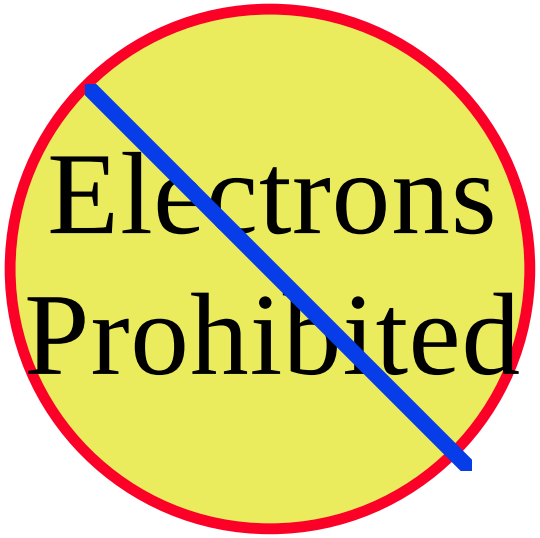
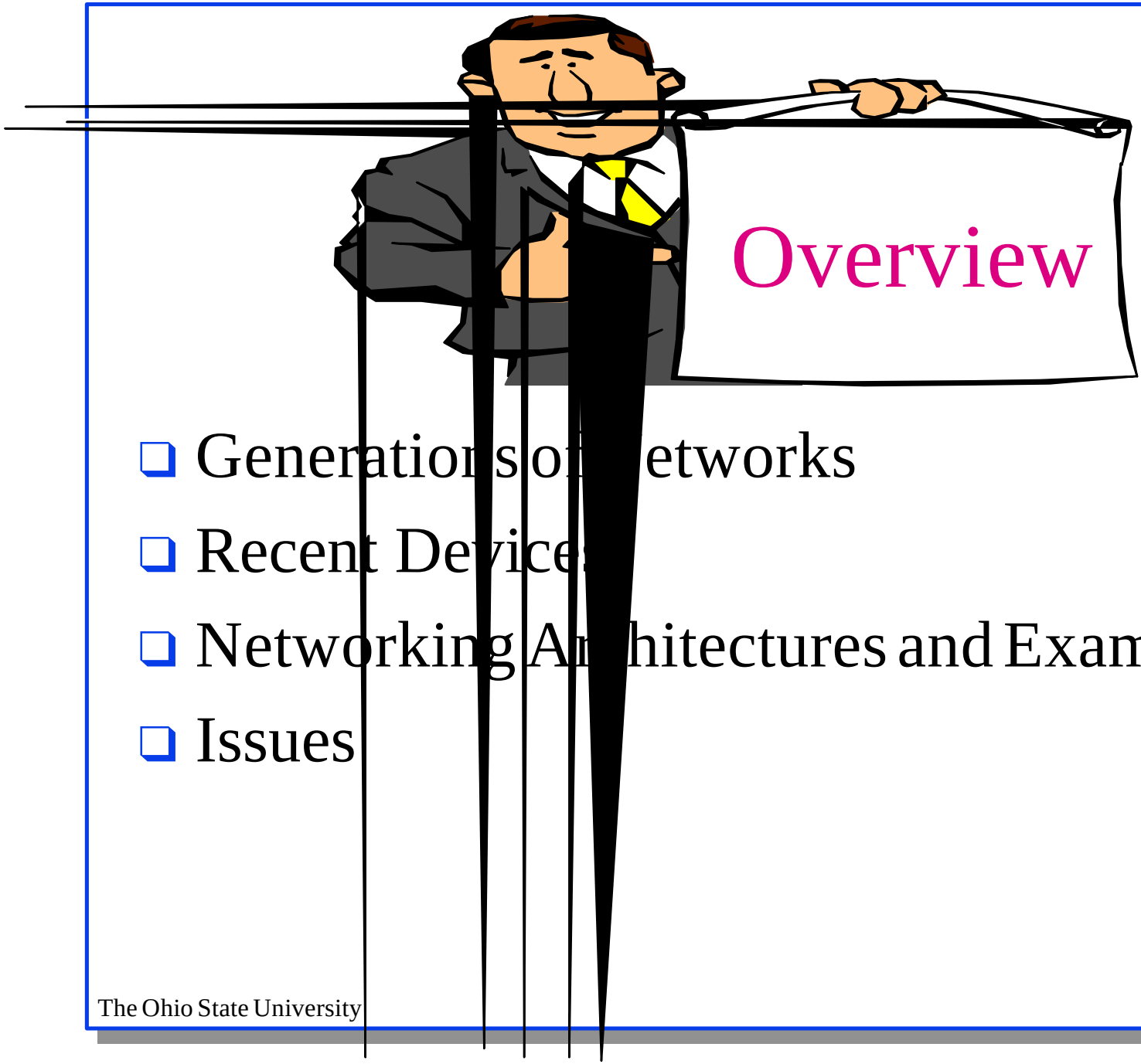
All-optical Networks



