



Department of Electrical Engineering
Indian Institute of Technology Kanpur

Introduction to Optical Networks

Yatindra Nath Singh
Assistant Professor
Electrical Engineering Department
Indian Institute of Technology, Kanpur
Email: ynsingh@ieee.org
<http://home.iitk.ac.in/~ynsingh>



What are optical network?

Telecomm Networks build using various communication media

- Twisted pair copper wire
- Coaxial cable
- Wireless (Radio, microwave, satellite, infrared)
- Optical fiber

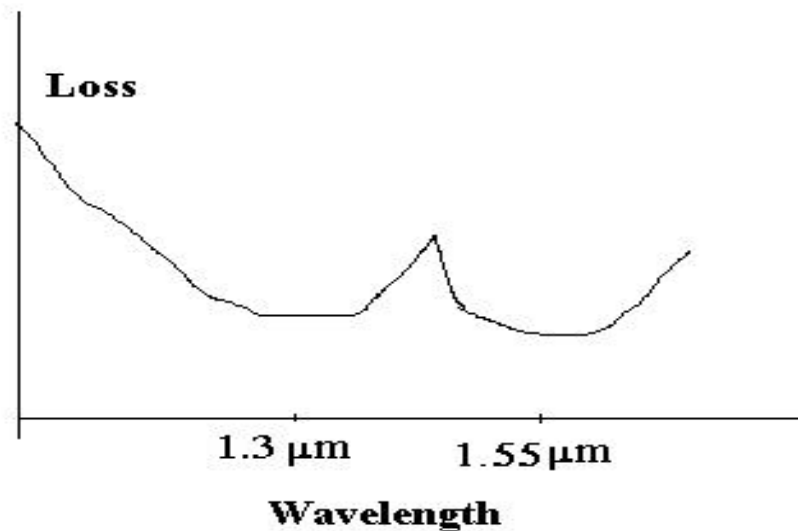


Optical fiber uses - carrier frequency of the order of 10^{15} Hz.

- Bandwidth generally a smaller fraction of carrier frequency

Large BW is available (of the order of 40 THz)

Optical fiber has low loss in 1.3 μm and 1.55 μm bands





Advantages of fiber

- Large Bandwidth-distance product.
- immunity to noise and interference
- very low cost per unit bandwidth
- easy upgradability using WDM technology
- Tapping of signal from fiber without being detected - difficult.



Due to all these advantages

- Optical fiber Networks have high capacity
- Can be used for providing the high bandwidth services
- Even in wireless, infrared means high bandwidth connectivity.

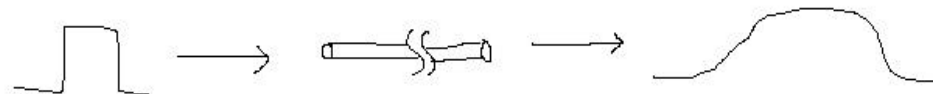
All the networks using optical fiber as transmission medium -
optical networks

When - transmitted signal remains in optical form till its arrival at
destination - *All-optical network*



