Enhancing Contention Resolution for Optical Packet Switching

[1] “Optical Packet Switching in Core Networks: Between Vision and Reality, ” T. S. El-bawab and J. D. Shin

[2] “Electrical Ingress Buffering and Traffic Aggregation for Optical Packet Switching and Their Effect on TCP-Level Performance in Optical Mesh Networks,” S. Yao, F. Xue, B. Mukherjee, S. J. Ben Yoo, and S. Dixit

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Outline

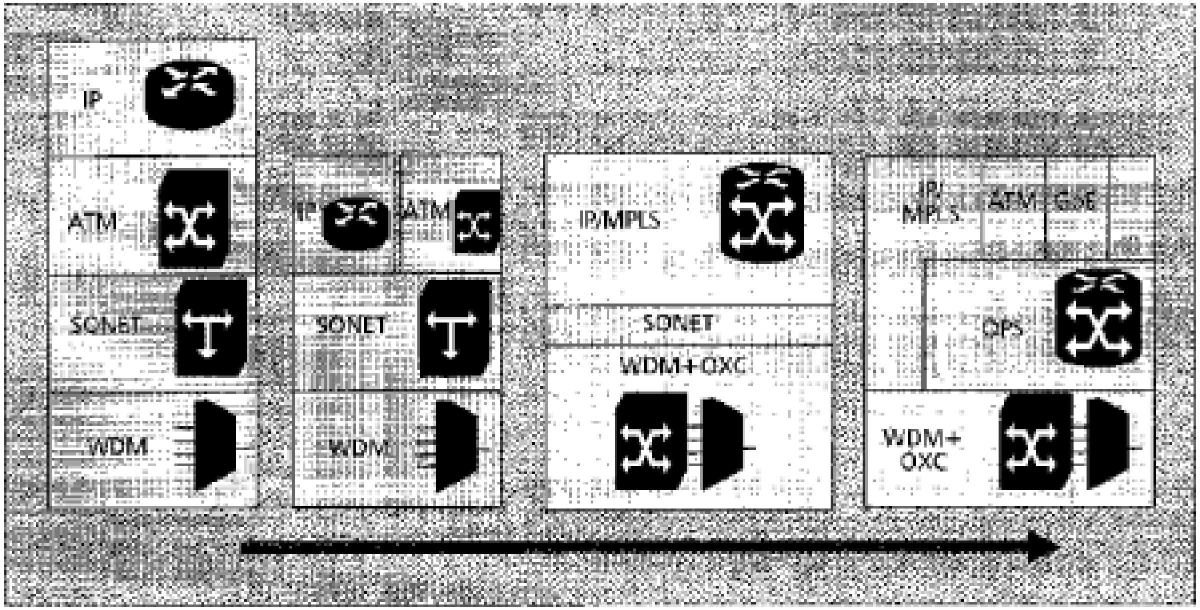
- Introduction
- Optical Packet Switching (OPS)
- The proposed scheme in [2]
- Performances
- Conclusions

Introduction (1/2)

- Switching capacities of electronic routers have difficulties in scaling into Tera-bps which WDM transmission is rapidly scaling.
- Optical packet switching (OPS) switches packet (payload data) in the optical domain without optical-electrical-optical (OEO) conversions.

Introduction (2/2)

