Introduction to Photonic Packet Switching

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Outline of the talk

- Introduction to switching
- types of switching
- functions in a switch
- why optical packet switching?
- switching in near future optical networks
- basic switching elements and buffering
- various architectures
- what we have been doing?
- conclusion

Information Switching

- Provide mechanisms to interconnect inputs to outputs

- needed to efficient utilize the network resources

Why?

- o Full mesh connectivity Vs. Switched connectivity (${}^{N}C_{2}$ and N/2 links respectively)
- o Resource sharing

• Types

- o *Circuit Switching*
- o *Packet switching*
- o *Cell switching*

Circuit switching

Example - conventional telephony.

Step involved in communication are

- Circuit setup, use and clearing.
- through switches (commonly known as Central Office or exchanges)

- In circuit switching, inefficient use of resources.

Voice/video/data transfer

- Bursty in nature, utilization is low.

- Others have to wait till line is released

Packet Switching

- Packetization and transfer of information (after source coding).
- Efficient use of line.
- More sources can use the line.
- For limited number of sources, the jitter induced degradation will be tolerable.

Jitter - bursts from more than one sources come at the same instant.

Cell Switching

- it is subset of packet switching

- fixed packet size (e.g. ATM cells)

- uses virtual circuits, routing decisions - during virtual circuit setup.

    For packets, routing decisions on individual packet basis

- If buffers in all the switches follows FIFO discipline

  in cell switching - cells delivered in order

  in packet switching - packet may not be delivered in order

Modern day switching devices (for backbone networks)

  IP Switches/ routers - example of packet switch

  ATM switches - example of cell switch

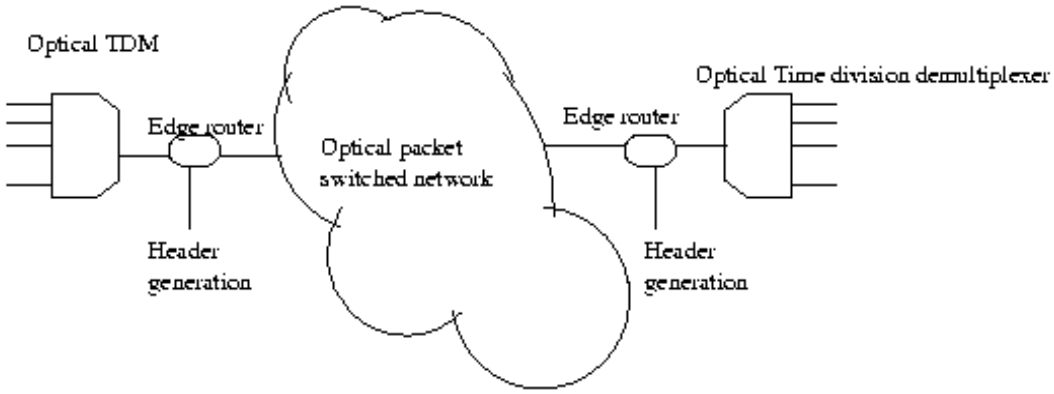
  SONET Add drop multiplexer - example of circuit switch

