# Introduction to Optical Networks

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# What are optical network?

Telecomm Networks build using various communication media

- Twisted pair copper wire

- Coaxial cable

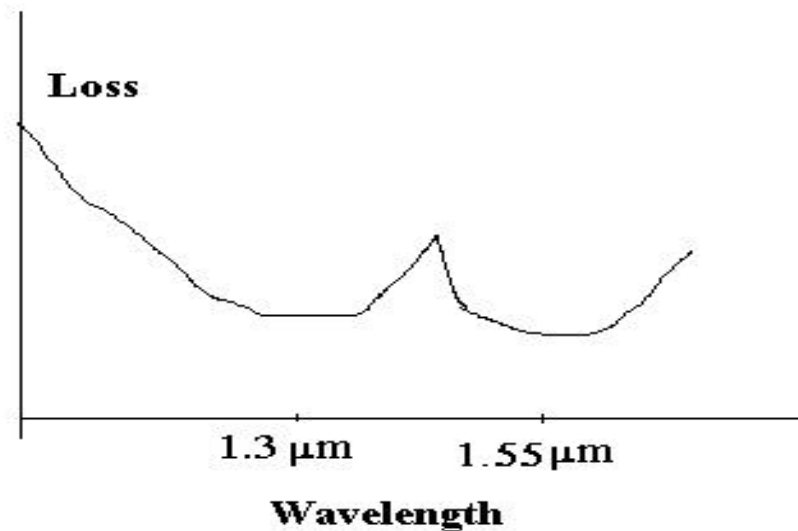- Wireless (Radio, microwave, satellite, infrared)

- 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 intereference

- 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

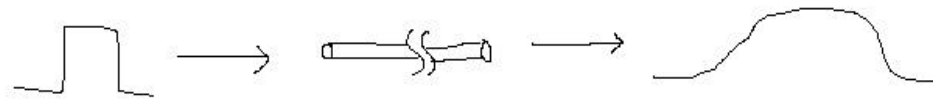- Even in wireless, infrared means high bandwidth connectivity.

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*
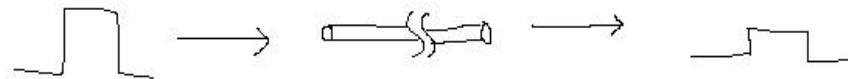
Degradation of signal in optical fiber
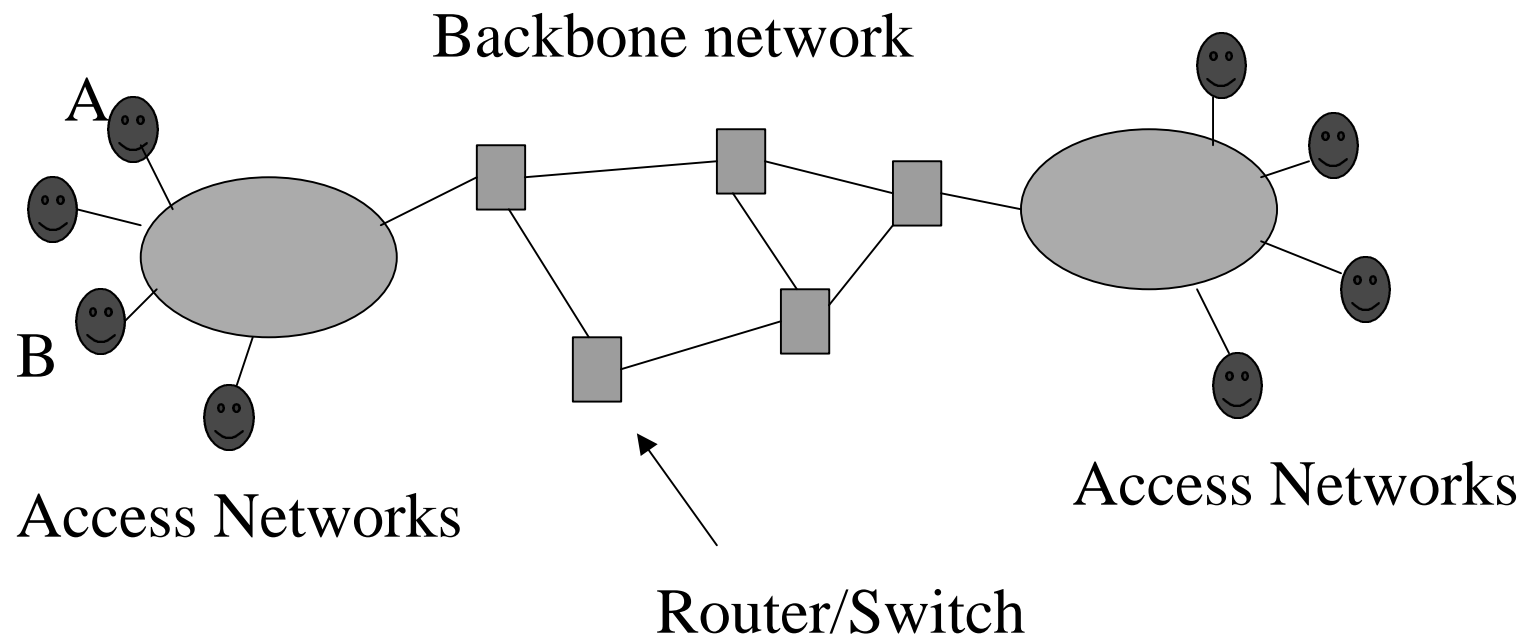
- Dispersion