Raj Jain

Raj Jain is now at
Washington University in Saint Louis
Jain@cse.wustl.edu
http://www.cse.wustl.edu/~jain/



Overview

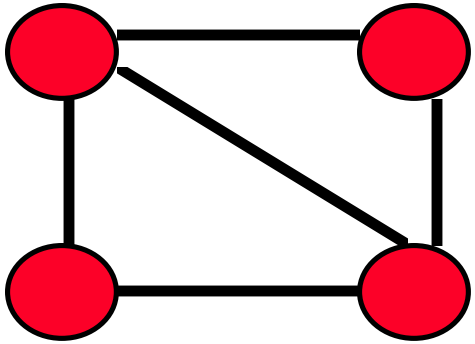
- Generations of Networks
- Recent Devices
- Networking Architectures and Examples
- Issues

Electro-optic Bottleneck

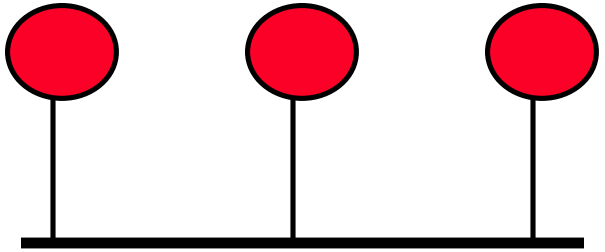
- Bandwidth of Fiber = 25 THz/window
- Bandwidth of electronics = 1 GHz
  $\Rightarrow$ One node cannot use all bandwidth
  $\Rightarrow$ Divide into parallel channels
  $\Rightarrow$ WDM, TDM, SDM
- Optical switching limited
  $\Rightarrow$ Use electronic switching