- Evolution



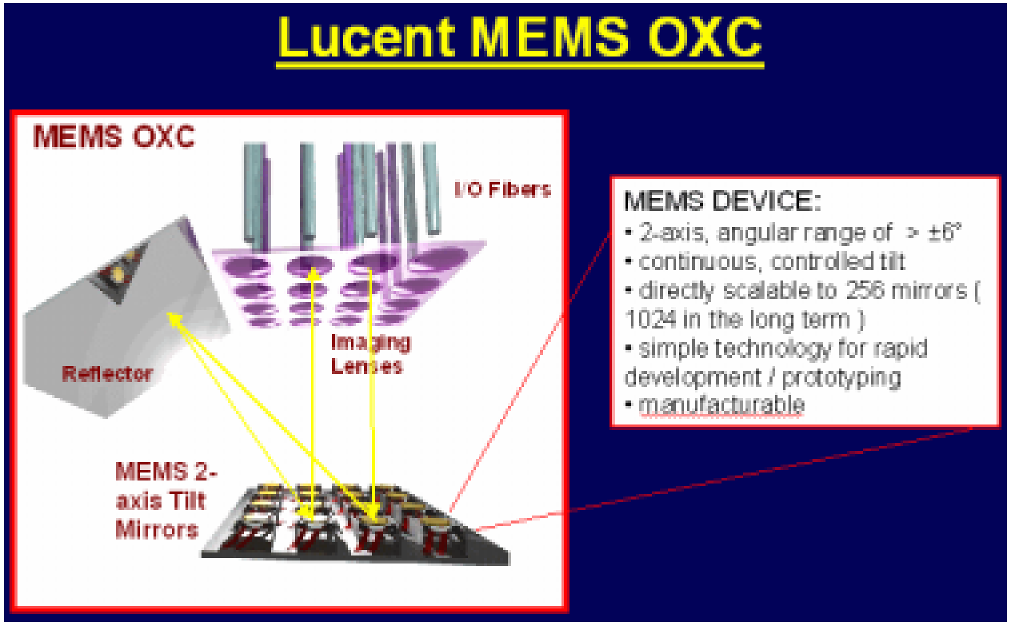
■ **Figure 1.** *The evolution of the protocol stack in telecommunications networks.*

OPS (1/4)

- Driving technologies of OPS:
  - Optical cross-connects (OXCs)
    - Optical micro-electromechanical systems (MEMS)
  - Optical add/drop multiplexers (OADMs)

  - Bubble jet
  - Liquid crystals
  - Thermo-optic switching

Recent Development



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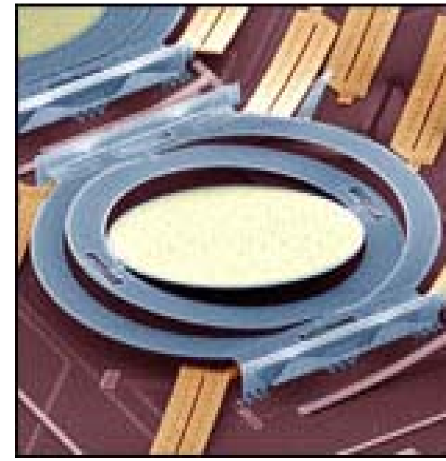


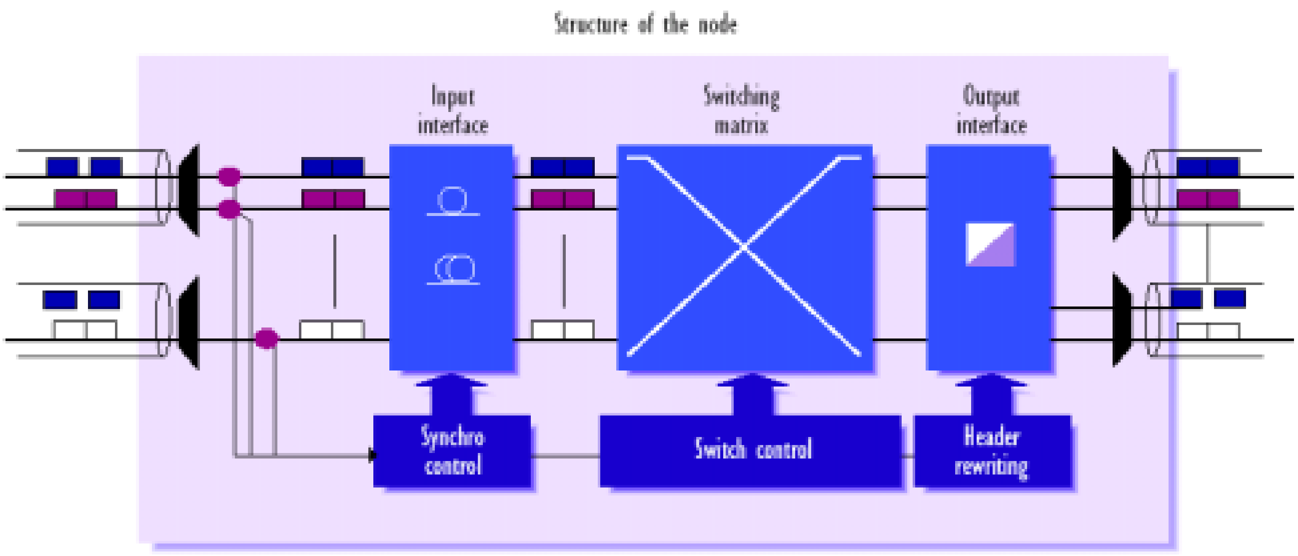
*Taken from Lucent Technology OXC webpage.

