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# “PHOTONIC PACKET SWITCHING FOR BROADBAND NETWORKS”

Dr. Rodney Tucker, University of Melbourne, Australia

Ottawa, May 28, 1996

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**Photonic Packet Switching  
for Broadband Networks**

**Rodney Tucker**  
**May 28, '96**  
**NRC, Ottawa**



# Photonic Packet Switching for Broadband Networks

*Rodney S. Tucker*

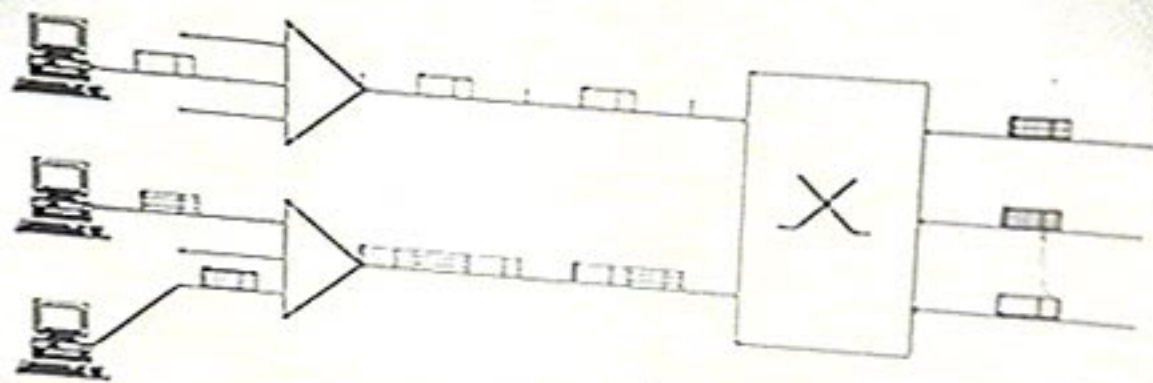
Australian Photonics Cooperative Research Centre  
Photonics Research Laboratory  
Department of Electrical and Electronic Engineering  
University of Melbourne  
Parkville Victoria 3052  
Australia

## **Summary**

- **Packet Switching and Photonics**
- **Technical Issues**
- **Key Photonic Components and Sub-Systems**
- **Proposals and Demonstrations**
- **Outlook**

## What is ATM ?

ATM (Asynchronous Transfer Mode) is a transfer (i.e. multiplexing and switching) technique based on:  
asynchronous multiplexing and  
virtual circuit packet switching

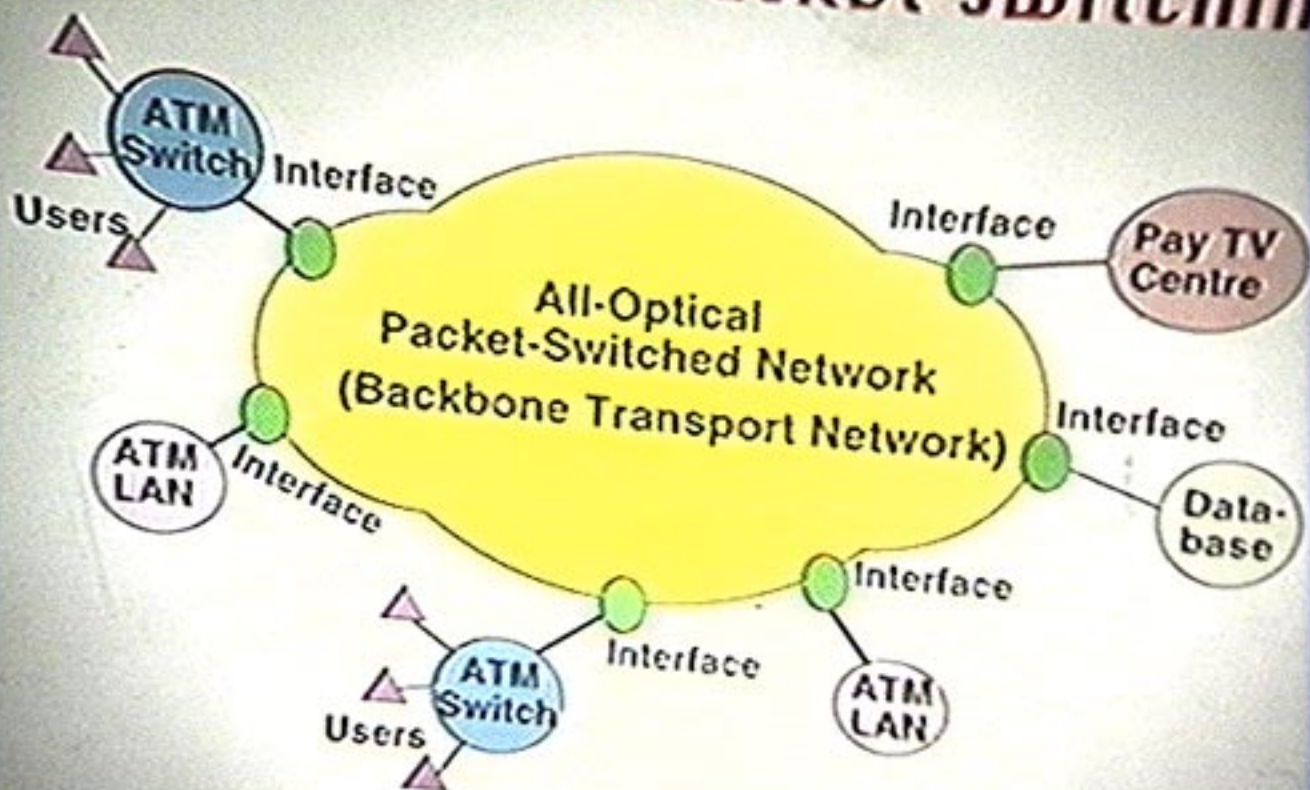


ATM employs fixed size packets called cells (53 bytes)

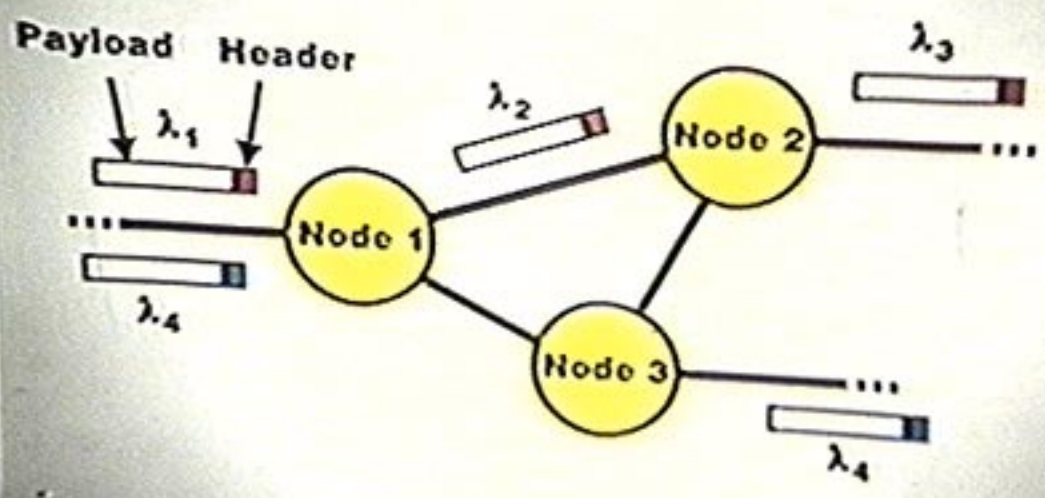
## **Electronic Packet Switching**

- **Emergence of ATM as a Standard**
- **Rapid Developments in Electronic ATM Switching**
- **Bit Rates to 2.4 Gbit/s**
- **Throughputs may Approach 1 Tbit/s**