Minimum dispersion at 1.3μm

 - Attenuation

Minimum attenuation at 1.55μm

## Telecommunication Networks

Essentially consists of two portions

Backbone network

A

B

Access Networks

Access Networks

Router/Switch

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

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
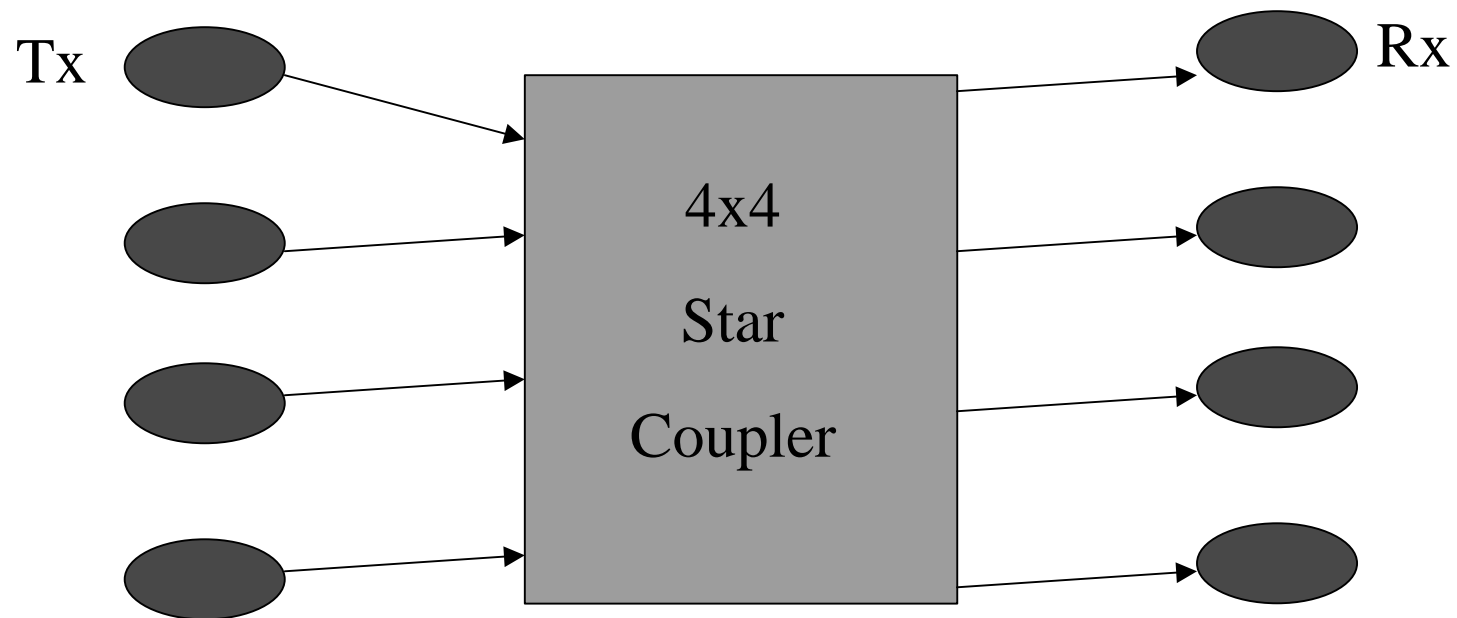
All-optical networks