Recently, Lucent technologies announced a new 256x256 fiber optic switch using 2-dimensional micromirror arrays. These mirrors use parallel-plate style actuators and are assembled to obtain 10 degrees of deflection. Since weak springs are used to lower actuation voltages, the resonance frequency is lower and in turn increases switching times.

OPS (2/4)

- OPS node architecture

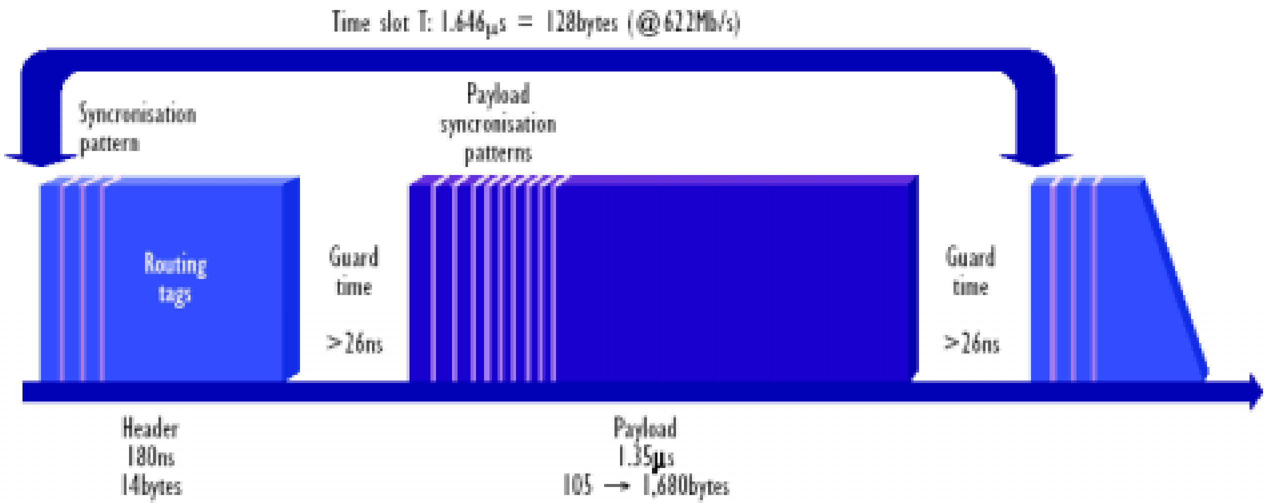
Figure 2: A Generic Optical Packet Switch, Consisting of an Input Interface, Switching Matrix, Output Interface and a Controller



OPS (3/4)

- Transmission mode in OPS
  - Synchronous (slotted)
  - Asynchronous
- Packet format in KEOPS project

Figure 1: The Optical Packet Format Proposed in the Advanced Communications Technologies and Services KEOPS Project



Each packet consists of a separate header and payload that are separated by a guard band.

OPS (4/4)