# Role of Photonic Packet Switching



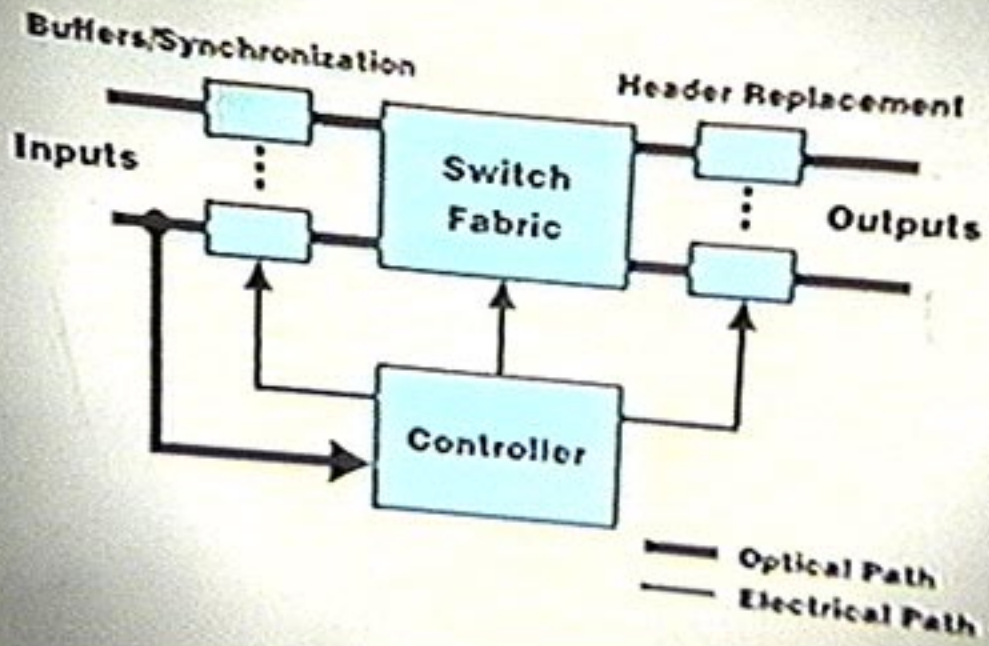
# All-Optical Packet-Switched Network



## **Why Photonic Packet Switching?**

- **Transparency of Photonic Components**
- **Electronic Bottleneck**
  - Bit Rates Above - 10 Gbit/s
  - Multiple Channels
- **Compatibility with Fibre Transmission Medium**
  - Multi-Wavelength Systems
  - All-Optical Networks
  - Elimination of O/E and E/O Converters
- **Non-ATM Systems**

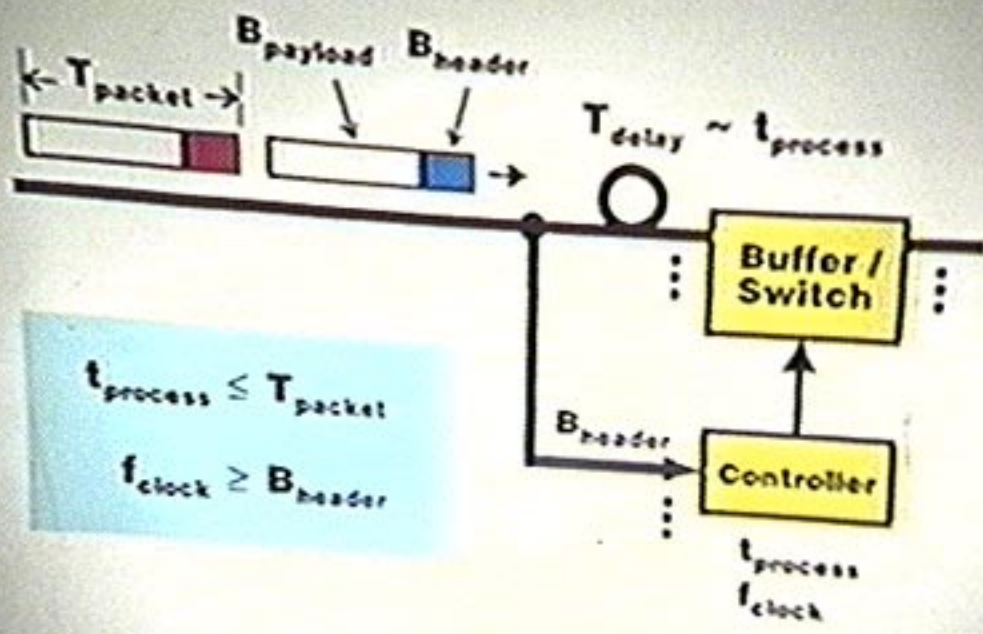
# Photonic Packet Switch



## **Photonic Packet Switching Issues**

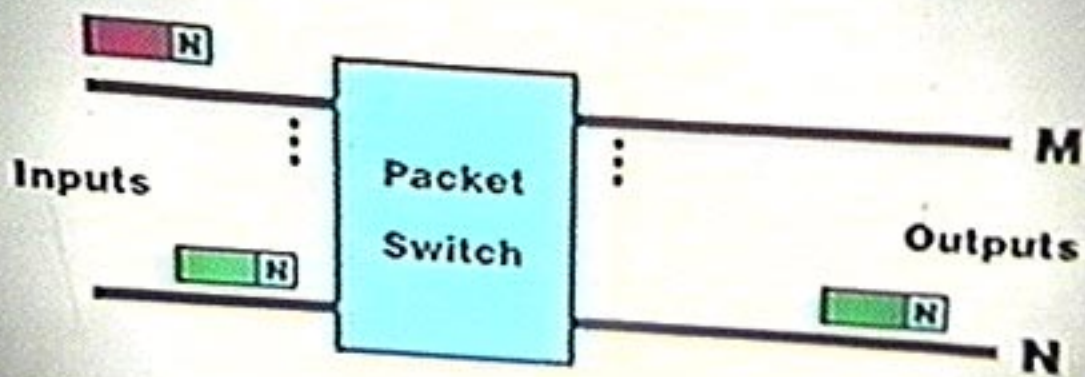
- **Optical and Electronic Processing/Control**
- **Contention Resolution and Buffering**
- **Packet Synchronization**
- **Switch Fabrics**
- **Centralized and Distributed Architectures**
- **Header Replacement**
- **Timing Recovery**
- **Signal Level Control/Thresholding**
- **Packet Compression/Decompression**