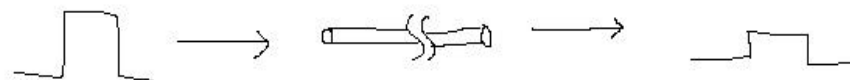
Degradation of signal in optical fiber

- Dispersion



Minimum dispersion at $1.3\mu\text{m}$

- Attenuation

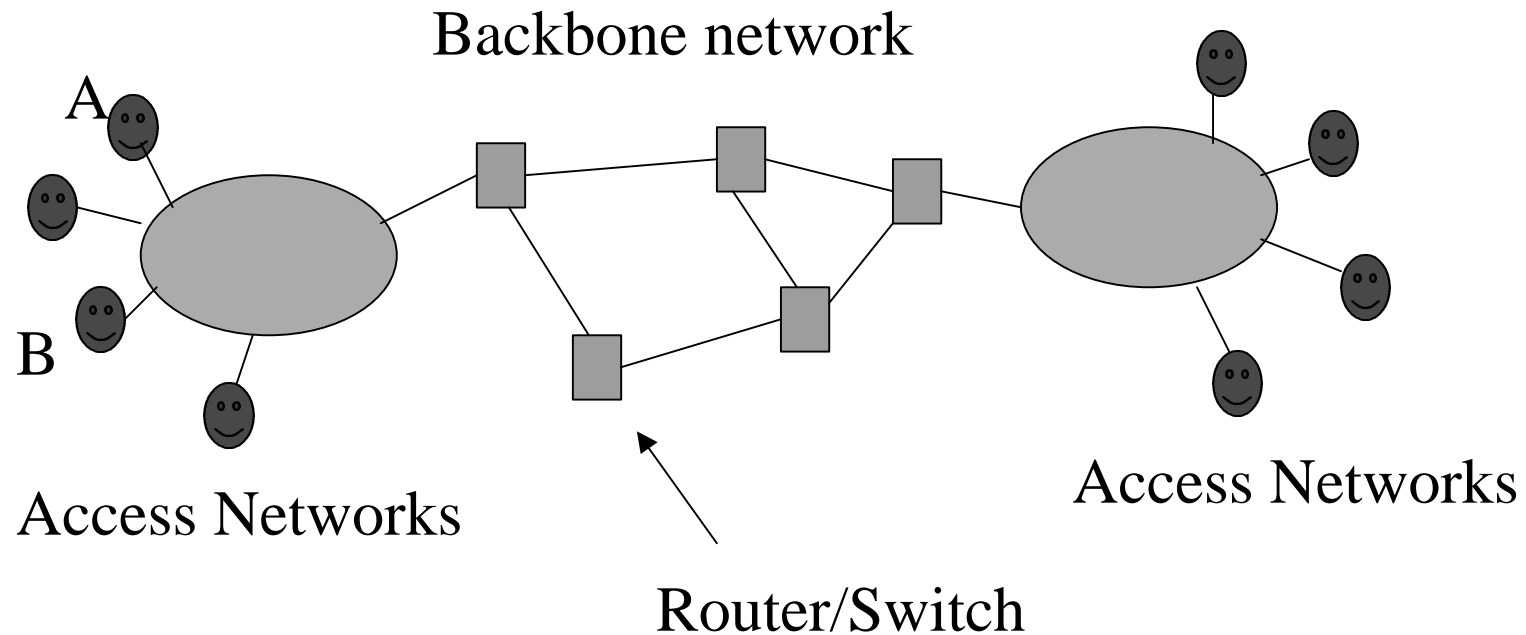


Minimum attenuation at $1.55\mu\text{m}$



Telecommunication Networks

Essentially consists of two portions





A and B communicate with each other via switch/router
(exchange in conventional terminology)

These are Switched Networks.

When the links are optical fiber - optical network

But the signal might go through E/O and O/E conversion
many times before reaching destination