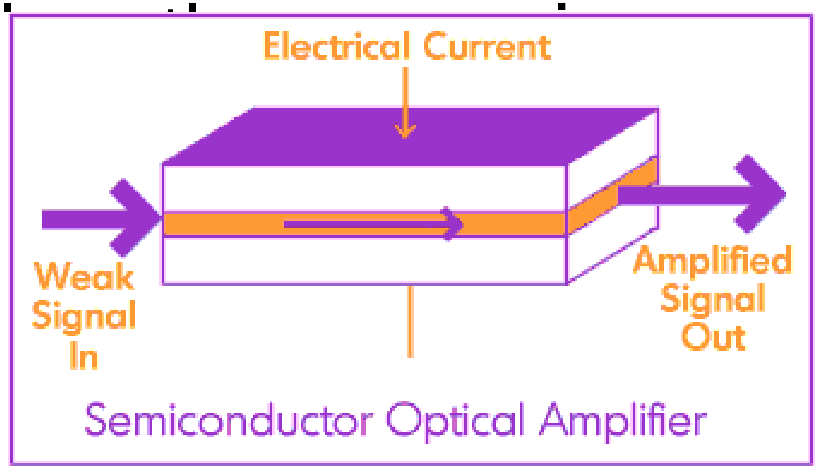
- OPS enabling technologies
  – 3R regeneration
  – Packet delineation and synchronization
  – Packet header processing
  – Optical buffering
  – Optical space switching
  – Wavelength conversion

Background

- One of the objectives in designing an OPS network is low packet loss rate (PLR or PPL).
- Packet loss is caused by packets dropped in contentions.
  - there are two or more packets contending for the same output fiber in the same wavelength, at the same time.
- Contentions can be easily resolved in electrical packet networks with store-and-forward.

Contention Resolution Mechanisms (1/3)

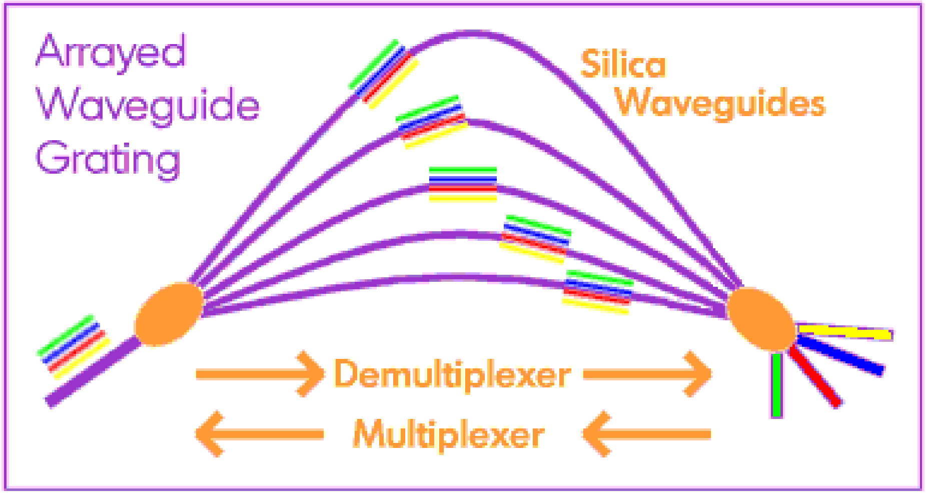
- Wave
  - Wa)
    - S (SOAs)
      0 Gb/s
      0 Gb/s



  - Pump lasers
  - No extra packet latency, jitter or packet reordering problem

Contention Resolution Mechanisms (2/3)

- Optic
  - Fib
    - A
    - W



s (AWGs)