Functions in a packet switch

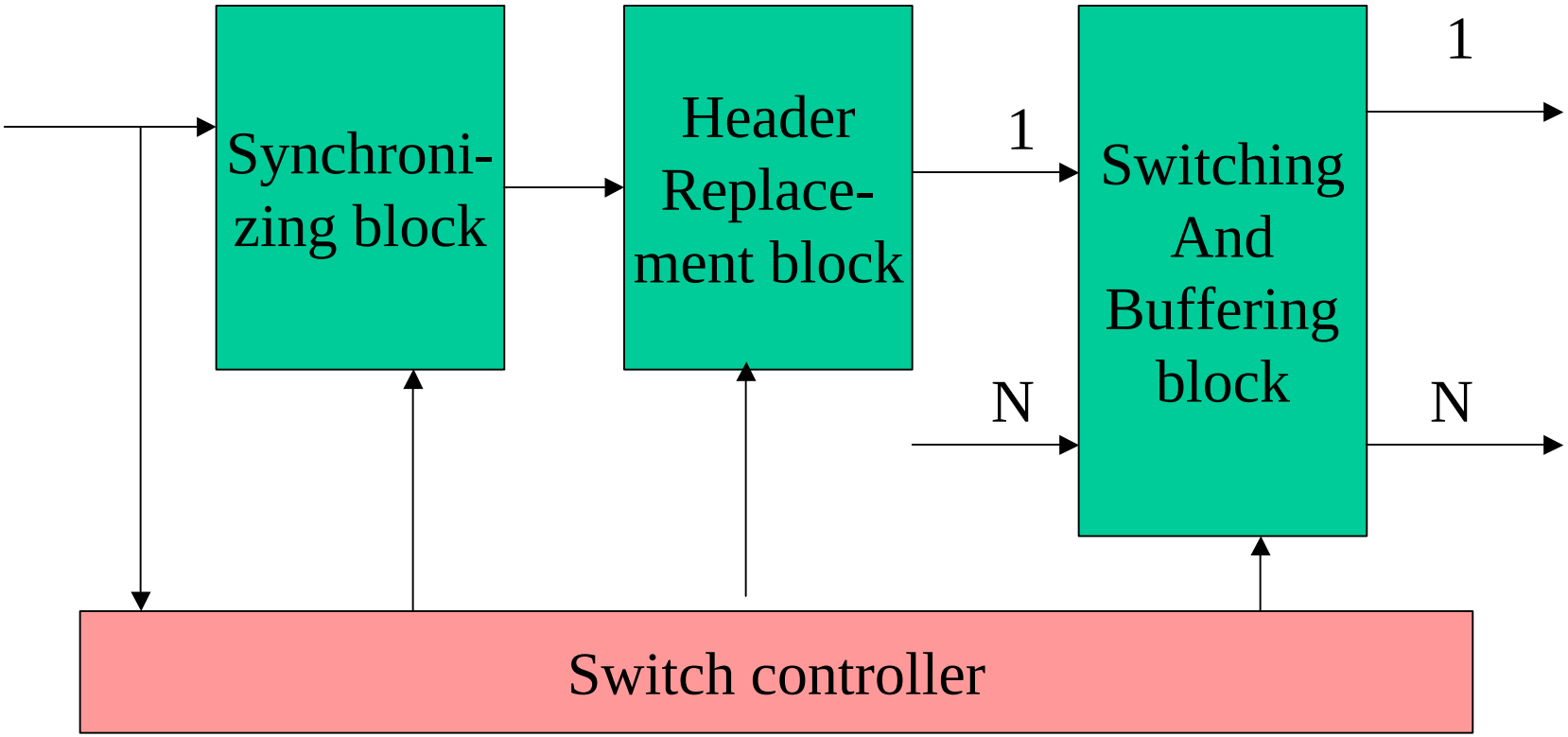
- **routing -** providing network connectivity information through routing tables
- **forwarding -** defining the output for each incoming packet (based on routing table)
- **switching -** directing each packet to proper output (defined by forwarding process)
- **buffering -** resolving contention by storing packets

Why optical packet swtiching?

- clock skew
- cheaper electronic interfaces
- bit rate, modulation and format can be non standard
    - Need to be agreed between two edge routers only.
    - leads to payload transparency.



Basic generic packet switch



- Routing and forwarding - difficult to implement using optical technology at the moment

- Switching and buffering - can be implemented optically as well as electronically

For photonic packet switch

- hybrid approach preferred

Routing and forwarding - using electronics

switching and buffering - optically

Current trend – use of optical wavelength routers in backbones

Backbones

- use optical fiber as transmission media
- increamental bandwidth possible using DWDM (Dense Wavelegnth Division Multiplexing);
- ITU-T grid specifies 100GHz channel spacing - 160 wavelengths in 1.5 μm band.

- With improvement in technology, optical components are becoming available for switching

IP routers/ SONET multiplexers use wavelength as lightpaths to communicate between them

Optical switches - to route the light paths are available

- these are optical circuit switches

Example:

- Lucent's Wavestar Lambdarouter - uses mirrors to route the light paths from one port to another port.
- Cisco ONS19500

Each of these switches

- need to have intelligence - to manage circuit setup, clearing and fault management

- All the control processors forms a network using certain predetermined wavelength
- Each processors run the operating system to manage the switch. Management entity (agent) uses this processor.
- These entities talk to each other using certain application protocol. Protocols or interfaces are still evlolving (IETF, Optical Inter-working Forum)

Problems

- BW granularity is poor.
    - IP Router A not connected to IP Router B. Both connected to IP Router C.
    - Packet from A to B goes via C.
    - AC and CB light path may share some physical link.
    - If traffic between AB high, Light path should be adjusted.
        - Average traffic per physical link should be minimized. (Algorithms for this - good open engineering problem).