Commonly deployed networks with fiber as point-to-point link

FDDI, DQDB, SONET/SDH, ATM, IEEE802.3



All-optical networks

- Broadcast

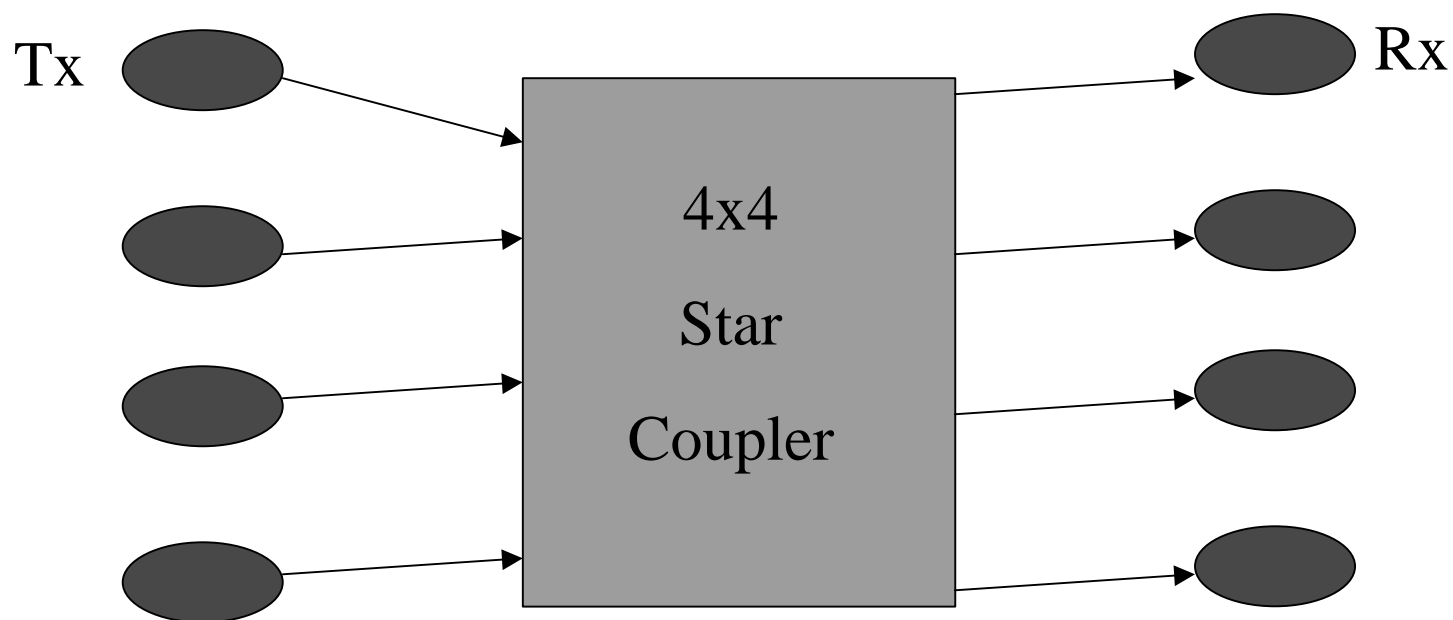
transmitted optical signal - received by everyone.

- Switched

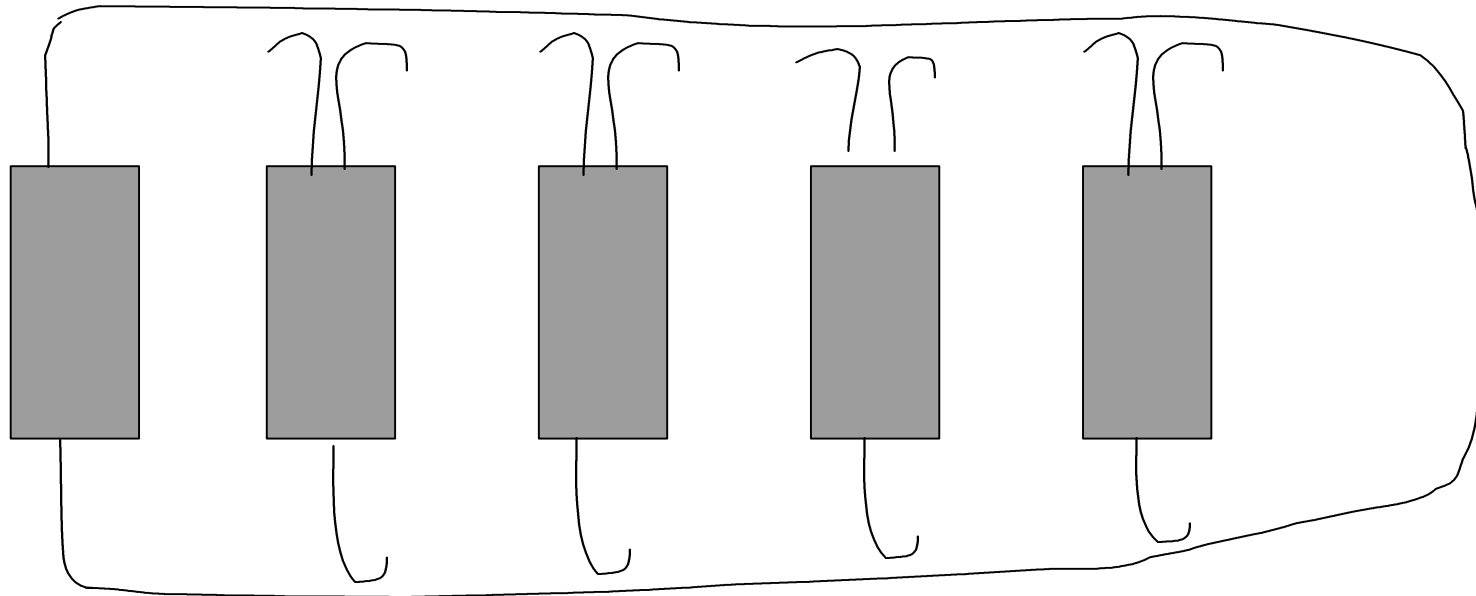
transmitted optical signal - switched through a specific path and received by the designated receiver.