  - No reordering problem

AWG

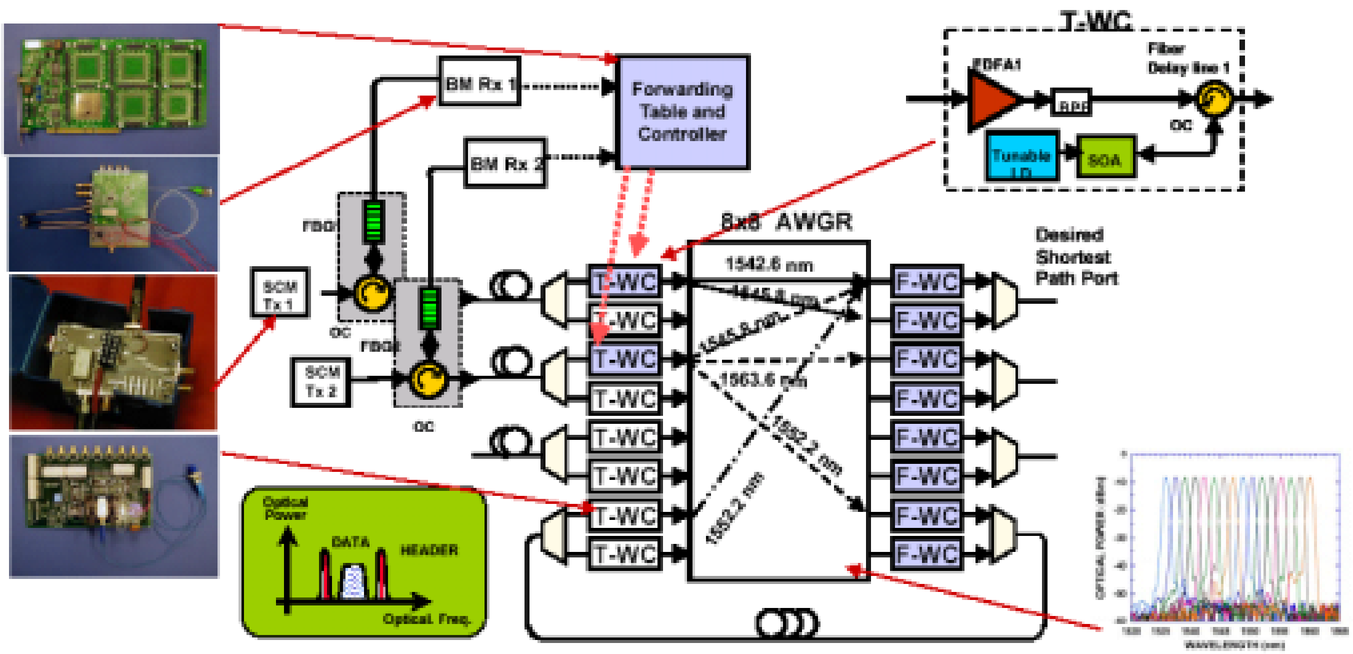


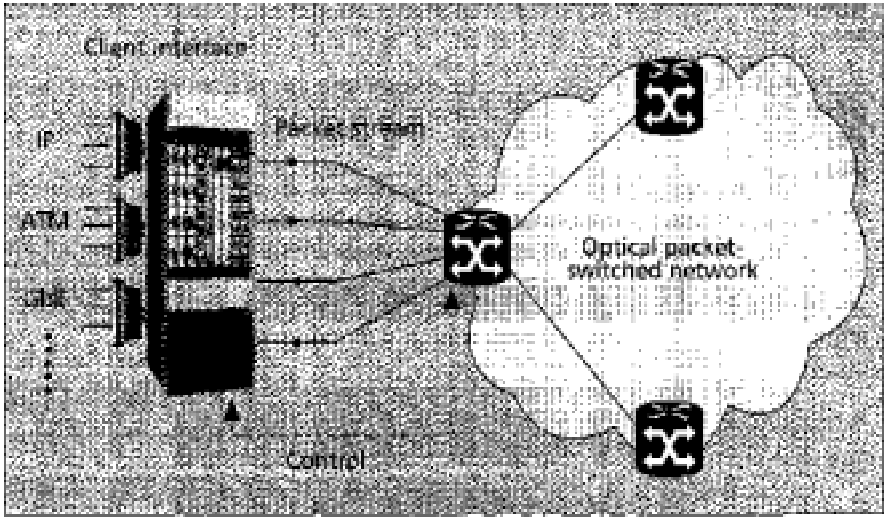
Fig. 1 A schematic of the optical packet routing system capable of contention resolution in wavelength, time, and space domains.

Contention Resolution Mechanisms (3/3)

- Space deflection
  - A multipath routing technique
  - Low-priority packets can have longer paths to their destinations compared to higher-priority packets.
  - Unnecessary bandwidth waste and out-of-order delivery