The above problem

- can be resolved - if optical packet switching is used.

Always use packet switching in lowest layer for efficiency.

- Optical packet switching means payload remains optical throughout from source to destination

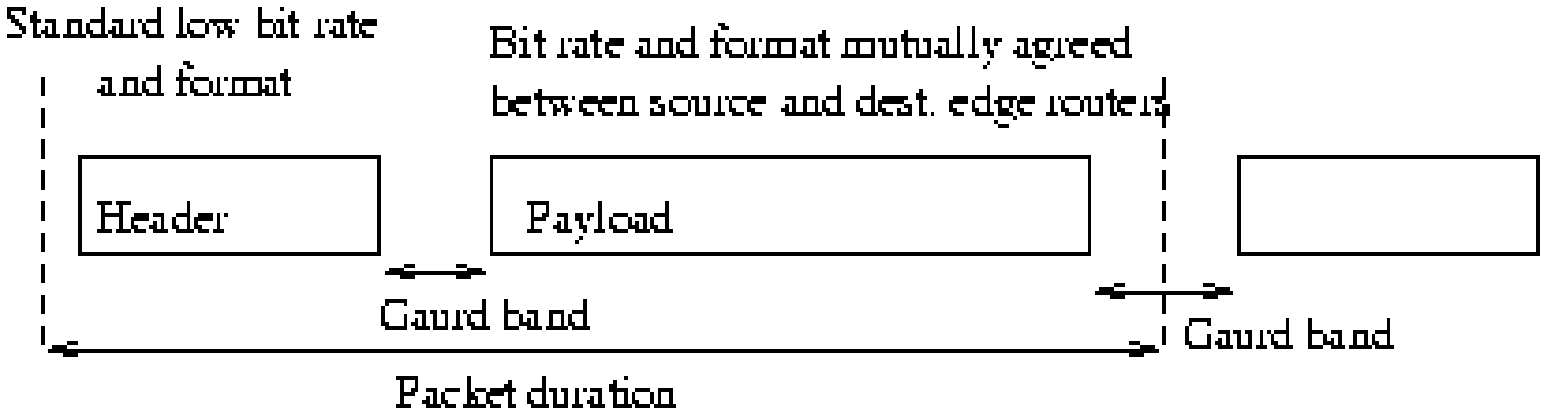
- No management algorithms to optimize the circuits continuously.

- Problems when traffic between various IP routers will change suddenly, can be avoided.

Other advantages

- As payload of packet remains optical throughout, different payload formats (e.g., bit rate, modulation) can be used.
- Since fiber can support very high bit rates (Bandwidth of fiber ~40 THz by conservative estimate)
    - Multiple packets for single destination can merged using optical TDM techniques into single payload.
    - The merged packets can be separated at the destination again using optical TD demuliplexing techniques.

Format for packets



For implementing certain optical header regeneration techniques

- packet format may be different. This structure need to be standardized over the network.

- for payload only duration need to be standardized.

Basic elements needed for the switching

- SOA
- Electro-optic switch (based on 2x2 coupler)
- Spatial Light modulator
- Tunable wavelength converters alongwith wavelength filter/ AWGM
- Fixed wavelength converter with tunable filter

For buffering

- No equivalent of RAM in optical domain.
  - Bits can be stored in bistable laser diodes or flip-flops made using optical logic gates. (Technology is matured for implementing large optical RAMs.)
- Optical fiber delay lines

Effective Refractive index in fiber ~ 1.5

Speed of light in fiber ~ 2×10^8 m/s

For packet with 1024 bytes = 8192 bits ~ 9000 bits (overhead bits, synchronization bits etc.), transmission rate 1Gb/s,

duration of transmission = 9×10^{-6} secs (slot period)