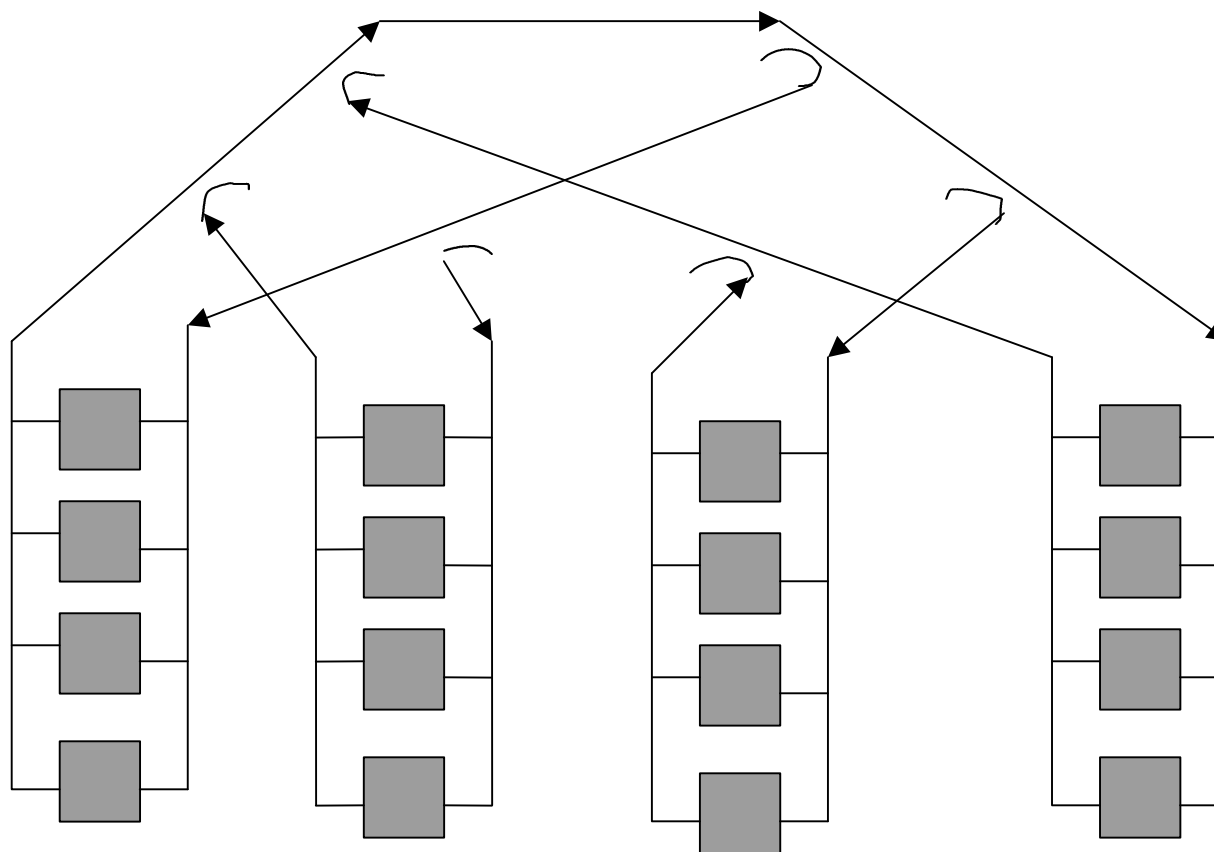
Broadcast optical networks



Star topology network



Folded Bus



Tree-net topology



In Broadcast networks

Bandwidth of single channel - shared by all the users.