- Broadcast

transmitted optical signal - received by everyone.
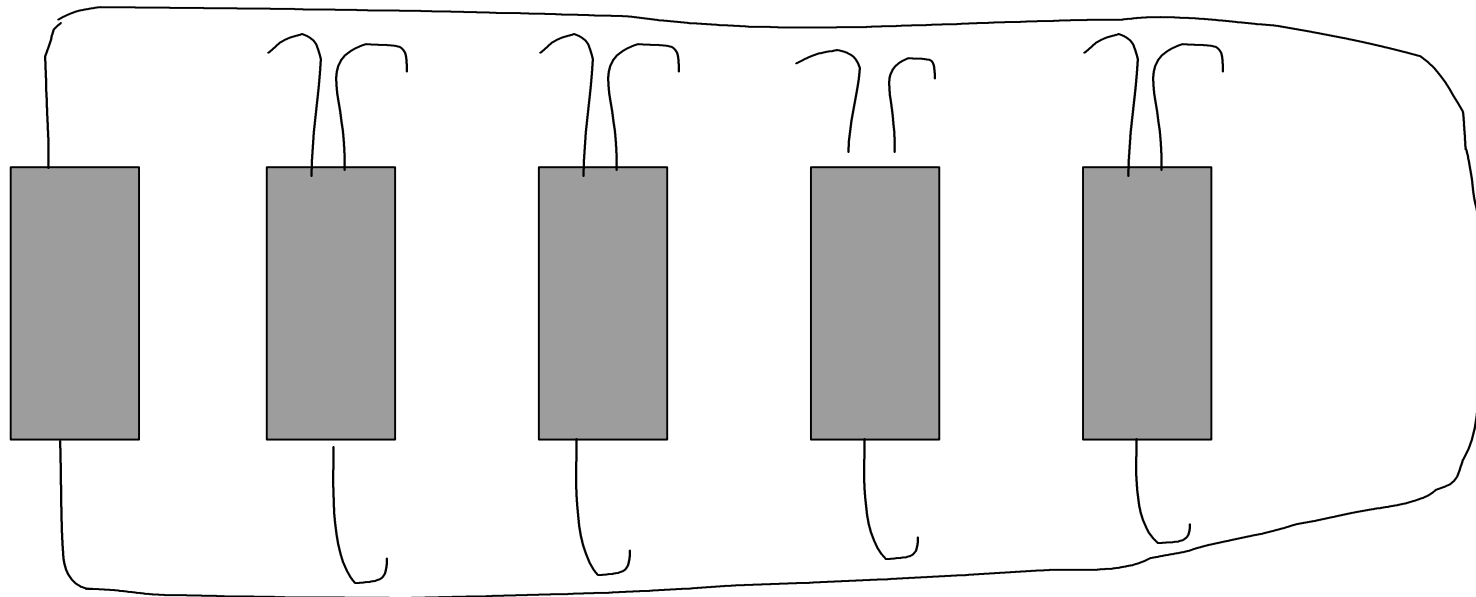
- Switched