# Optical vs. Electronic Control

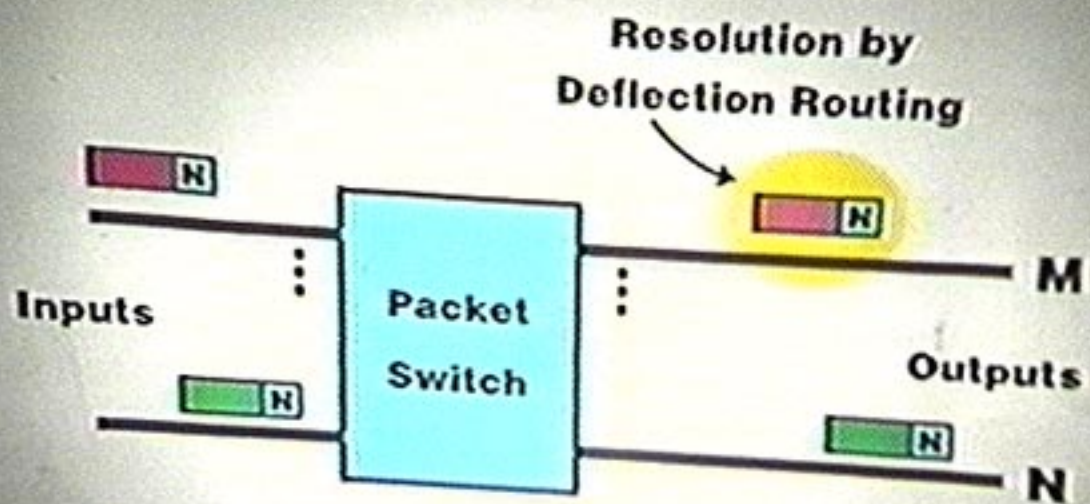


$t_{\text{process}} \leq T_{\text{packet}}$   
 $t_{\text{clock}} \geq B_{\text{header}}$