Media access using media access control protocols

MAC protocols need to consider

- The network is high speed

High speed network - packet transmission time

comparable to packet propagation time



To use the available bandwidth

- Wavelength division multiple access (WDMA)
- Time division multiple access (TDMA)
- Code division multiple access (CDMA)

O/E and E/O interfaces cannot operate above few tens' of Gbit/s

⇒ WDMA - currently implementable technology.



Optical TDMA, CDMA implementations

- need very short pulses (can be generated by mode locked lasers).
- Time division multiplexers/ demultiplexer requires very tight tolerance of fiber length (due to tight timing requirements)
- Encoder and decoders will require again very tight tolerance in fiber length used for delay lines.
- Dispersion - need to be taken care of.

WDMA

- Existing available devices can be used.



Media access control protocols for multiple channels

Classification based on tunability

- Fixed transmitter fixed receivers (FTFR)
- Tunable transmitter fixed receivers (TTFR)
- Fixed transmitter tunable receiver (FTTR)
- Tunable transmitter tunable receiver (TTTR)

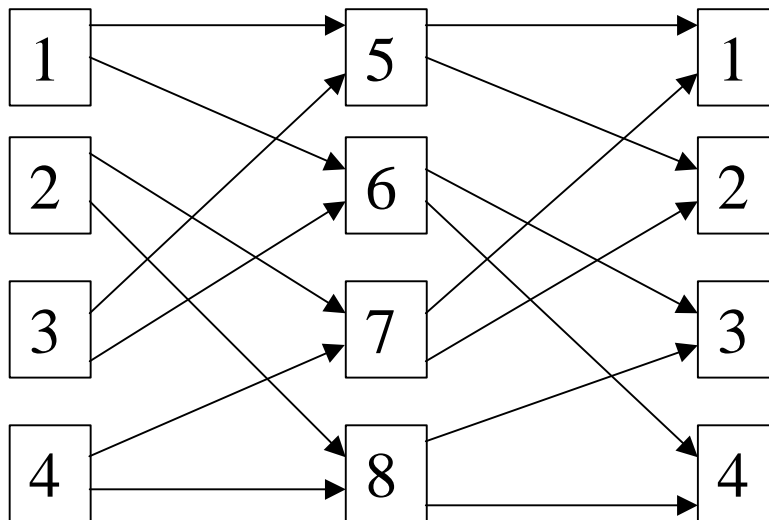
Tunability makes the devices costly.

- FTFR based multihop networks.



Strong similarity with switching networks

Virtual topology is built over broadcast medium



- All the links seen here
are on different
wavelength

- Each node has two fixed
transmitter and two fixed
receiver



Some other Multihop topologies investigated in literature

- Hypercube
- Manhattan street network (Torus)
- Dual bus
- Ring



For MAC protocols with tunable component proposed solutions generally use

- Scheduling - a schedule for transmission and reception on the basis of statistics is computed periodically by centralised or distributed algorithms and used for coordination.
- pretransmission coordination using dedicated channel