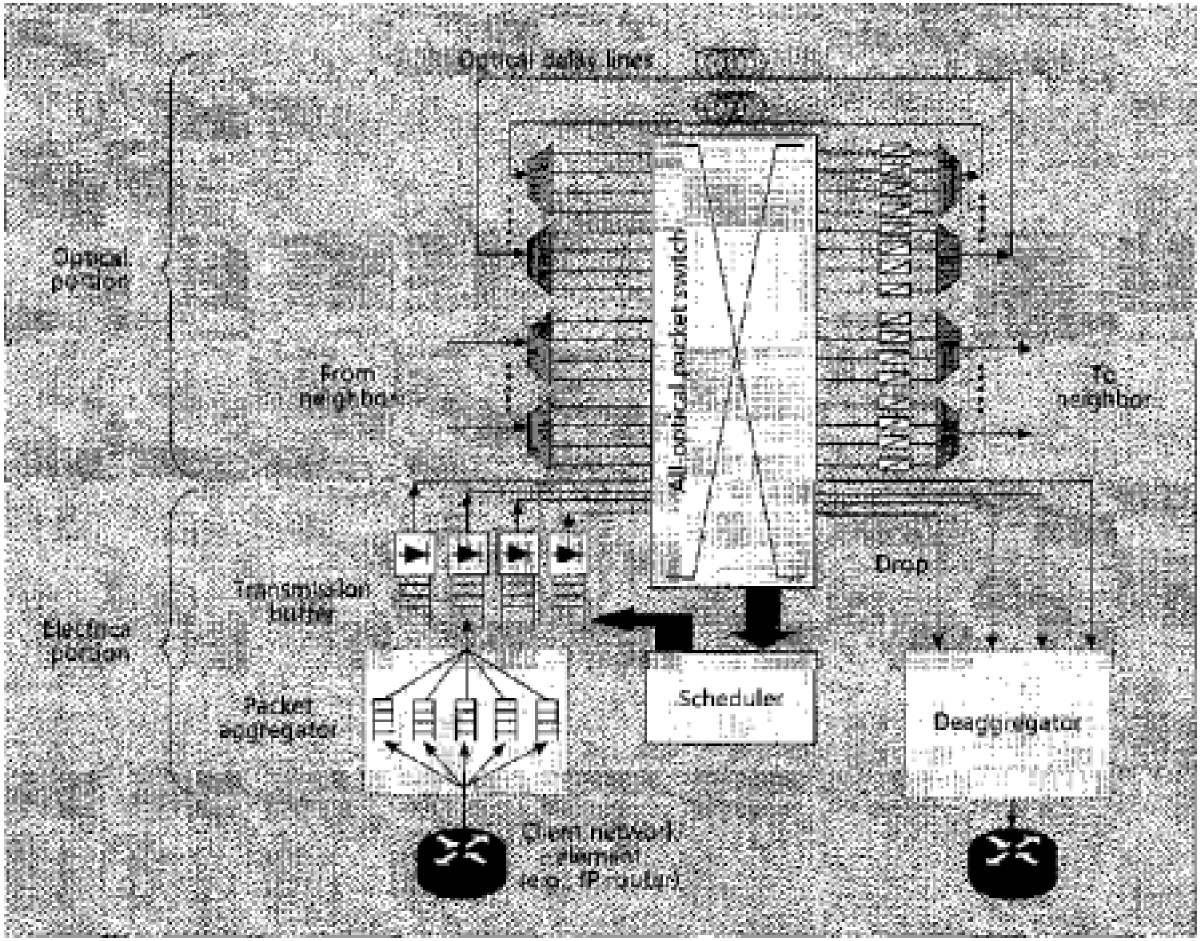
The Proposed Scheme

- Exploiting inexpensive electrical buffering at the network ingress.



■ Figure 2. *The client interface of OPS networks.*

Architecture



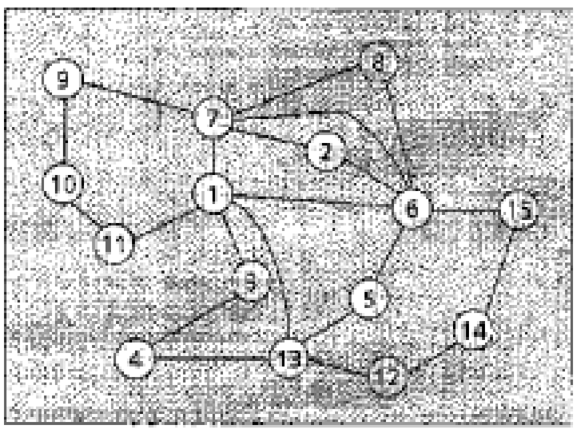
■ Figure 3. *The architecture of the proposed optical packet switch with an electrical ingress buffer and traffic aggregation.*