Fiber length to delay the packet by one slot = 1.8 km

$$l = \frac{c}{n} \times \frac{b}{T}$$

l - length of loop,

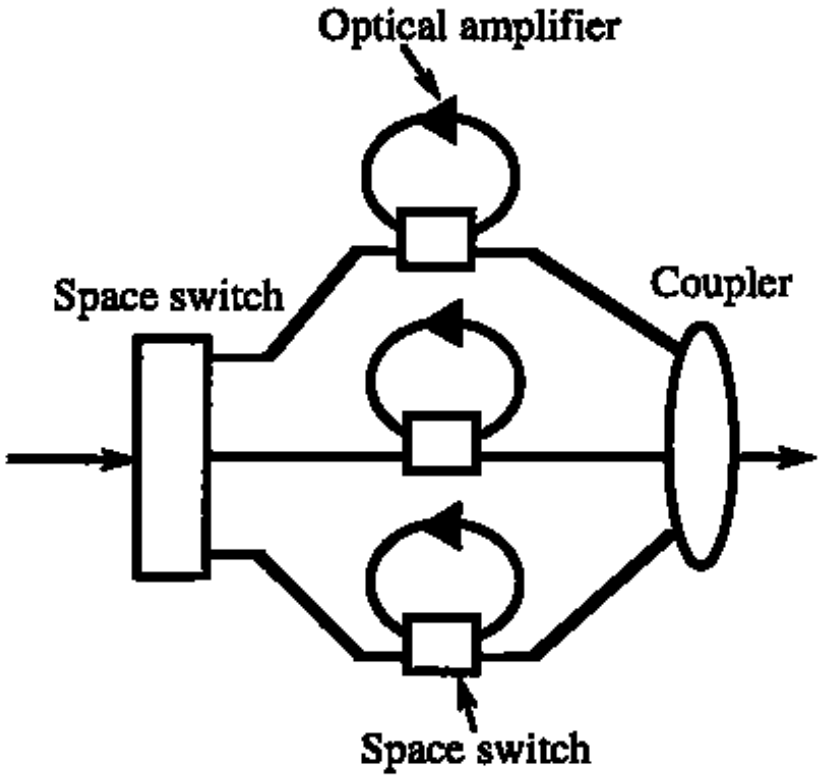
c - Speed of light,

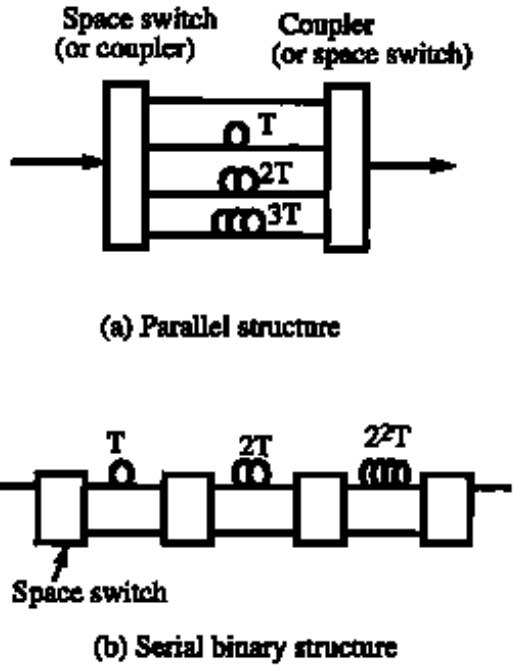
n - R.I. of fiber,