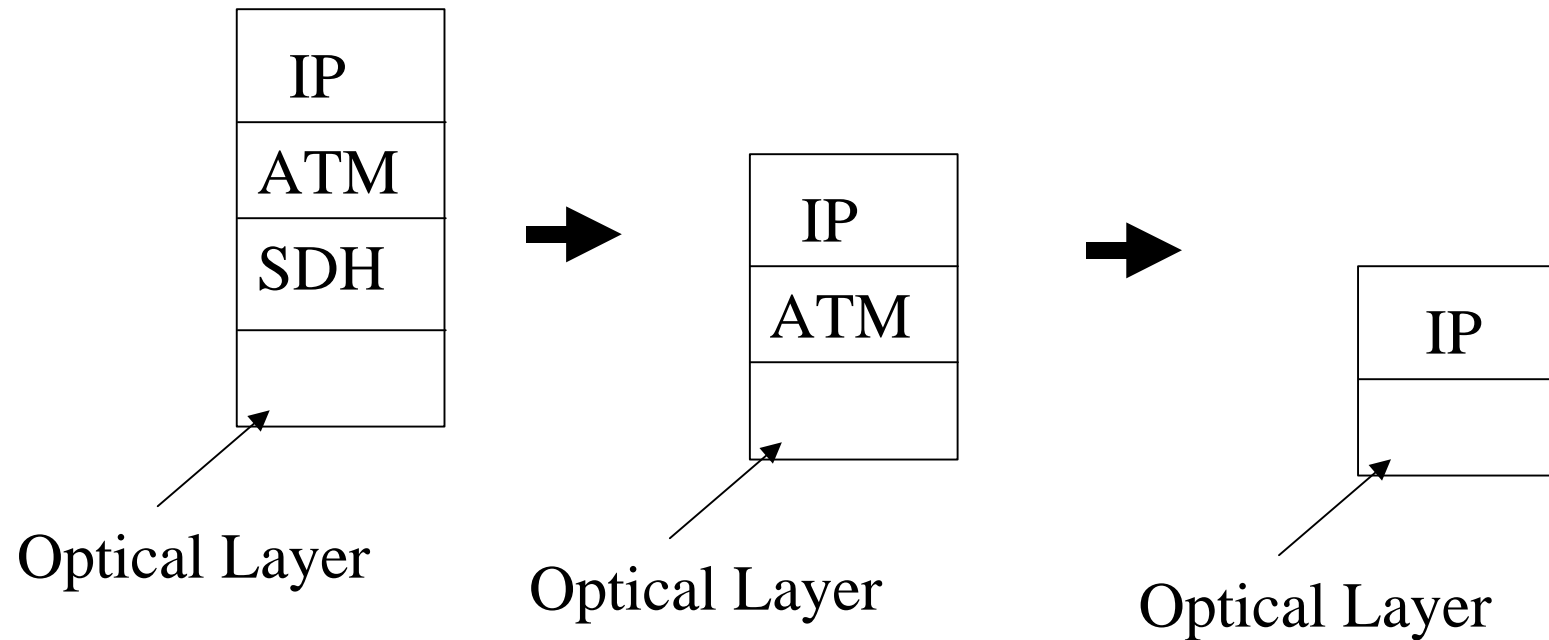
Switched Network

- uses optical switches

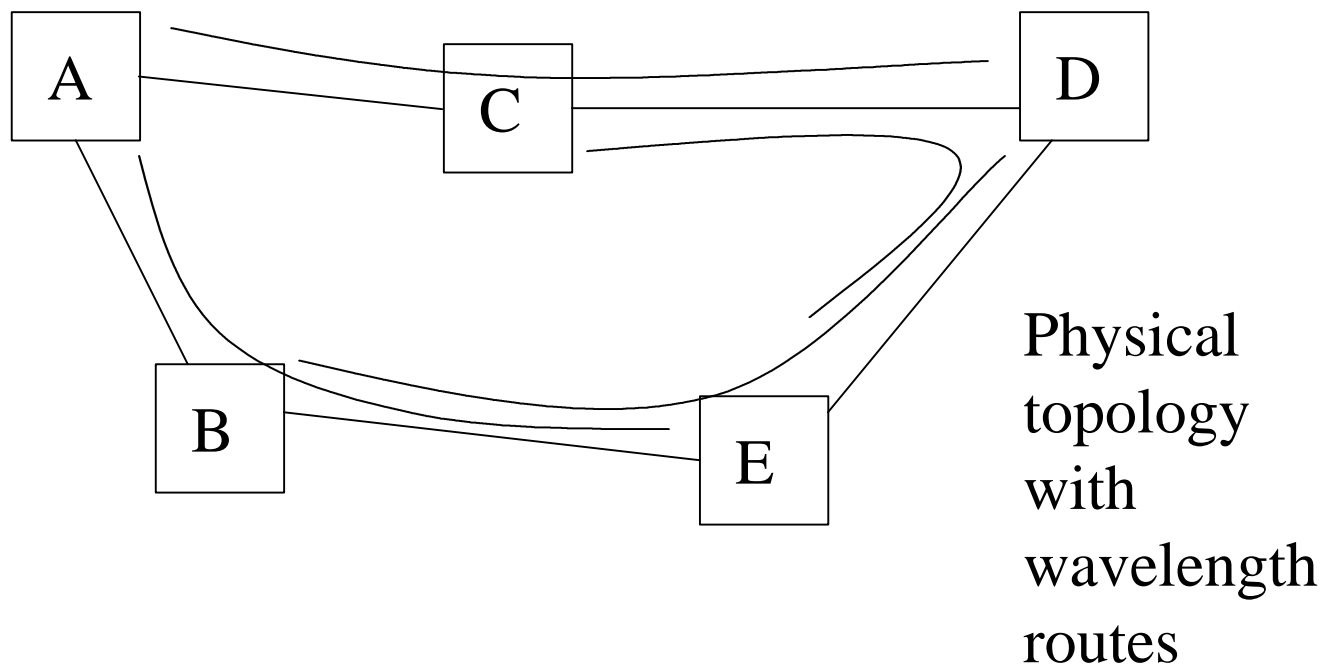
classified as circuit switched or packet switched. Commercially emphasis on circuit switched all-optical networks.