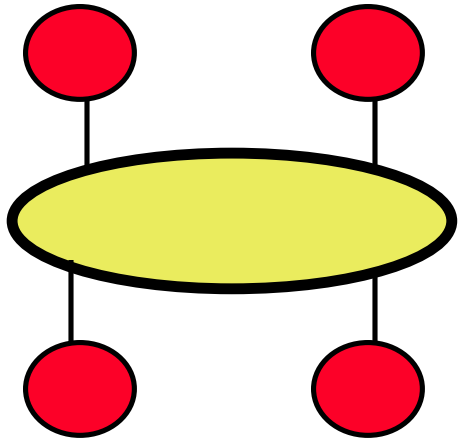
Generations of Networks

- Electronic point-to-point

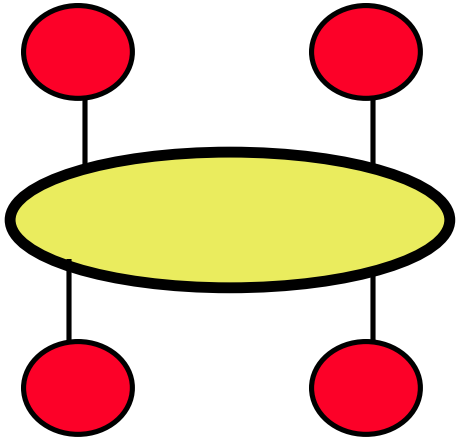


- Electronic multipoint

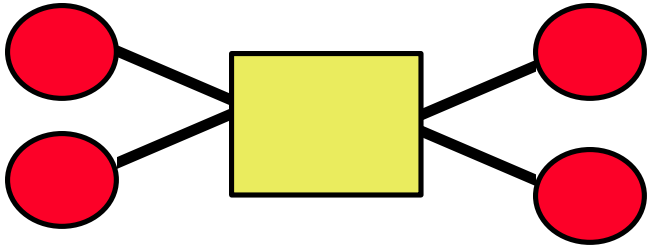




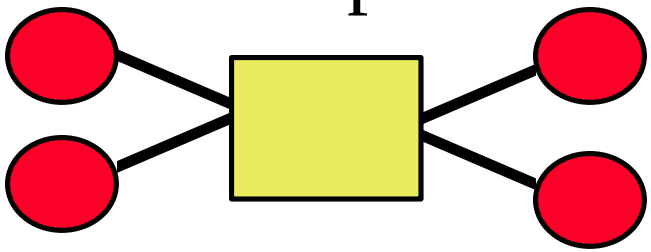
- Optic version of electronic networks



- All-optical with electronic controls

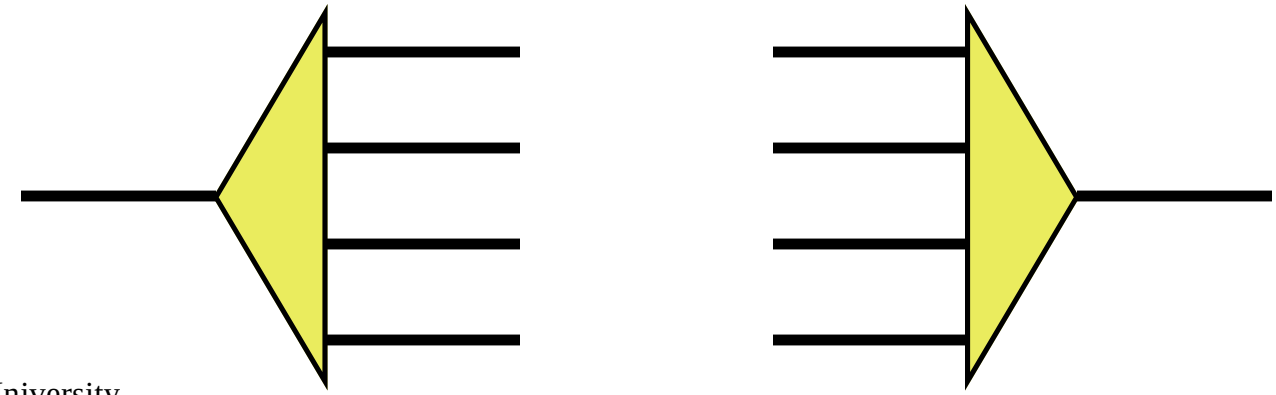


- All-optical with optical controls

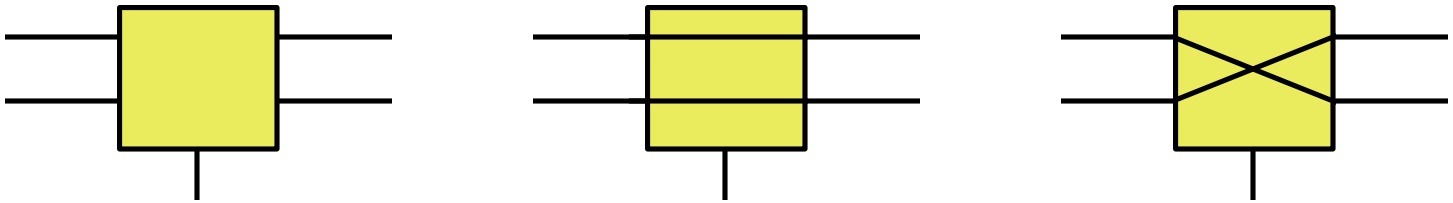


Key Technologies

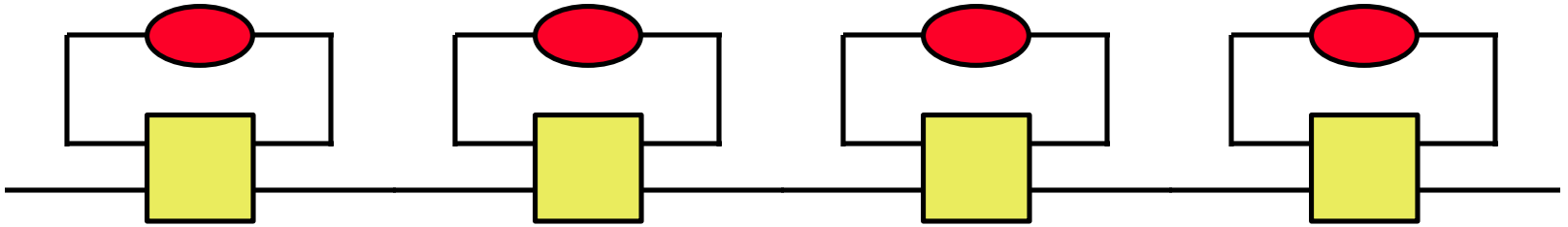
- Tunable Lasers
- Fast tuning receivers
- Frequency converters
- Amplifiers
- Splitters, Combiners