transmitted optical signal - switched through a specific

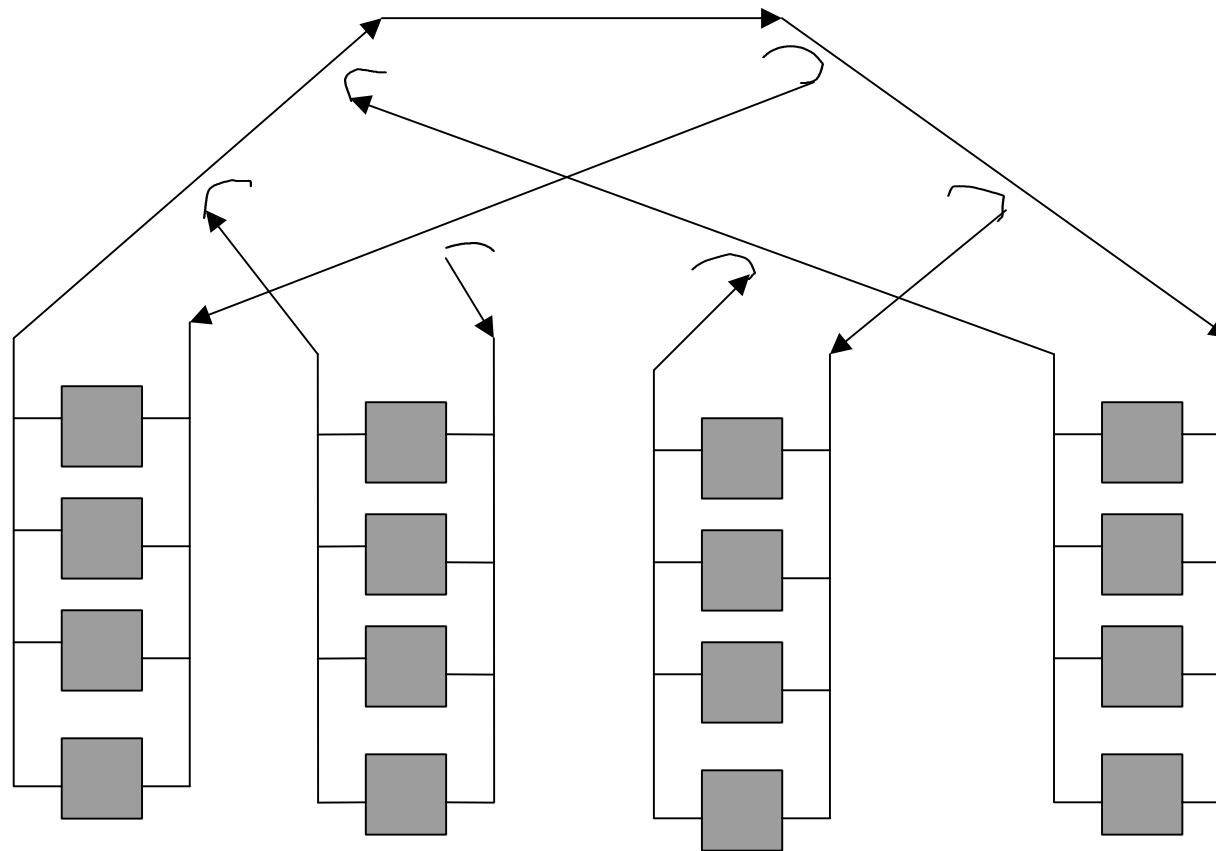path and received by the designated receiver.