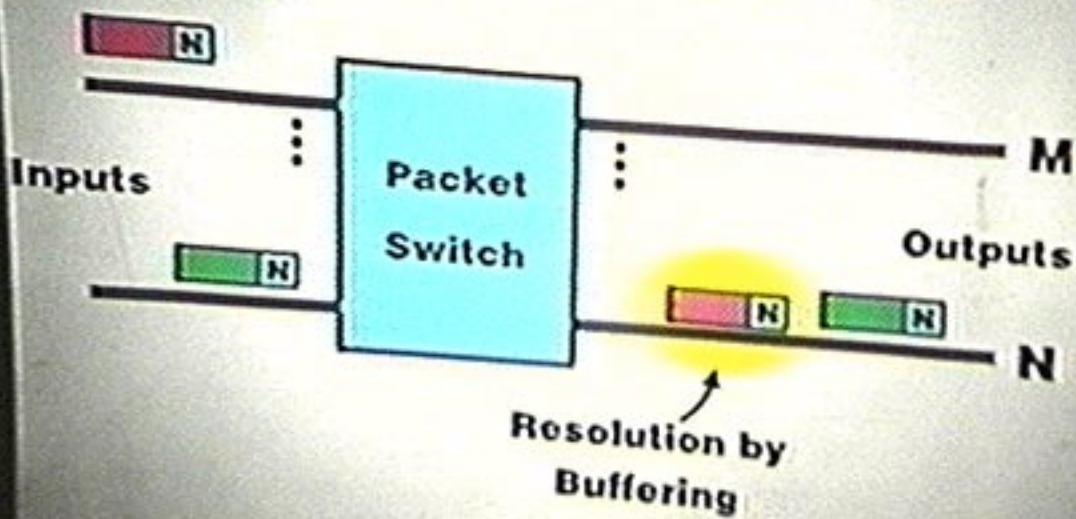
## Contention Resolution



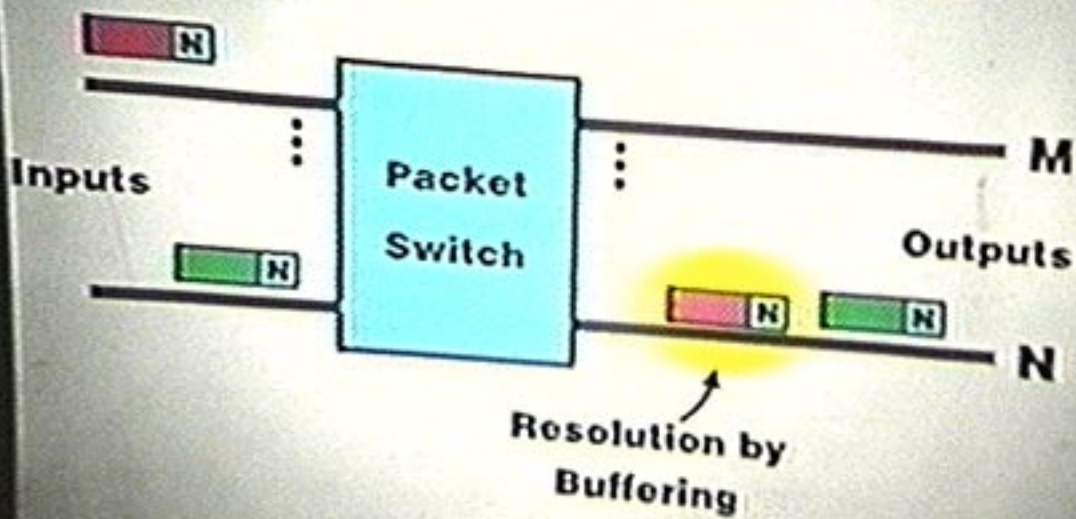
## Contention Resolution



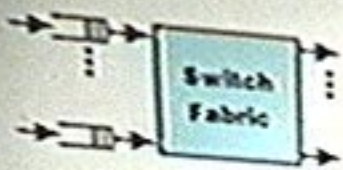
# Contention Resolution



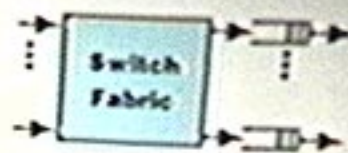
# Contention Resolution



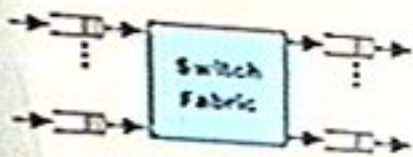
## Buffering



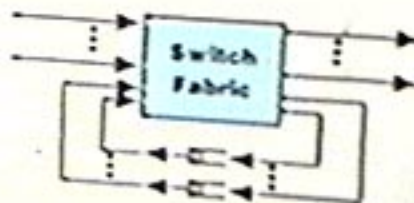
Input Buffers



Output Buffers



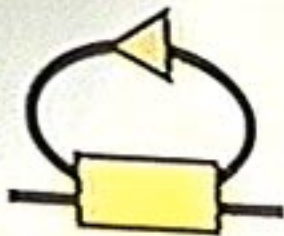
Input and Output Buffers



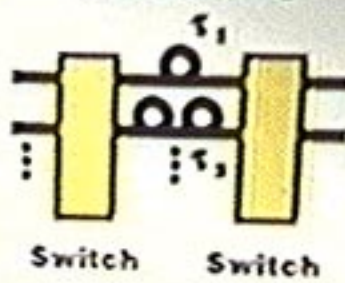
Recirculation Buffers

## Optical Buffers

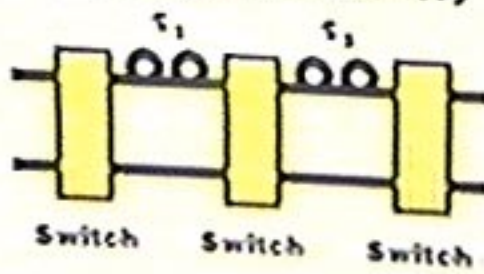
Loop Memory



Staggering



Travelling-Wave Memory

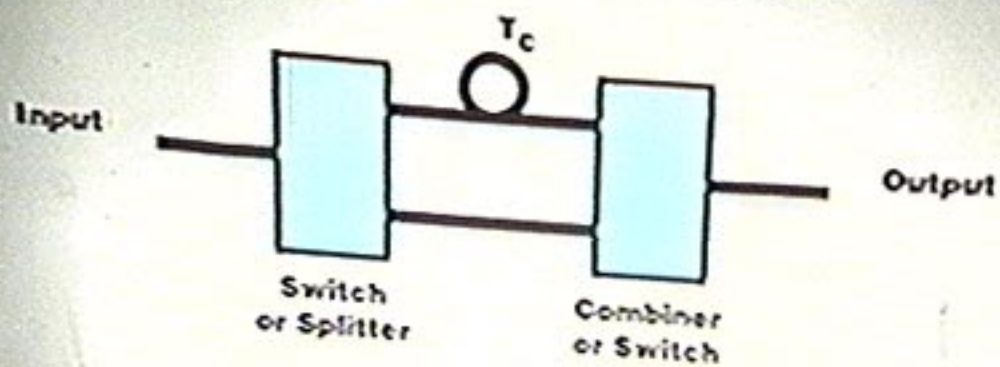


## **Optical Buffer Memory Requirements**

- **Ease of Control**
- **Optical Transparency**
- **Adequate Capacity**
- **Simplicity (Minimum Components)**
- **Output Power Independent of Storage Time**
- **Low Noise**
- **First-In-First-Out (FIFO) Capability**

## Single-Cell Memories

### 1. Unit Delay Memory

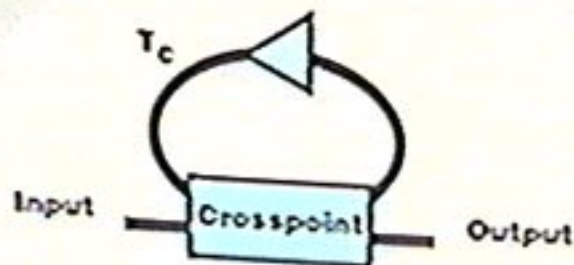


- Simple
- Buffer capacity = one cell
- Maximum buffering time =  $T_c$

$T_c = \text{Cell Period}$

# Single-Cell Memories

## 2. Loop Memory

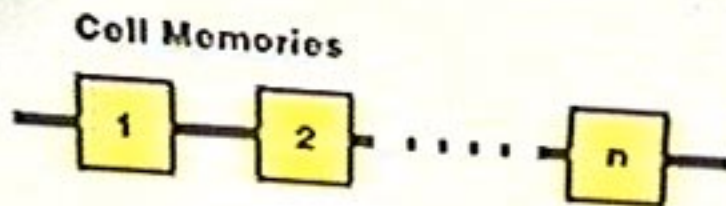


$T_c = \text{Cell Period}$

- Small component count
- Amplifier required in loop
- Buffer capacity = one cell
- Maximum buffering time limited by amplifier noise
- Random access
- Capacity expandable by WDM

## Multi-Cell Memories

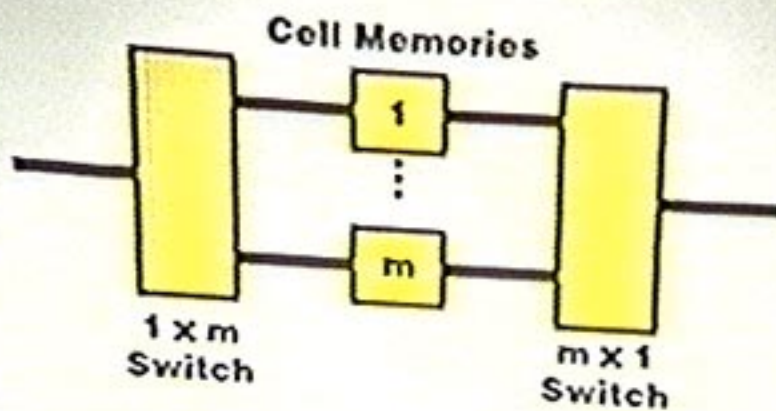
### 1. Serial Structure



- Buffer capacity =  $n$  cells
- Maximum buffering time =  $n \times$  ( cell memory buffering time )

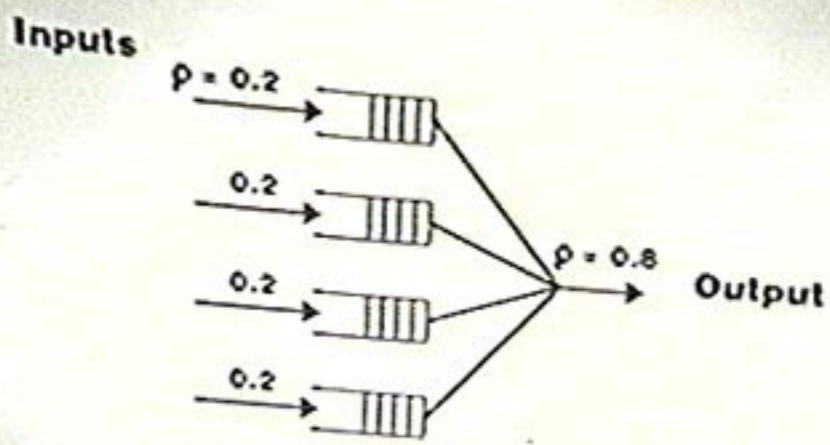
## Multi-Cell Memories

### 2. Parallel Structure



- Maximum buffer capacity =  $m$
- Maximum buffering time limited by cell memories