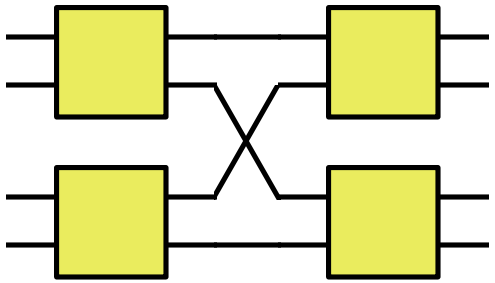
Directional Couplers



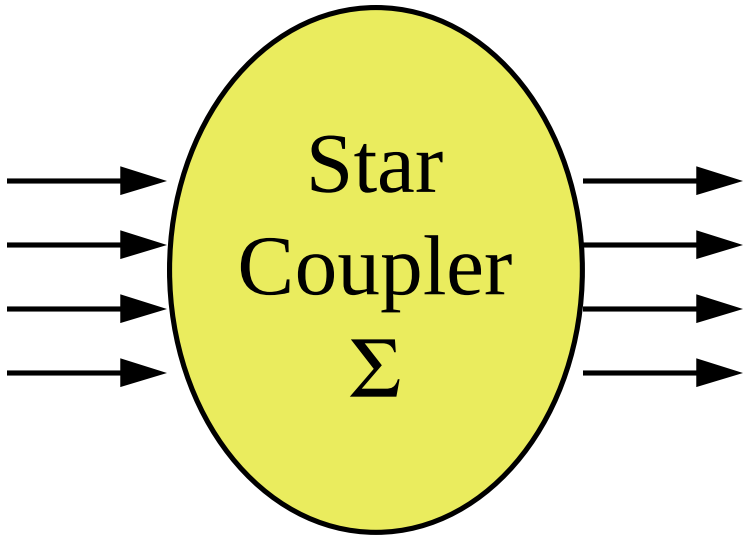
- Can be used in bus networks:



- Larger switches can be built out of 2×2 switches

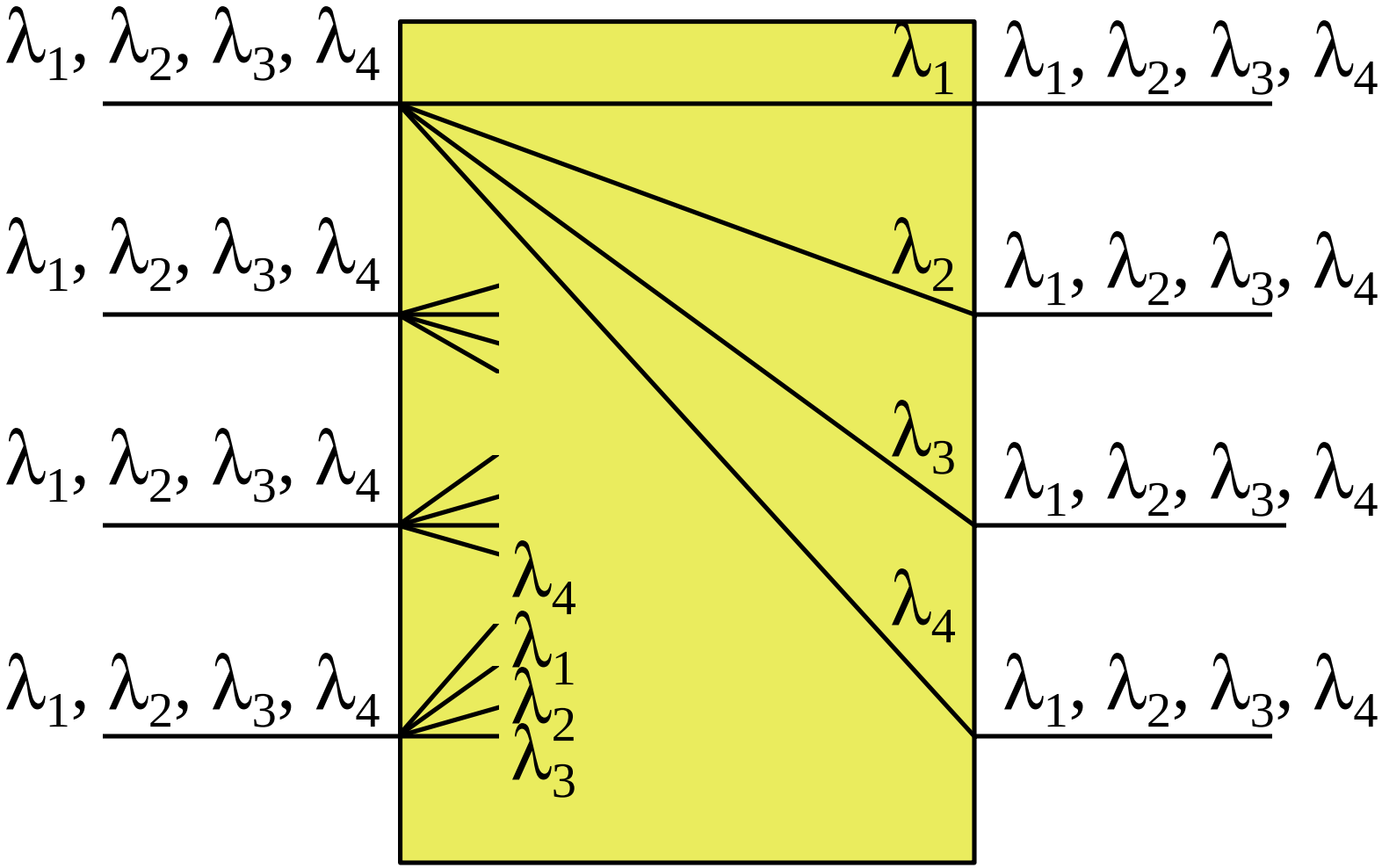


Star Couplers



- n inputs, n outputs = 2n ports
- Power divided n ways
- non-uniform division+excess loss

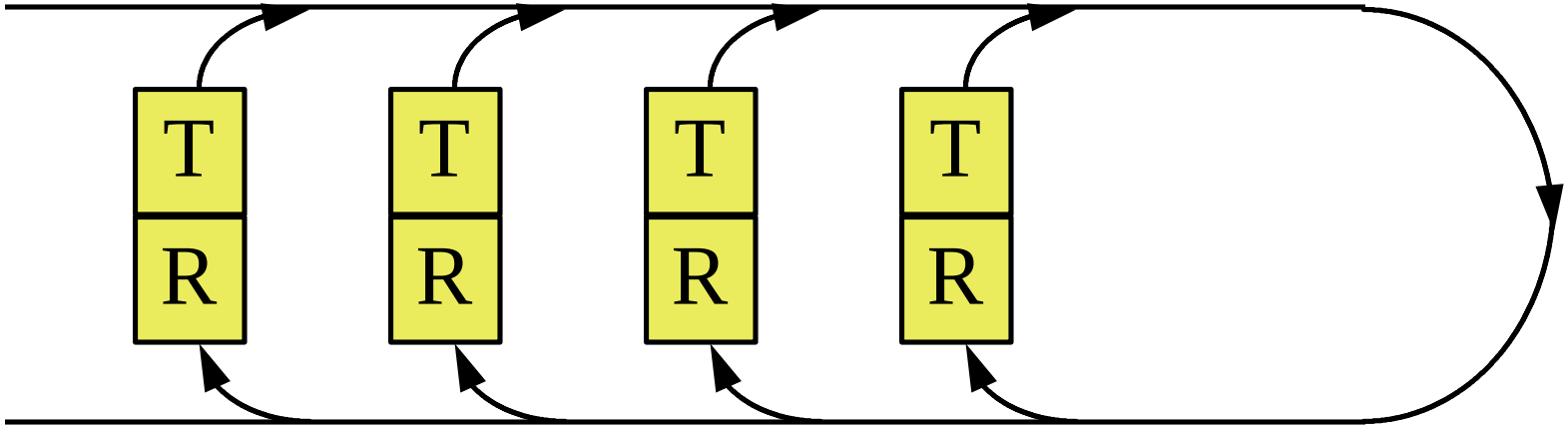
Wavelength Router



Physical Topologies

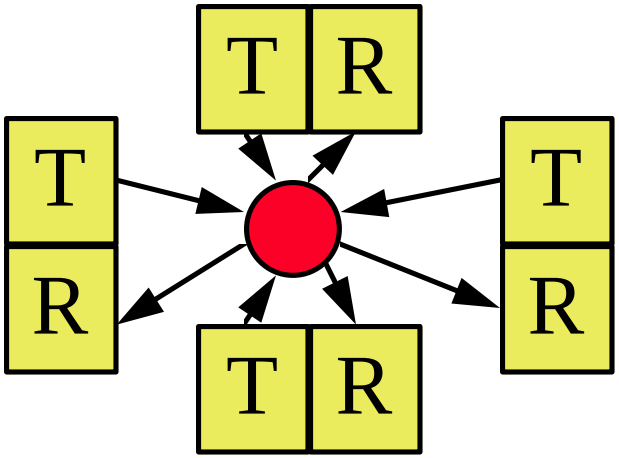
- Bus
- Star
- Tree
- Mesh

Physical Topology: Bus



- Broadcast ⇒ More power loss than star
  - ⇒Tunable taps or amplifiers
- Currently star preferred over bus