# Broadcast optical networks

Tx

4x4

Star

Coupler

Rx

## 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 requirments)

- 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)
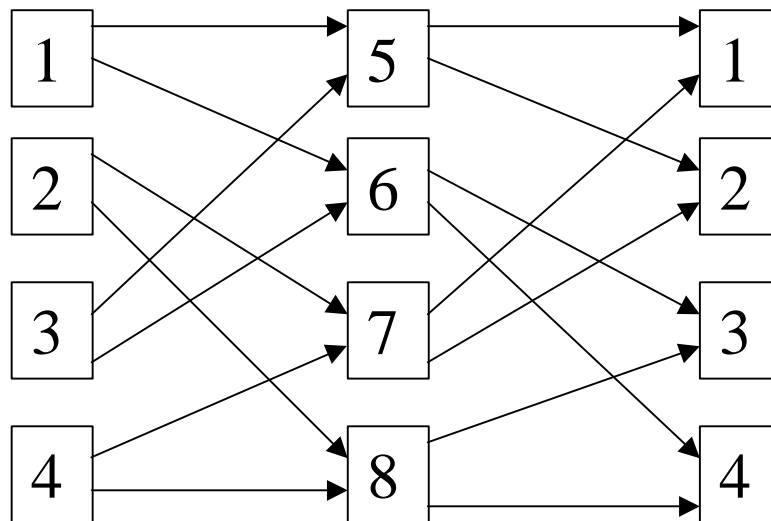
- Tunable transmitter tunable receiver (TTTR)

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 litrature

- Hypercube

- Manhattan street network (Torus)

- Dual bus

- Ring

For MAC protocols with tunable component proposed solutions generally use

- Schedulling - a schedule for transmission and reception on the basis of stastistics is computed periodically by centralised or distributed algorithms and used for coordination.

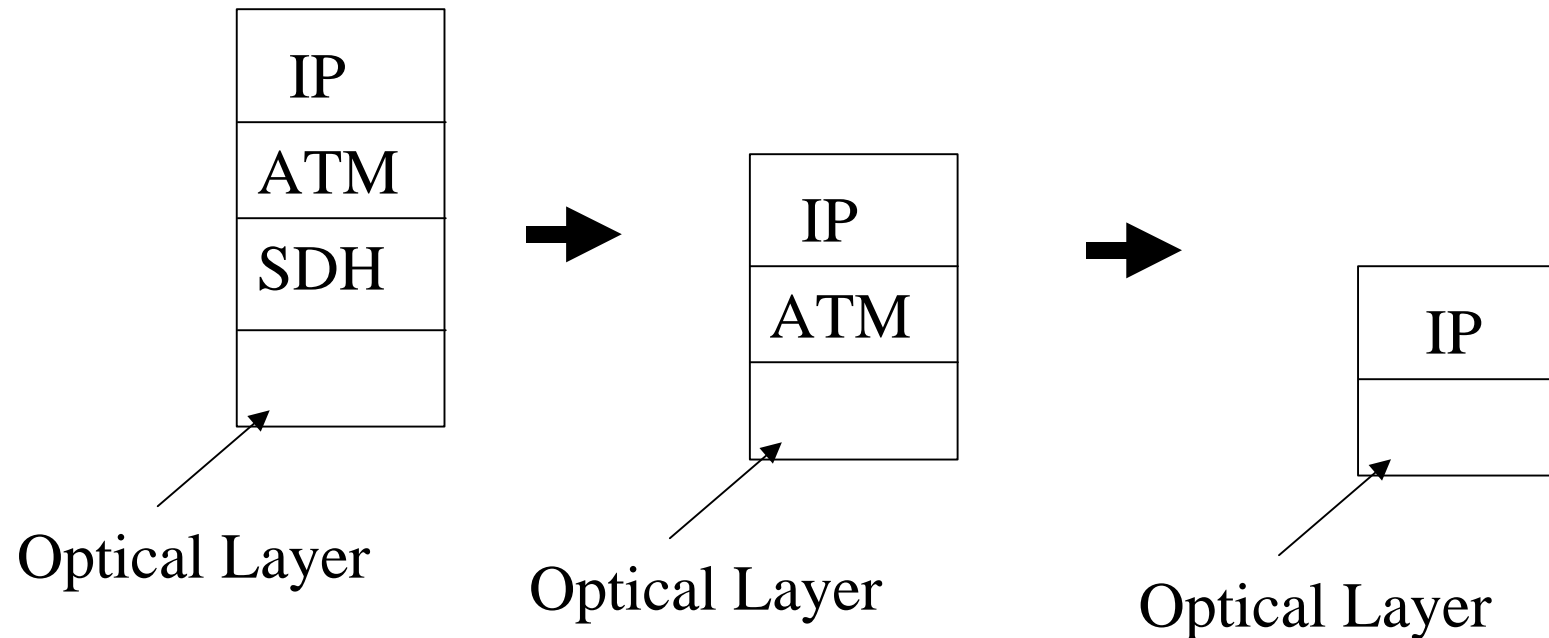- pretransmission coordination using dedicated channel