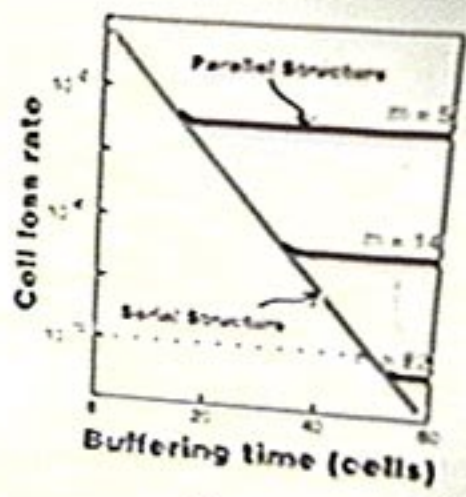
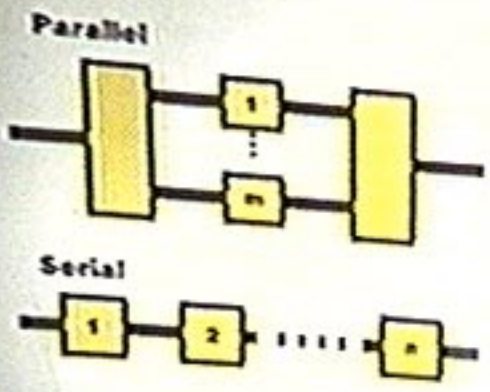
## Multi-Cell Memory Simulation



Poisson Statistics, FIFO Polling

Maeda et al. '94

# Multi-Cell Memory Simulation



Maeda et al. '94

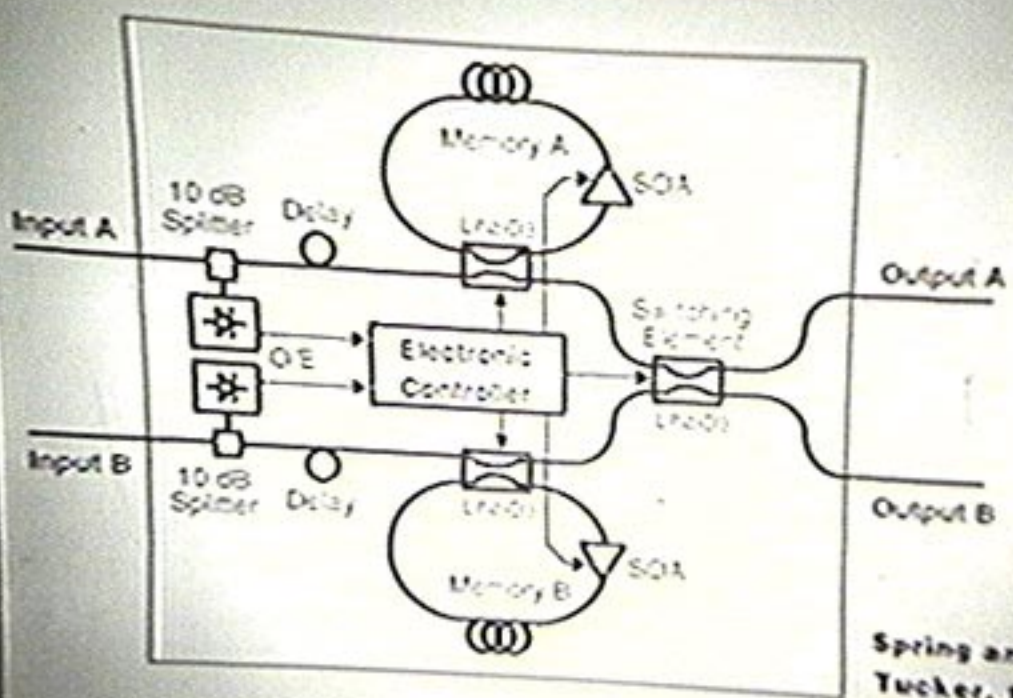
Bostica et al. '93

# MODEL OF THE PHOTONIC ATM CROSS-CONNECT



Link Termination (LT), Exchange Termination (ET), Cell Aggregator (CA), Packet Compressor (PC), Packet Decompressor (PD), Frequency Converter (FC), Butterworth Filter Array (SF), Tunable Filter (TF), Wideband Amplifier (A)

# Photonic Packet Switch with Input Buffers



Spring and Tucker, 1993

ALCATEL

SWITCH FABRIC BLOCK  
DIAGRAM --> SPECTRO TIME SWITCH

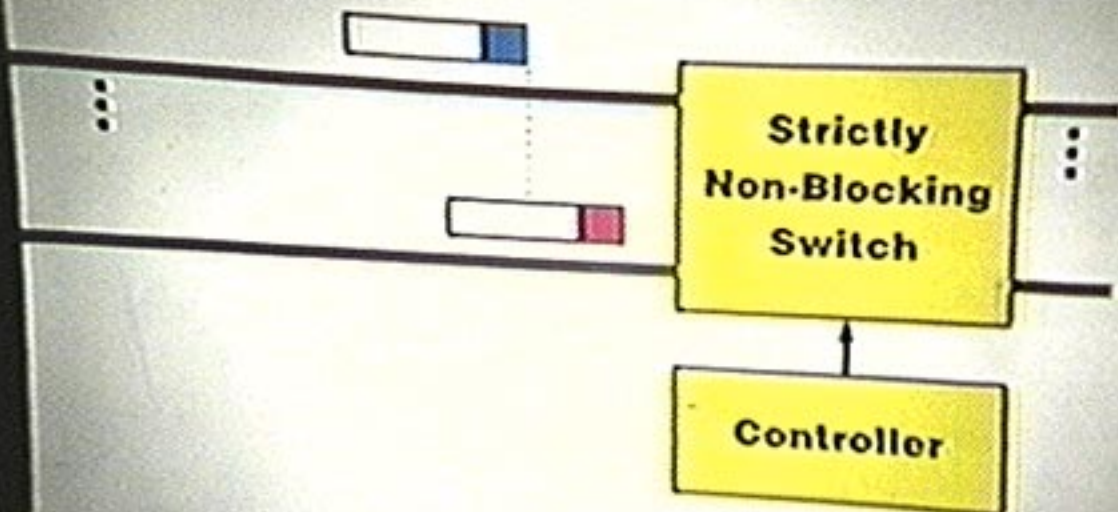


ALCATEL

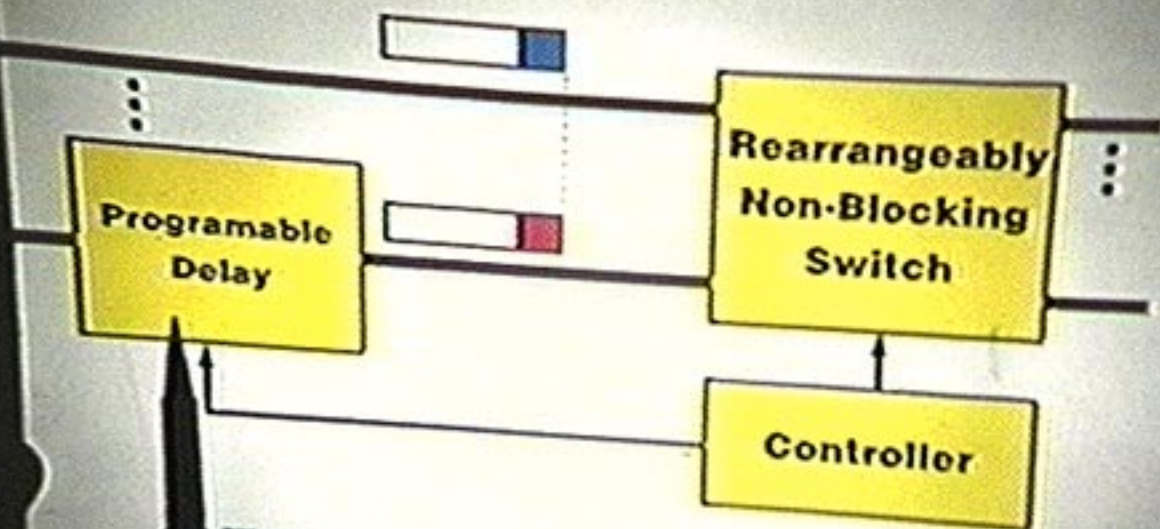
# ATM Optical Switching (ATMOS)