Physical Topology: Star



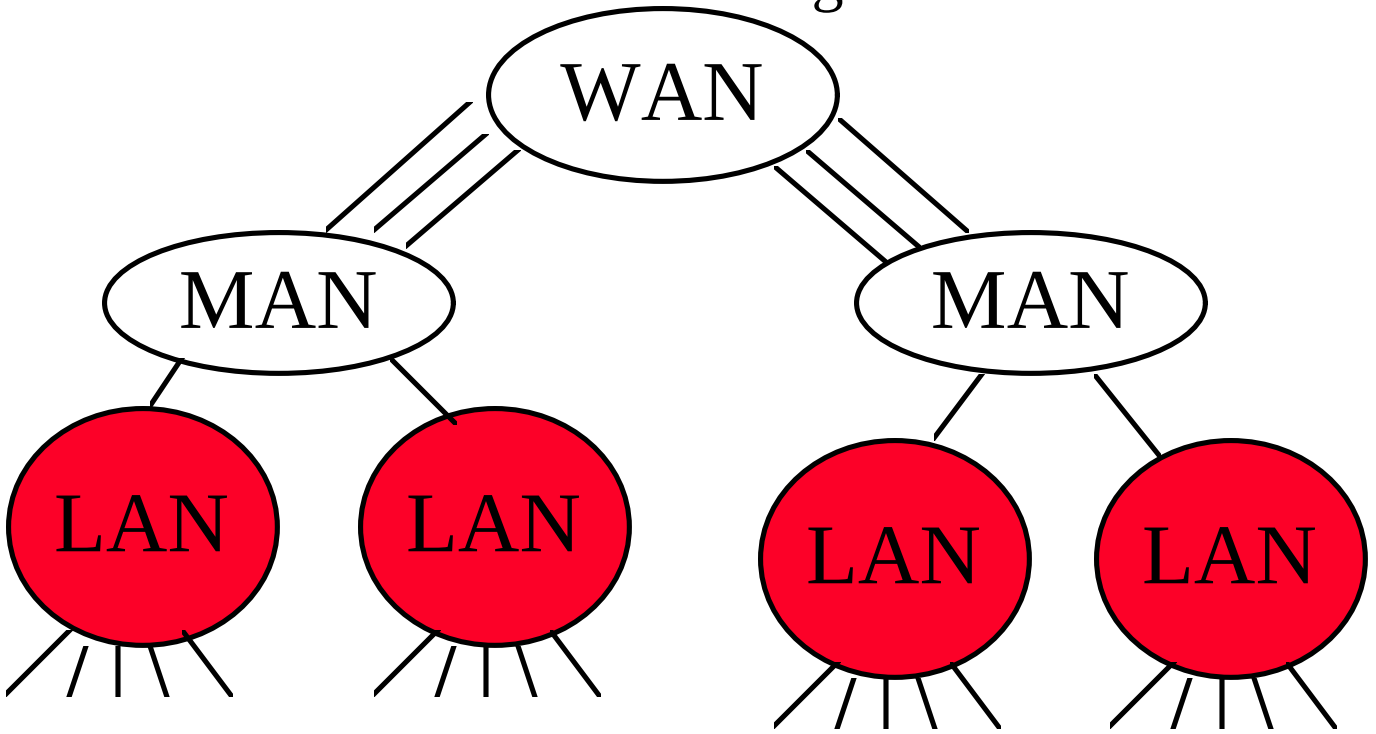
- Non-tunable transmitters and receivers
  Tunable transmitters s ⇒ Space division switch
  Tunable receivers ⇒ Allows multicasts
  Both tunable ⇒ Allows more nodes than wavelengths
- Broadcast ⇒ Power wasted (No shortage of bandwidth but shortage of photons. Opposite of electro-optics networks)
  - ⇒ Amplifiers just before the receiver filter