b - number of bits in packet,

T - transmission rate

Various types of buffers





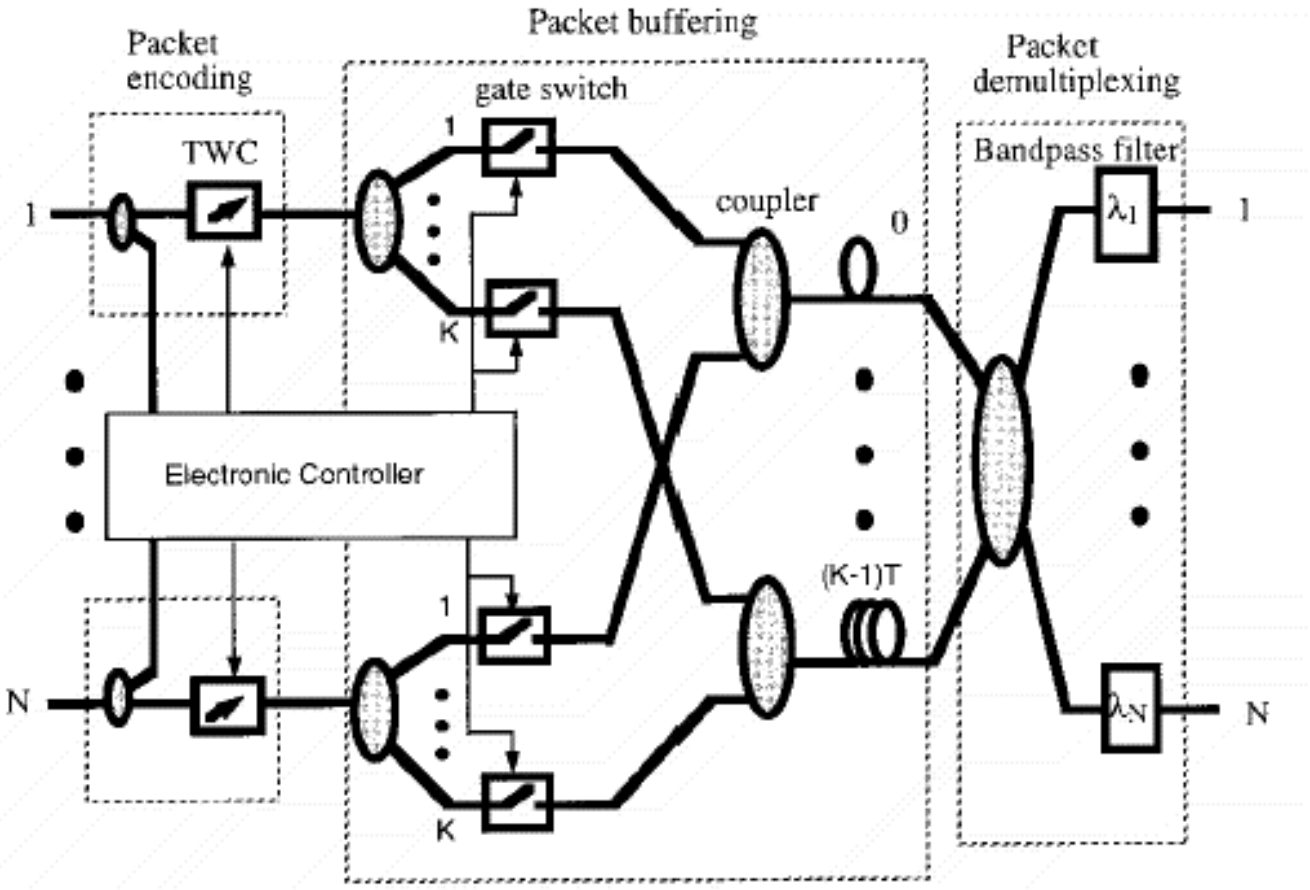
Other devices available

- WDM (multiplexers, demultiplexers),
- Couplers,
- filters,
- Add drop multiplexers