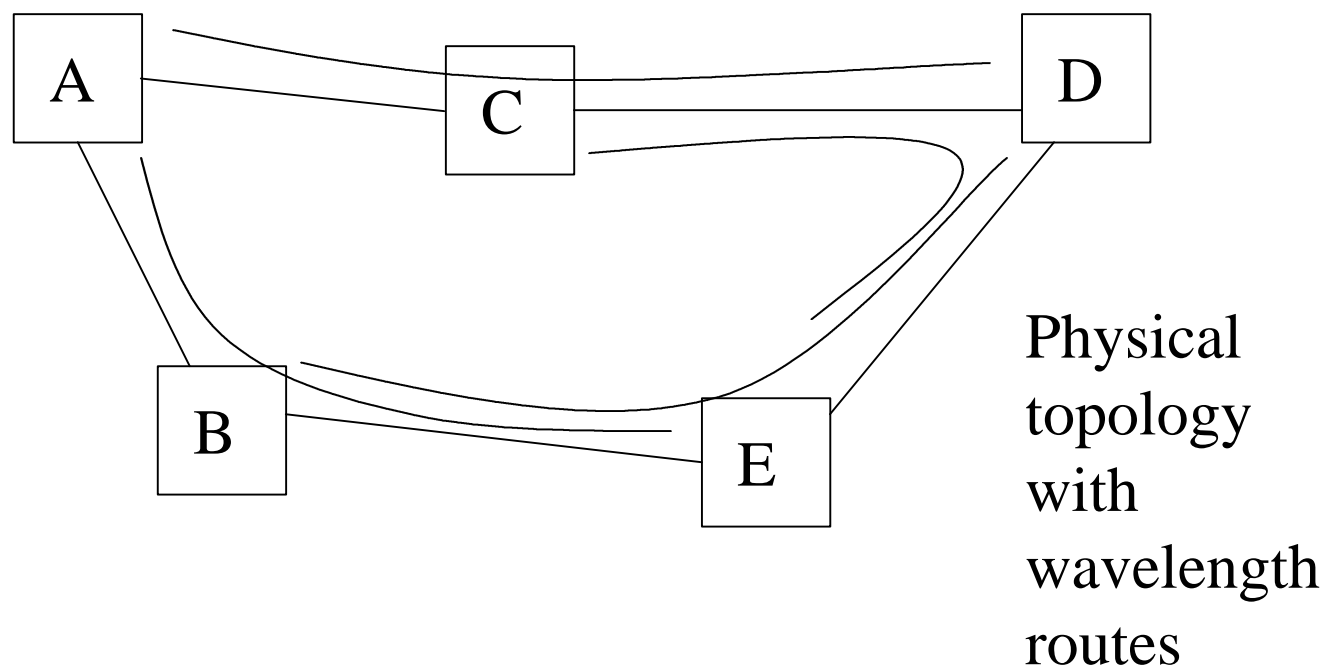Switched Network

- uses optical switches

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