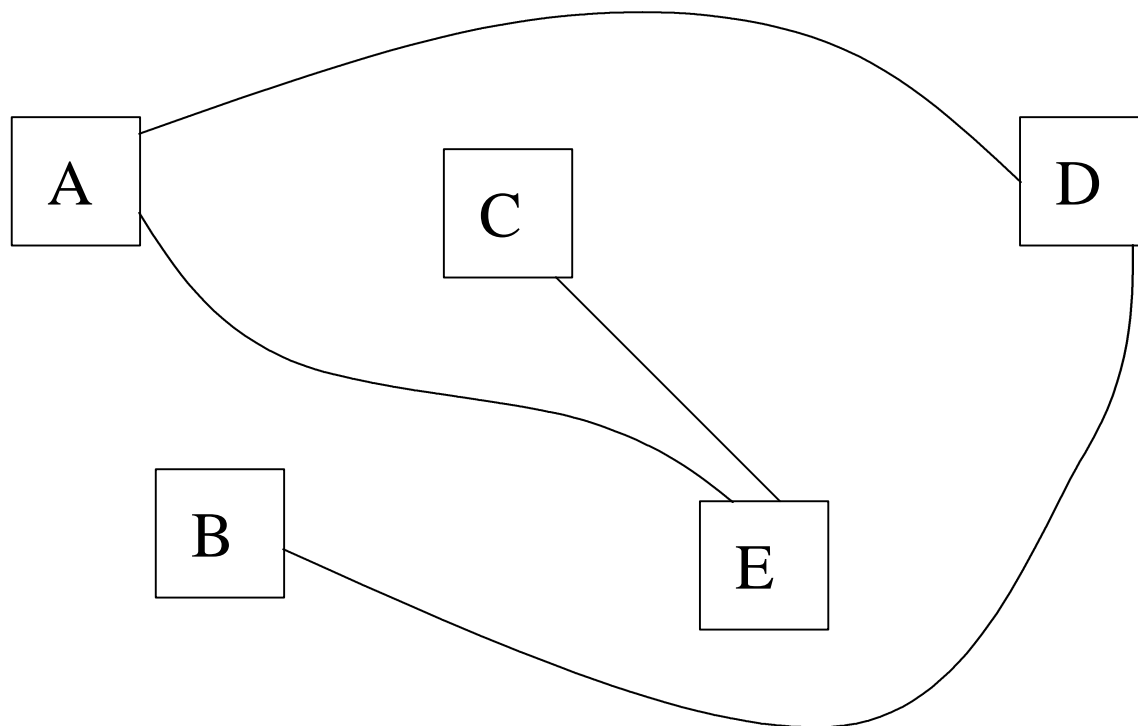
- due to near term feasibility.
- also known as wavelength routed networks

These network can be used to provide virtual topology to be used by SDH, ATM or directly by IP layer.



As time progresses IP over WDM will take over





Virtual topology



In IP over WDM

- possibility of reconfigurable topology means continuous optimisation of topology depending on traffic condition can be done.

Issues

- Estimation of condition when the reconfiguration is needed (will be done by IP layer)
- Management algorithms for optical layer to work with limited wavelength.
- Fault management in optical layer.