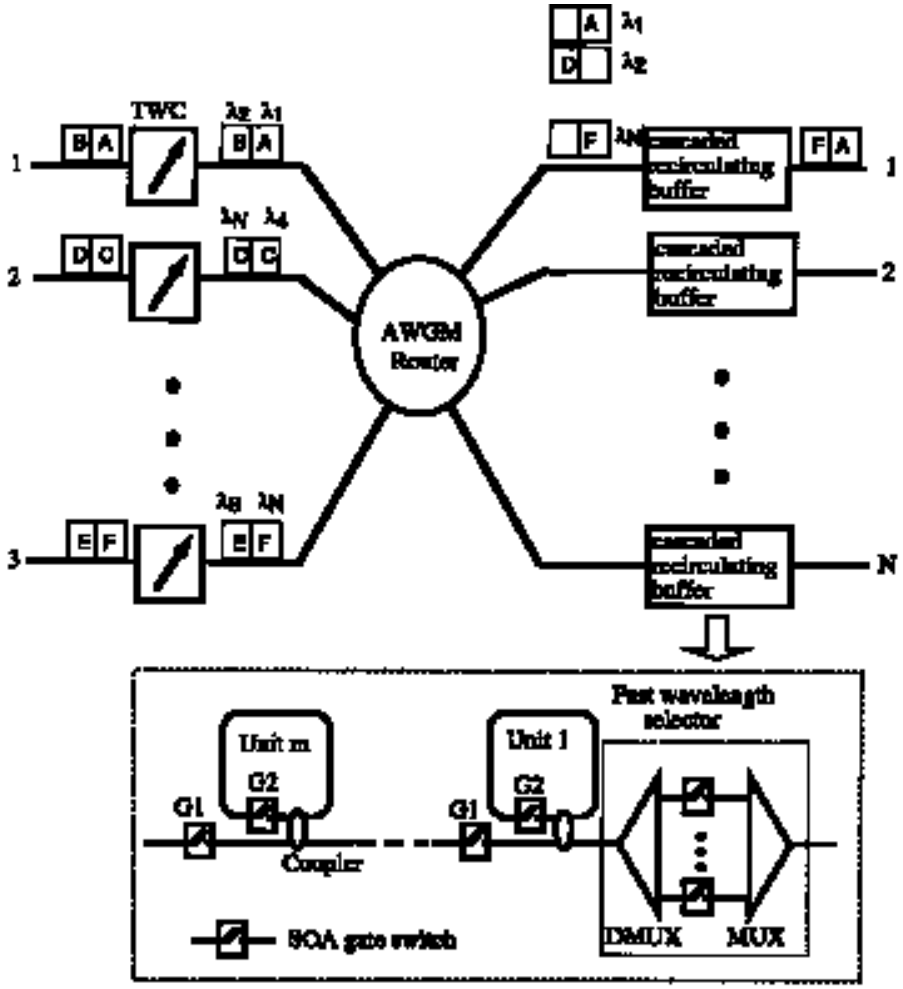
using these and other elements

switch architectures can be build.

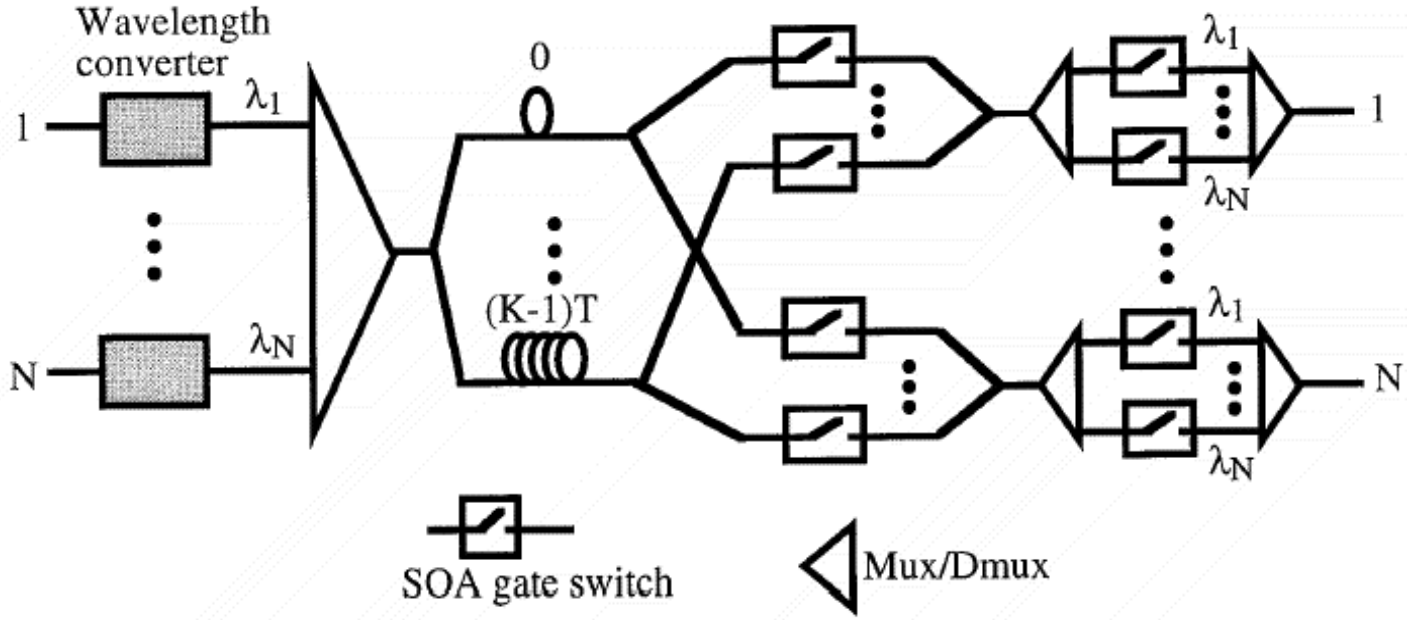
Wavelength routed all-optical packet switch