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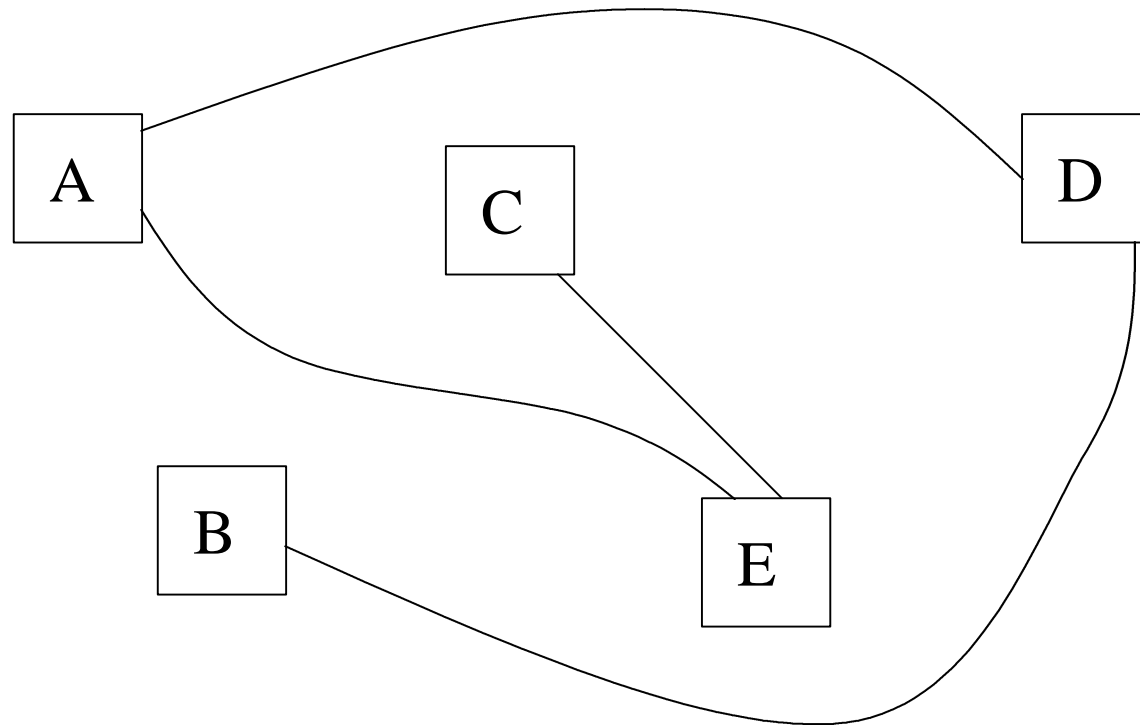
- also knows as wavelength routed networks