Main Components

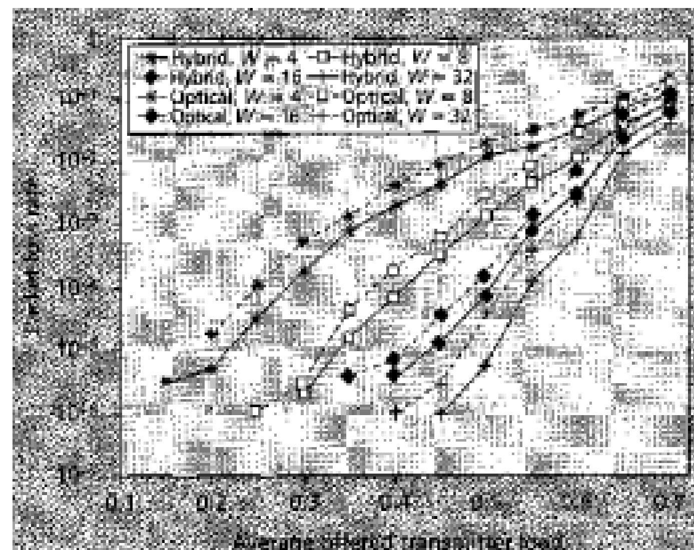
- Packet Aggregator
  - Departure of Aggregates is triggered by threshold or timeout.
- Transmission buffer
  - An aggregate is send into the switch fabric when desired wavelength becomes vacant.

Performance (1/2)

- Ingress buffering, # of wavelengths

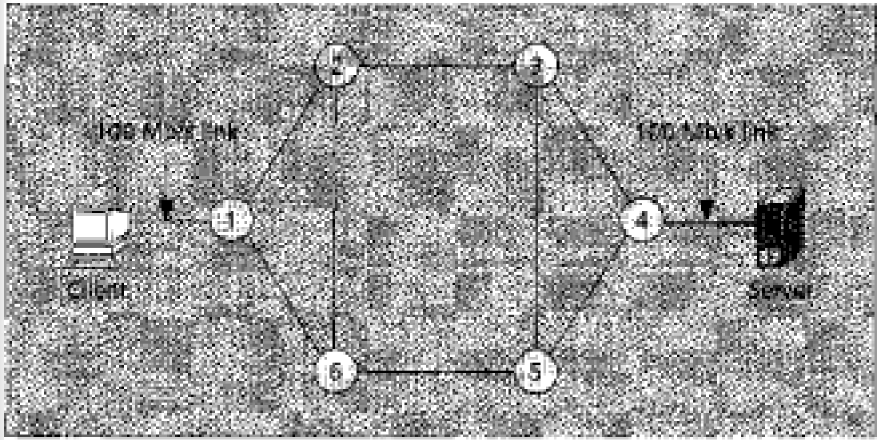


■ **Figure 4.** *An example mesh network topology used in the simulation experiments.*

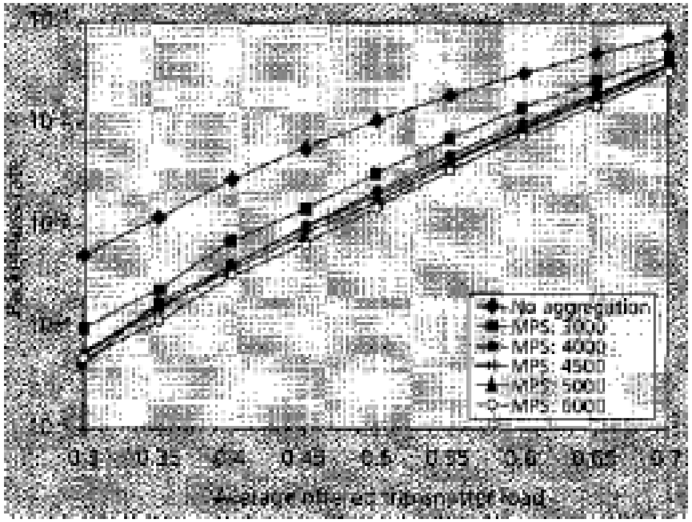


Performance (2/2)

