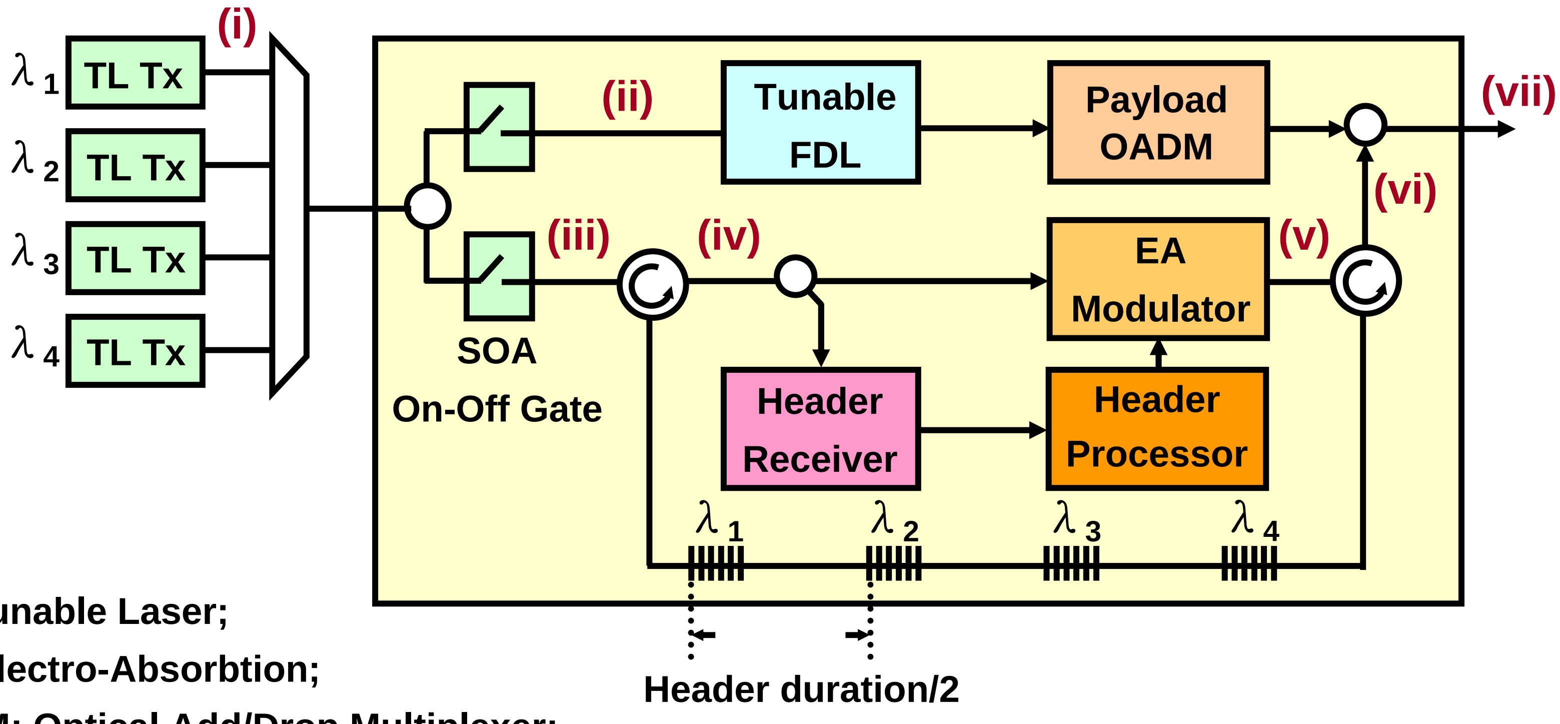
Number of nodes = 48

Number of wavelengths = 4

Inter node distance = 10 slots

Experimental Setup

- Header: RZ-encoded and 26 bits long at a data rate of 1 Gb/s
  - Includes 8-bit preamble, 4-bit header control and 6-bit address
- Payload: NRZ-encoded and 250 bytes long at a data rate of 10 Gb/s