Star Example: IBM's Rainbow

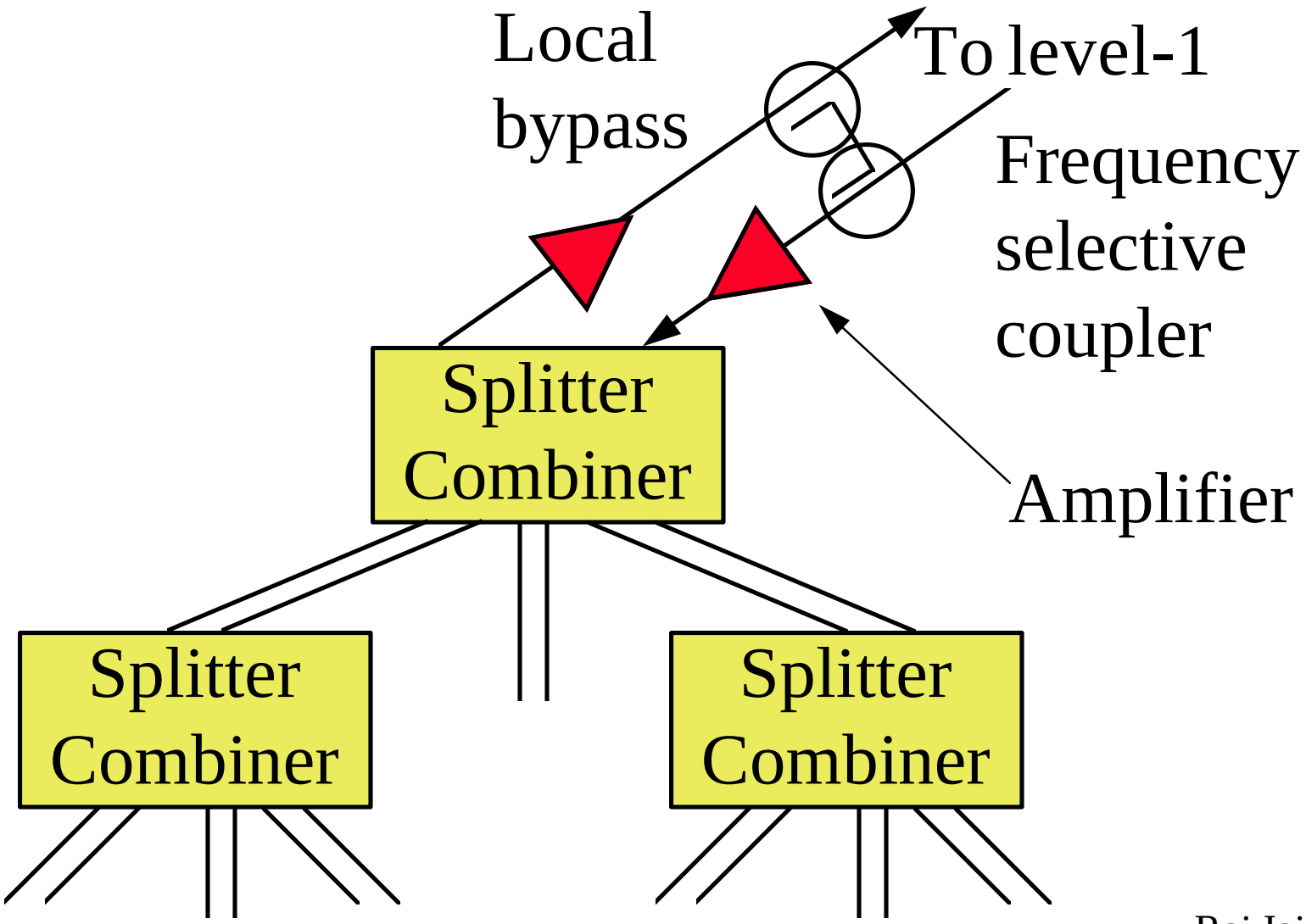
- 32 nodes max
- 300 Mb/s per node, Circuit switched
- Fixed transmitter, Tunable receiver
- Circular search: Scan l1, l2, ..., ln
- Transmitter l: ``I want to talk to m..."
- Transmitter m: ``Let's talk"
- Used PC's in demo
- Multiple boards for bridges

DEC-AT&T-MIT AON

- Star coupler for LAN
  Wavelength routers for MAN
  Space division for WAN
- Each User has a dedicated wavelength address



AON Level 0


Local
bypass
To level-1
Frequency
selective
coupler
Amplifier
Splitter
Combiner
Splitter
Combiner
Splitter
Combiner

Issues in Optical Networking

- Lower cost
- Sources:
  - Fast tunable lasers:
    Tunable over 10 nm in 1-2 ns
  - Large tuning ranges:
    Tunable over 200 nm in ms
  - Stable frequency
- Optical wavelength converters

- Optical Storage
- Optical recognition of headers
- Scalability
- Lower power dissipation
- TDM: Clock synchronization/distribution

Scalability

- No more than 200 one-Gbps channels due to amplifiers
  - Required spacing = $6 \times$ bandwidth
  - WDM has a scalability problem
- Solutions:
  - Wavelength reuse
    $\Rightarrow$ Wavelength allocation
  - Wavelength conversion
  - Multihop

Lower power dissipation

-
- Using Poisson distribution of photons in a pulse
  - $Pr(n)=(m^n e^{-m})/n!$
  - $Pr(0)=e^{-m}$
  - Minimum energy for e^{-21} or 10^{-9} BER = 21 photons
- In practice, 100 photons = 100 hν = 20 aJ