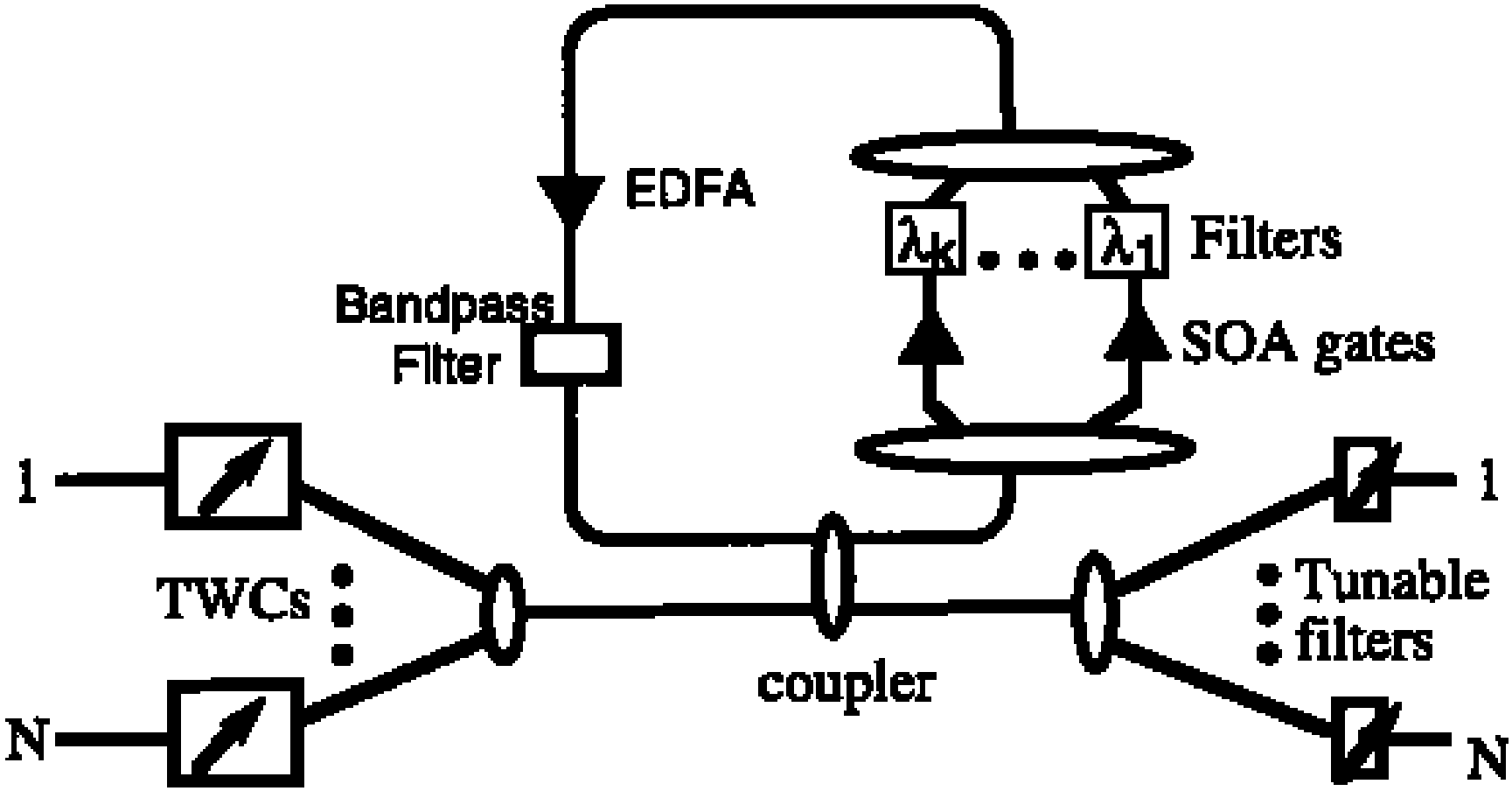
Frontiernet architecture : another wavelength routed switch



