Introduction to Photonic Packet Switching

Yatindra Nath Singh
Electrical Engineering Dept.
IIT Kanpur-208016
Email: ynsingh@ieee.org
http://home.iitk.ac.in/~ynsingh
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 efficiently utilize the network resources

Why?

- Full mesh connectivity Vs. Switched connectivity ($NC_2$ and $N/2$ links respectively)
- Resource sharing

• Types
  - Circuit Switching
  - Packet switching
  - 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 switching?
• 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

Synchronizing block

Header Replacement block

Switching And Buffering block

Switch controller
- 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

- incremental bandwidth possible using DWDM (Dense Wavelength 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 form a network using certain predetermined wavelength

- Each processor runs 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 evolving (IETF, Optical Interworking 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 \(\sim 40 \text{ THz} \) 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 demultiplexing 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 ~ $2 \times 10^8$ m/s

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

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

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

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

- $l$ - 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)


- 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 backbone

- 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 pursuing?

- 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.