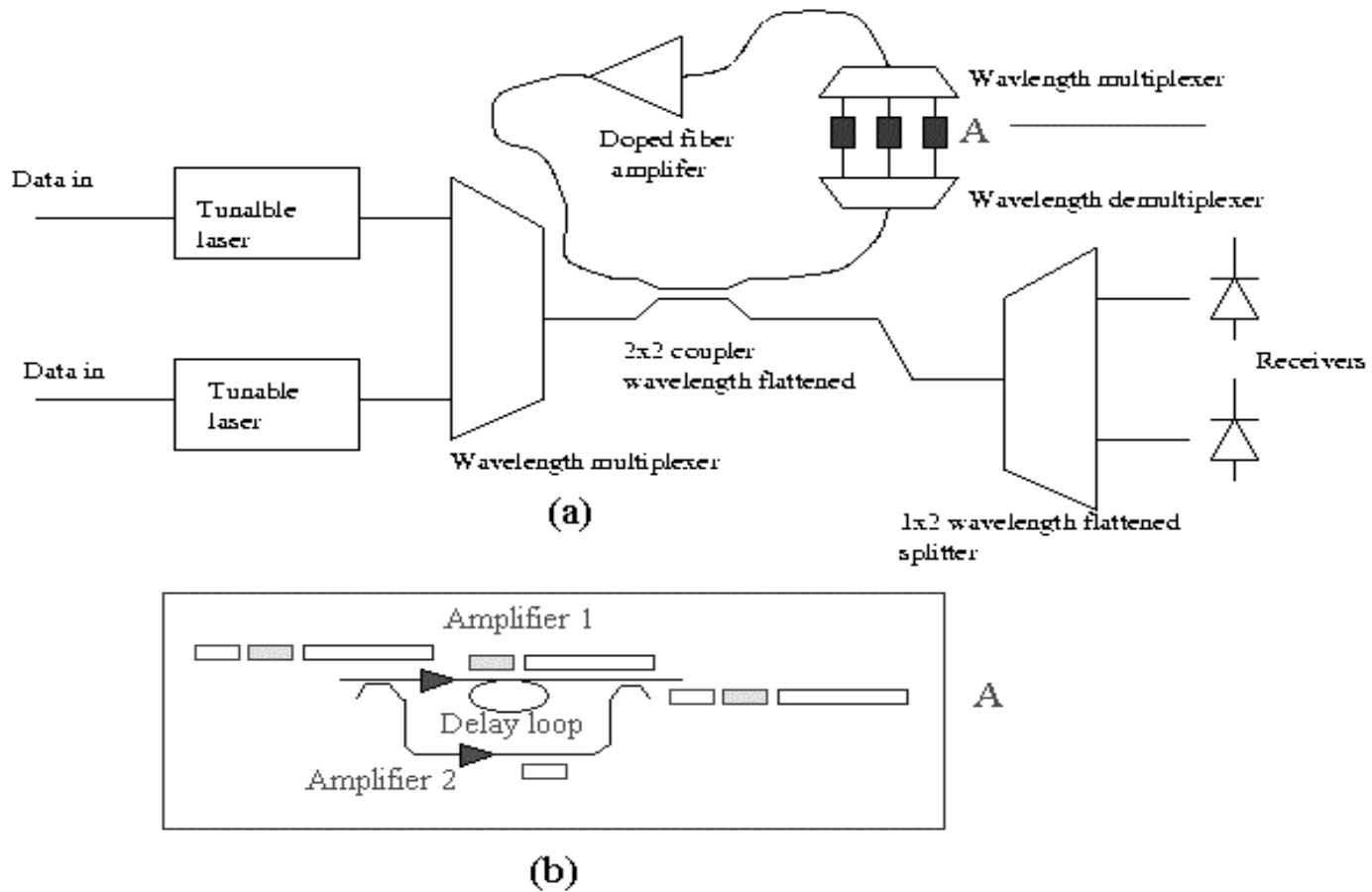
Other exciting things in optical networks

- Switching techniques and architectures.
- Network architectures using devices and phenomenon based on optical nonlinearity
- Multiwavelength soliton networks.



What we have been doing in IIT Kanpur in the area of optical networks

- Studies in all-optical packet switched architecture.
- Investigation on all-optical subscriber access network
- Routing and management problems in IP over WDM





What future will have

- All-optical packet switched WANs as backbone networks having huge capacities.
 - All-optical subscriber access networks (will be quite limited)
- Most of the access network is expected to be dominated by wireless. Infrared will have its share in it.