## Packet Synchronization



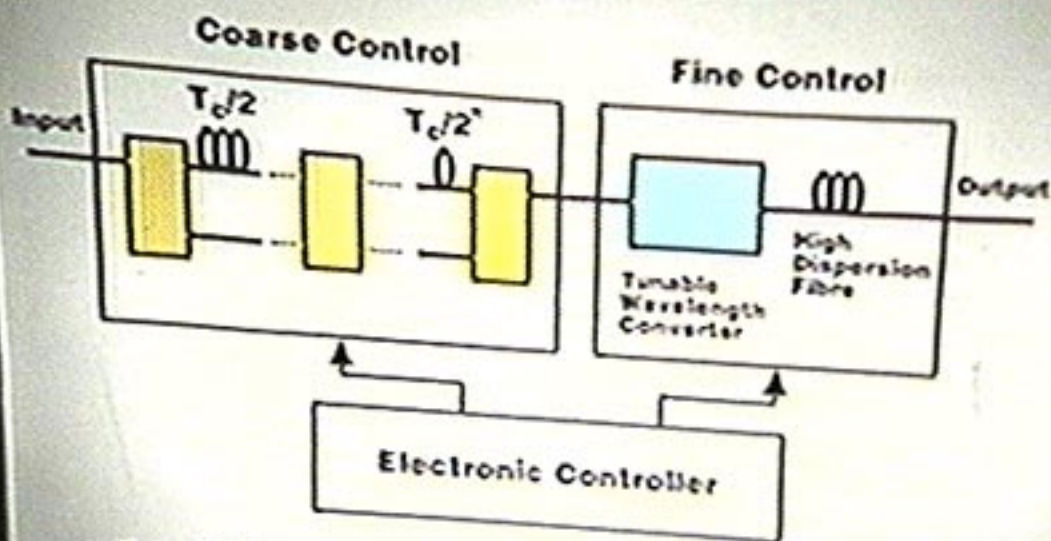
# Packet Synchronization



Thompson '87  
Prucnal '93  
Haas '93

Delay Realizations  
Optical Processing  
Packet Flipping

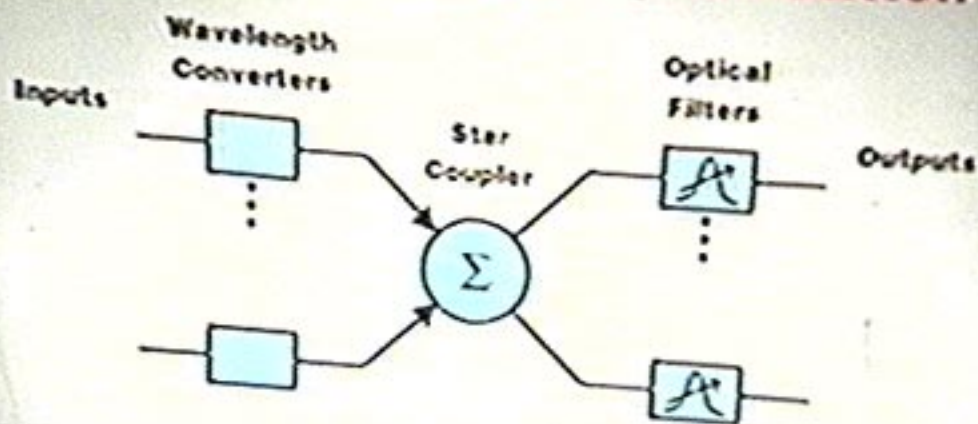
# Programable Delay for Cell Synchronization



$T_c$  = Cell Period

Burzio et al. ECOC'94

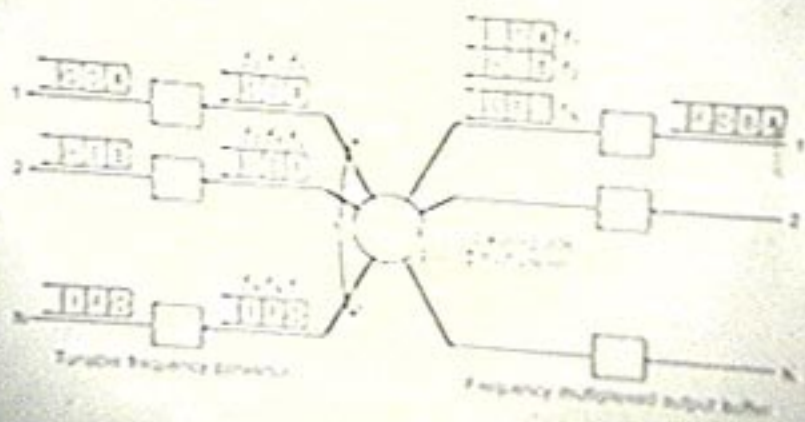
## Broadcast and Select Space Switch



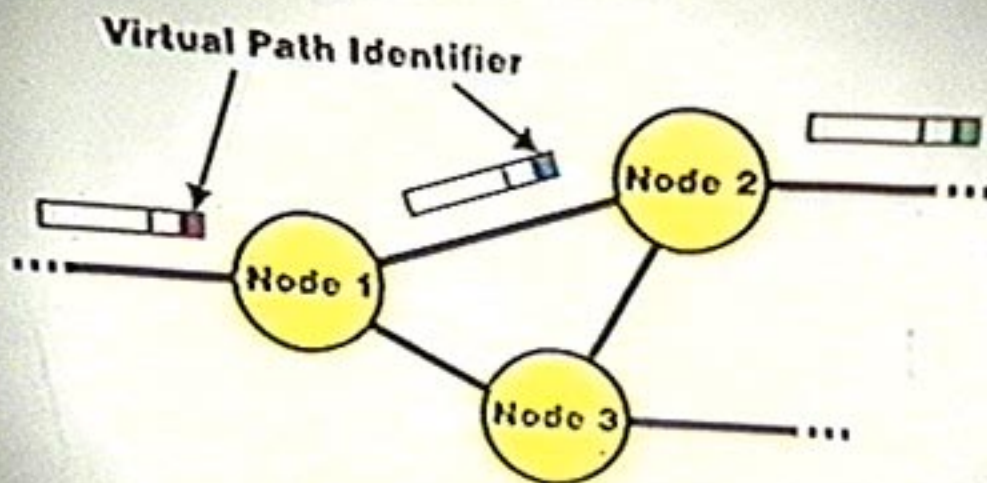
- Fast tunability required ( $\lambda$  converters or filters)
- Tunable filters provide multicasting capability
- Compatible with multi-wavelength buffers