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

| IP |
|----|
| ATM |
| SDH |
| |

Optical Layer

➡

| IP |
|----|
| ATM |
| |

Optical Layer

➡

| IP |
|----|
| |

Optical Layer

As time progresses IP over WDM will take over

Physical topology with wavelength routes

Virtual topology

In IP over WDM

- possibility of reconfigurable topology means continous
  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.
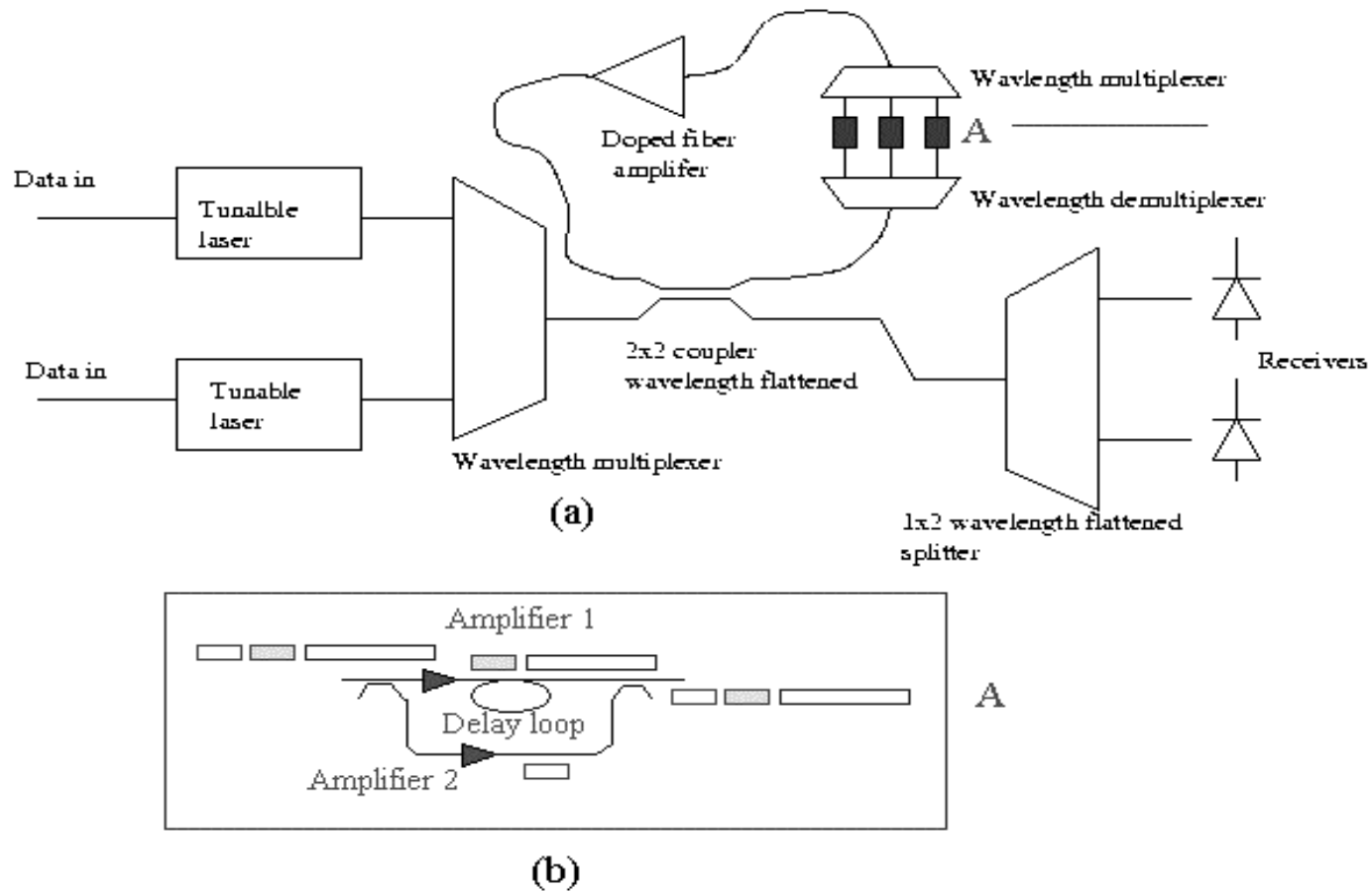
- Fault management in optical layer.

Other exciting things in optical networks

- Switching techniques and architectures.

- Network architectures using devices and phenomenon based on optical nonlinearty

- 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

Wavelength multiplexer

Doped fiber amplifer

A

Wavelength demultiplexer

Data in

Tunalble laser

Wavelength multiplexer

Data in

Tunable laser

2x2 coupler wavelength flattened

Receivers

1x2 wavelength flattened splitter

(a)

Amplifier 1

Delay loop

A

Amplifier 2

(b)

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.