- Maximum payload size (MPS)



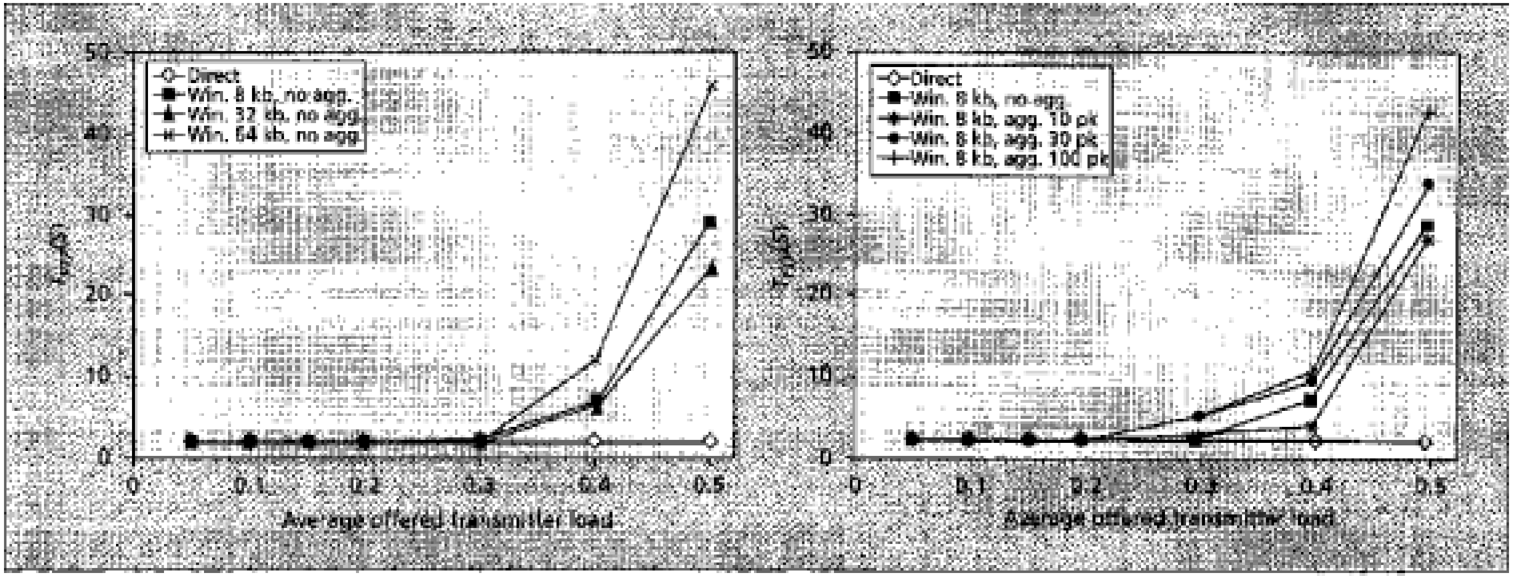
■ **Figure 6.** *The network topology for the TCP experiment.*



Why dose aggregation help?

- Both bursty arrivals and irregular packet size distribution impede convention resolution.
  - Almost 75% IP packets are smaller than 552 bytes.
  - Nearly half are 40-44 bytes.
  - Over half of the total traffic is carried in packet of 1500 bytes.

TCP Performance



■ **Figure 7.** *A comparison of TFTP a) for different TCP window sizes; b) for different aggregation schemes.*

Conclusions

- The scheme exploits inexpensive electrical buffering to improve the performance of optical contention resolution resources by allowing them to solely handle transit packets.
- Packet aggregation that smoothens optical packet size and reduces the burstiness of Internet traffic can significantly improve the TCP performance.

Discussions

- The Scheduler
  - Priorities of transit and local packets
  - Fairness among transmission queues
- Suspicions on the simulation
  - Figure 4: where are the ingress nodes?
  - Figure 7b: 8000/1500=5.33 pkts, so how to achieve 10~100 pkts aggregate?