Photonic ATM switch using frequency-routing-type  
time-division interconnection network

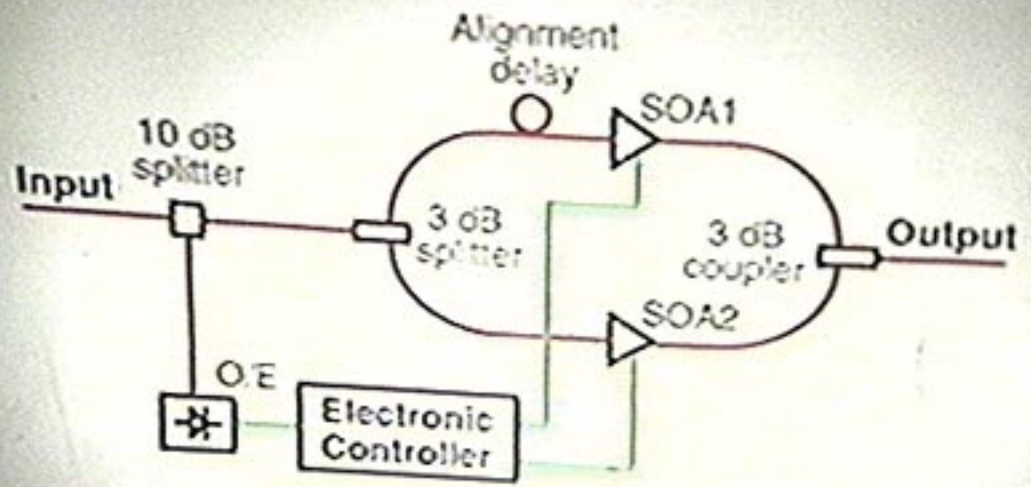
-FRONTIERNET-



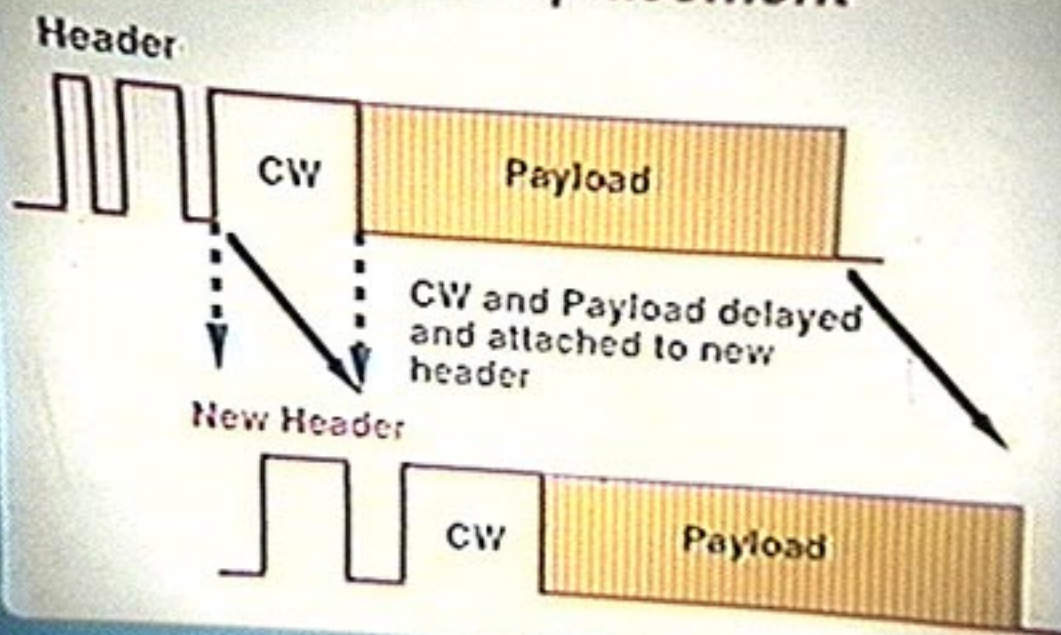
## Header Replacement



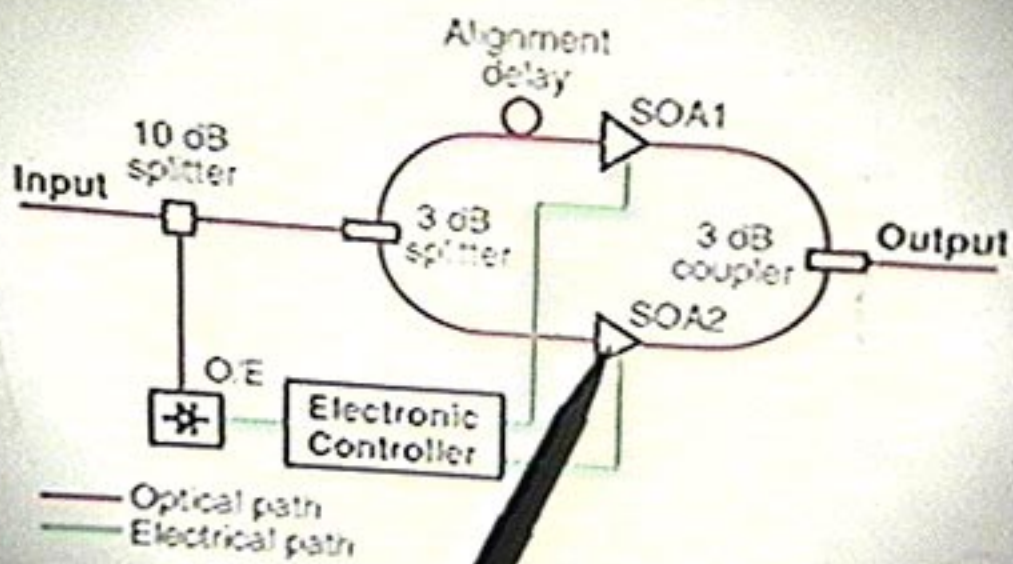
# Photonic Header Replacement Module



## Header Replacement

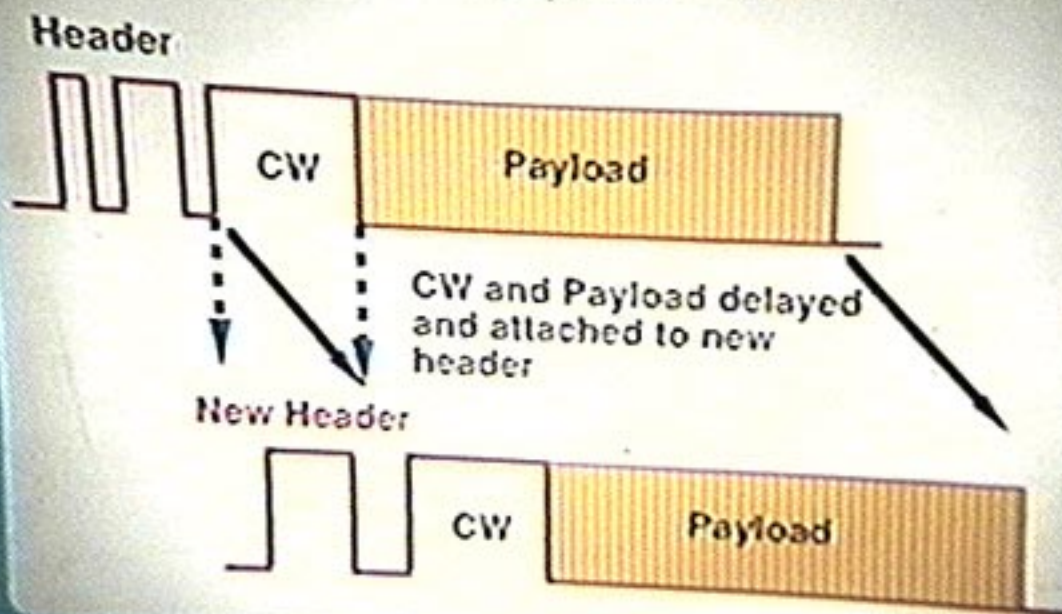


# Photonic Header Replacement Module



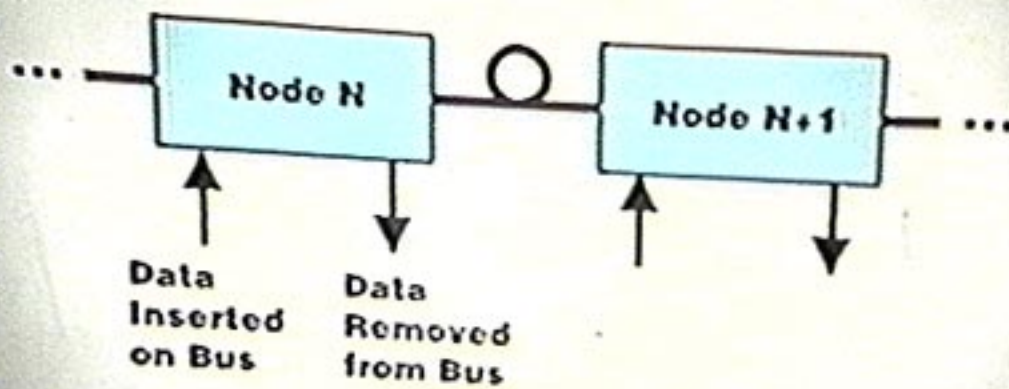
Spring and Tucker, '93

## Header Replacement

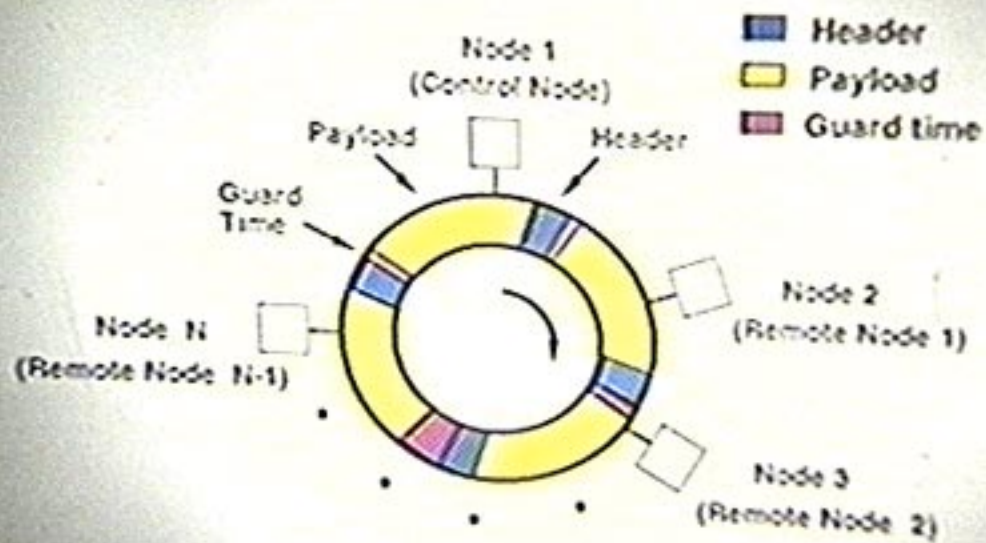