Broadcast and select type of switch



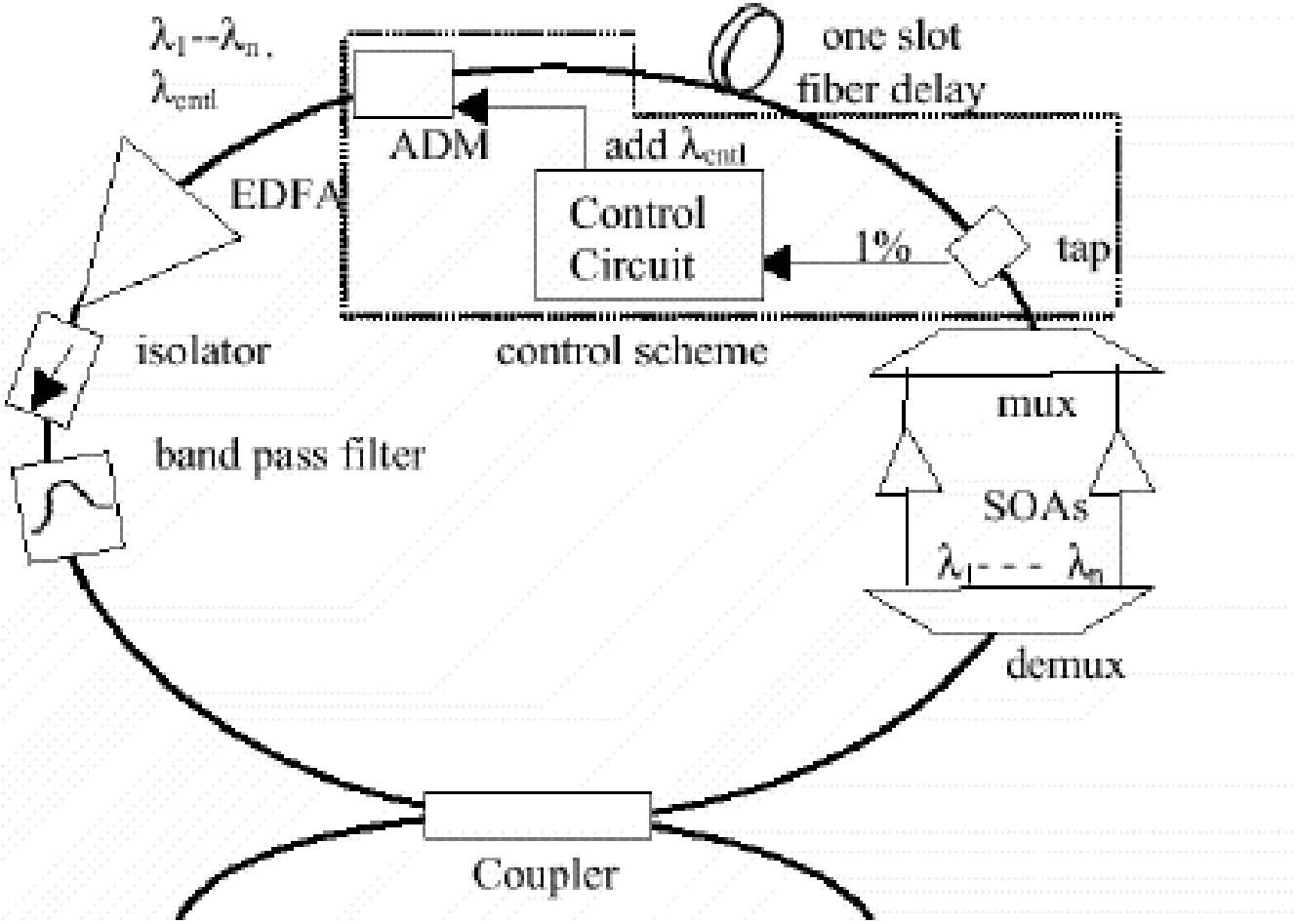
Fiber loop memory based switch



What we have been done so far? (using analysis and simulations)

- degradation due to ASE noise with number of recirculations
- control algorithm for the switch (with and without priority mechanisms
- queuing performance analysis (exact and approaximate methods) – appeared in IEEE comm. Letters, may 2001. Detailed paper submitted in IEEE/OSA Journal of Lightwave technology.
- gain control techniques for EDFA to optimize switch performance
- gain in the loop should be maintained equal to loss for optimized operation.

Recent results on this submitted to Electronics Letters.



Summary and future scope

- Optical switching is viable technique for switching in bachbone
- Investigations in high speed optical memories needed.
- control function of routing and forwarding using optical processing (need investigation)
- Switching architecture using free space optics

What other work we have been persuing?

- Design and implementation of operating system for Cradle UMS chip? Goal is to build multiprotocol router using UMS.

- Design and implementation of software system for automated deployment of software systems in network management scenario.

- Agent based management system for educational technology infrastructure testbed in IIT Kanpur.