Power=Energy per pulse/Switching time

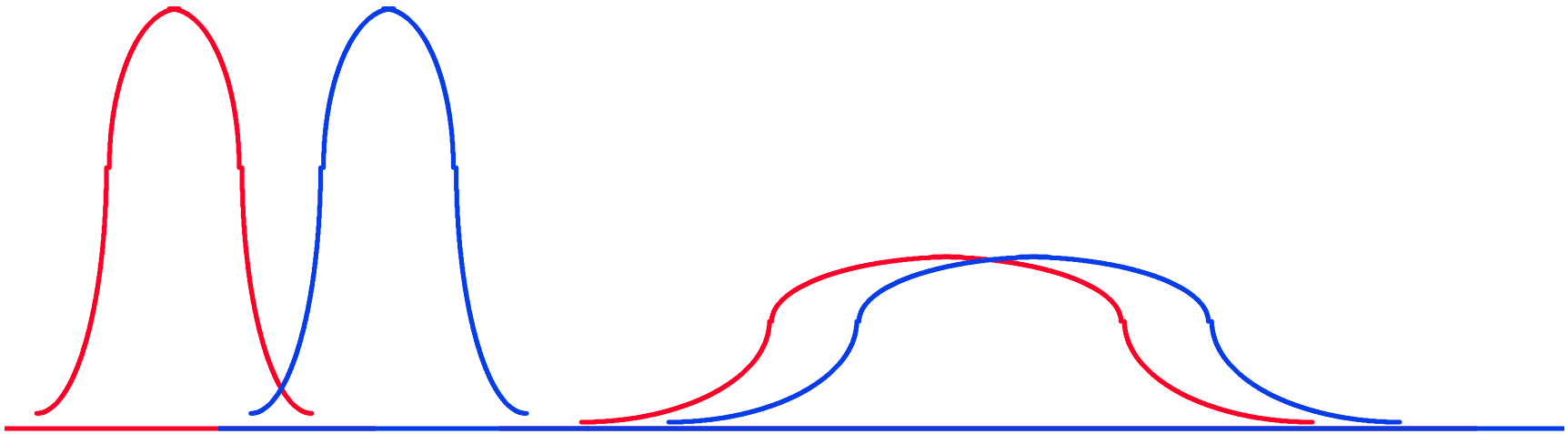
Protocol Design Issues

- Channel assignment
  Channel=Space, Time, Wavelength
- End-user access
- Move switching functions at intermediate nodes to optical domain
- Minimize and move all protocol processing to end-nodes

Attenuation and Dispersion

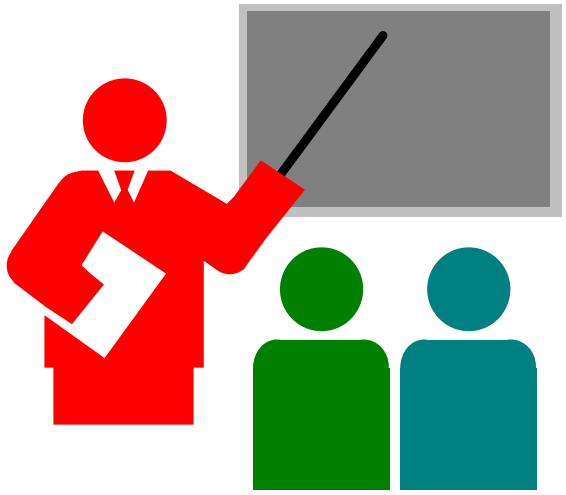
Solitons

- Light velocity is a function of amplitude
  $\Rightarrow$ Index of dispersion is non-linear:
  - $n=n_0 + n_2E^2$, Where, E=field strength
  - No dispersion if the pulse is sech(t)



- Need high amplitude pulses (100 mW) and high non-linearity
- Solitons have no distortion but must be amplified periodically (10 km)
- Erbium doped fiber amplifiers are used
- Can be very short duration 10 ps
  $\Rightarrow$ High bit rate

Summary



- All-optical=No electronic conversion of data
- Based on star coupler, wavelength routers
- WDM has scability problem
- TDM has clock synchronization problem
- Solitons for long-distance and high-speed

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  - http://www.watson.ibm.com/xw-d902-route.html
  - http://www.watson.ibm.com/xw-d902-ona.html
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  - http://www.watson.ibm.com/xw-d902-papers.html

Recent Advances in Networking and Telecommunications Seminar Series 1996: Tentative Dates

Last Tuesday of the month (mostly), 3:45-5:15 PM

- January 30, 1996
- February 27, 1996
- March 26, 1996
- April 30, 1996
- May 28, 1996
- June 18, 1996
- August 27, 1996
- September 24, 1996
- October 15, 1996
- November 26, 1996

Potential Topics for 1996

- IPng: Next Generation Internat Protocol
- Frame Relay
- SMDS
- Gigabit Networking Standards: Fiber Channel and HIPPI
- Technologies for 6 Mb/s to Home: ADSL, HDSL
- Integrated services (Multimedia) on IP
- Wireless ATM
- Multiprotocol over ATM
- ISDN
- GPS Applications to Networking

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