## Ring and Bus Networks

Optical Add/Drop  
Multiplexers

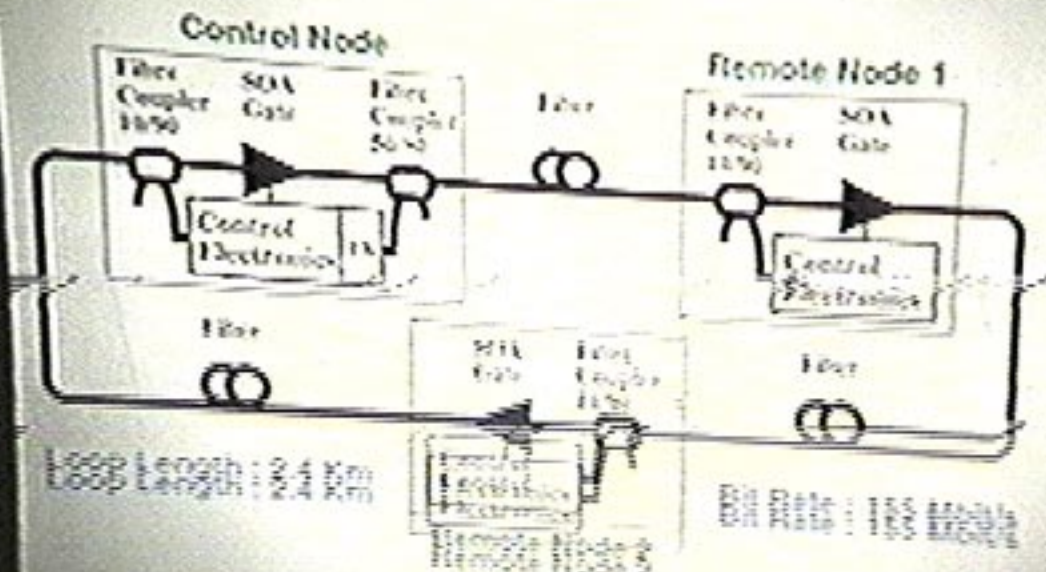


# Slotted Ring Architecture



# Experimental Photonic Packet-Switched LAN

Cai et al., '93



## **Other Issues**

- **Timing Recovery**
- **Signal Level Control and Thresholding**
- **Packet Compression and Decompression**

## **Photonic Packet Switching — Outlook**

- **Tbit/s Throughput**
- **Device Developments**
  - Frequency Converters, Filters
  - Amplifiers, Gates
  - Buffer Memories
- **Non-ATM Applications**
  - Ring/Bus
  - LAN/MAN
  - All-Optical Networks