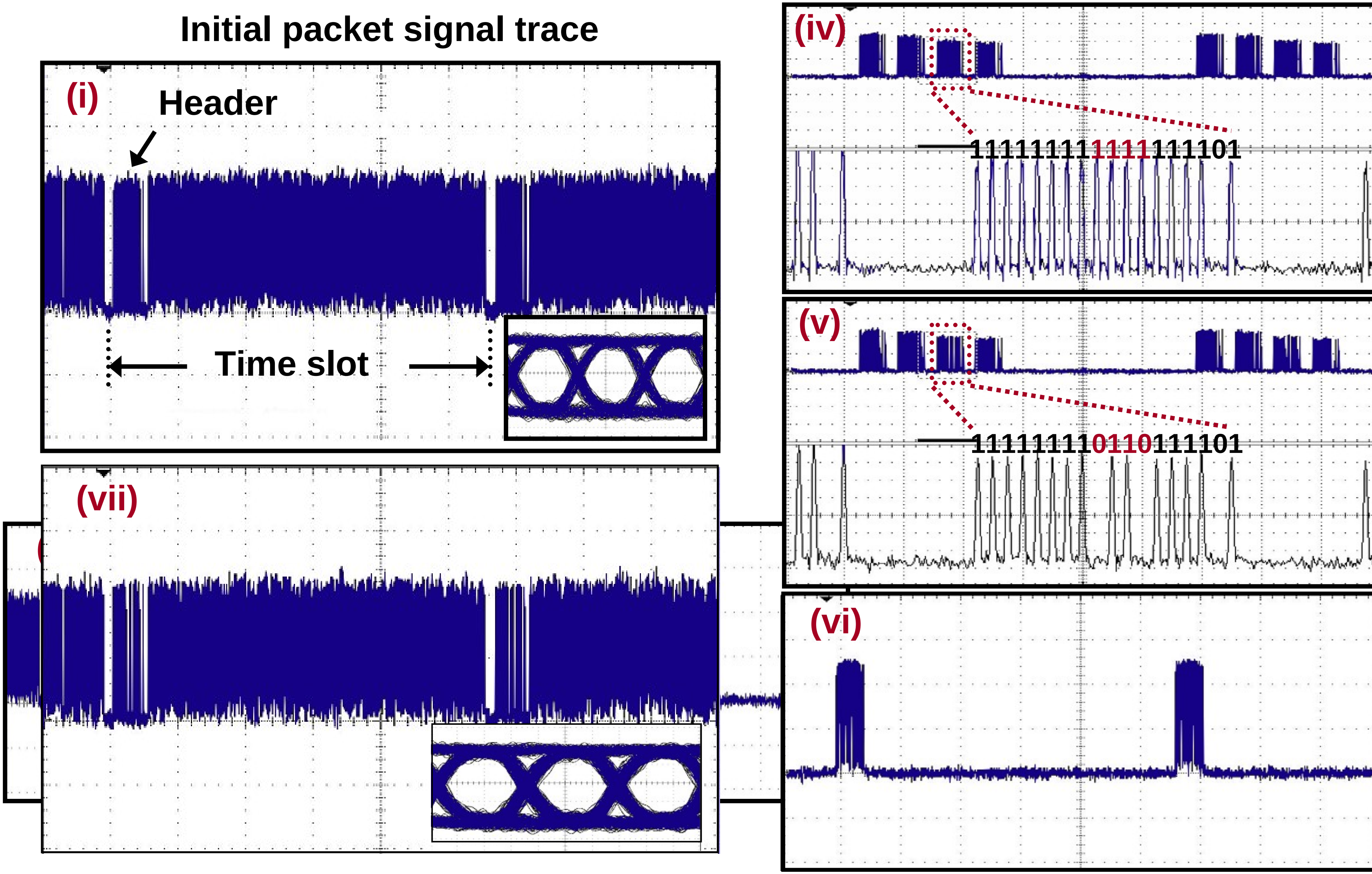
Legend:

TL: Tunable Laser;

EA: Electro-Absorbtion;

OADM: Optical Add/Drop Multiplexer;

Experimental Results- Header & Payload



Conclusions

- **We have proposed a novel system, OPACS, encompassing an efficient in-band header control and high-performance MAC**
- **By making use of wavelength/time conversion techniques, optical headers are efficiently received, modified, and re-transmitted**
- **OPACS uses the DQMGW to enable dynamically bandwidth allocation on space (granularity) and on time (window)**
- **Compared with two existing approaches (HORNET DQBR and WDMA), OPACS achieves higher throughput, lower packet delay, and exceptional fairness under various traffic settings**
- **Experimental testbed demonstrates the viability of OPACS**