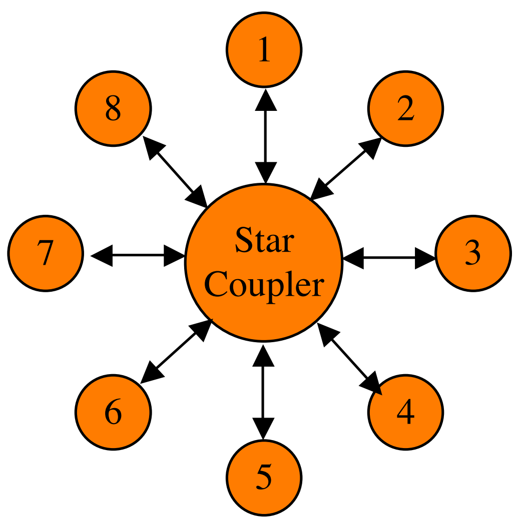
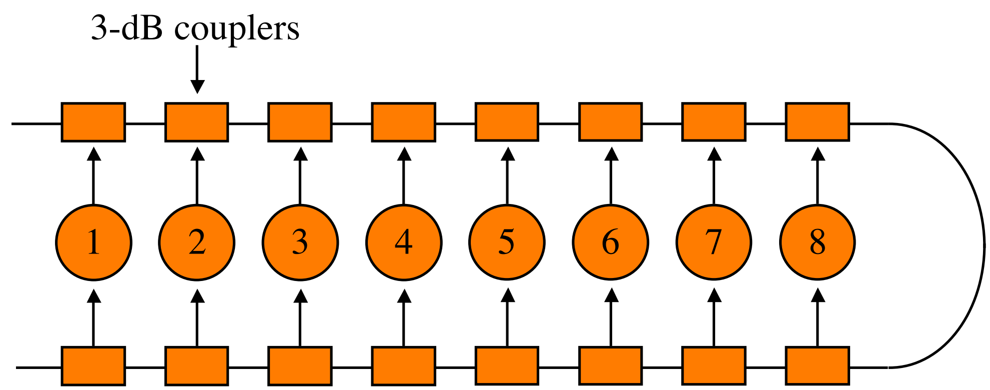
Lecture 4: Optical Broadcast and Select Networks

Optical Broadcast and Select Networks

- The network sends signals received from all users back out to all users (broadcast)
- There is no routing performed in a B&S network



Optical Star Broadcast Topology

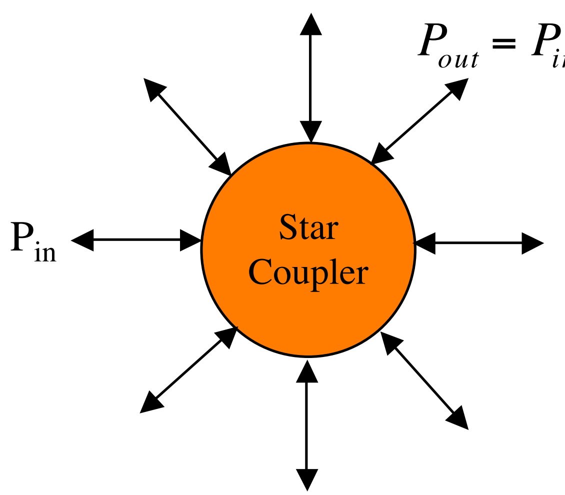


Optical Bus Topology

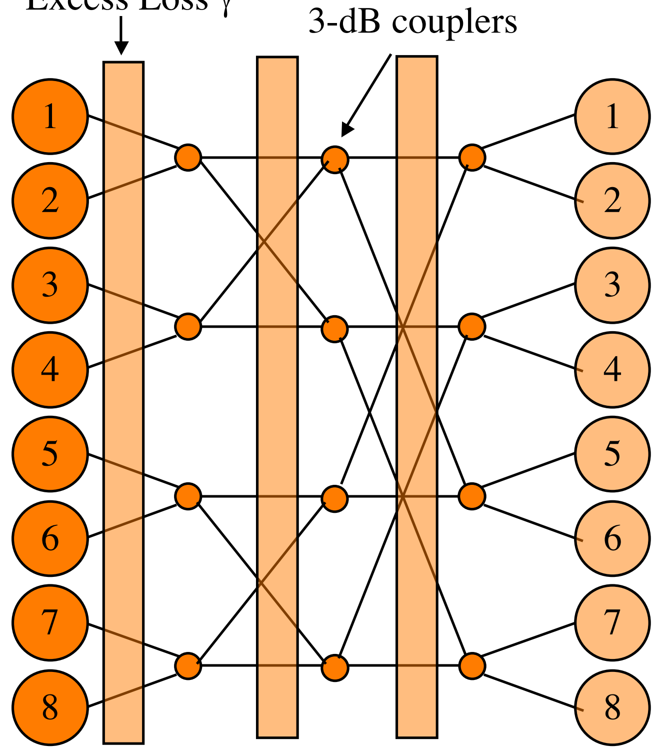
Power Loss in Optical B&S Networks

Without optical amplifiers, the optical power from any transmitter is distributed to all other users with loss that scales with the number of users

$$P_{out} = P_{in}\left(\frac{\gamma}{2}\right)^{\log_2 N}$$



$L_{star} = 10\log_{10}N - (\log_2 N)10\log_{10}\gamma$ *



Star Coupler

* Ignoring fiber loss

Power Loss in Optical B&S Networks

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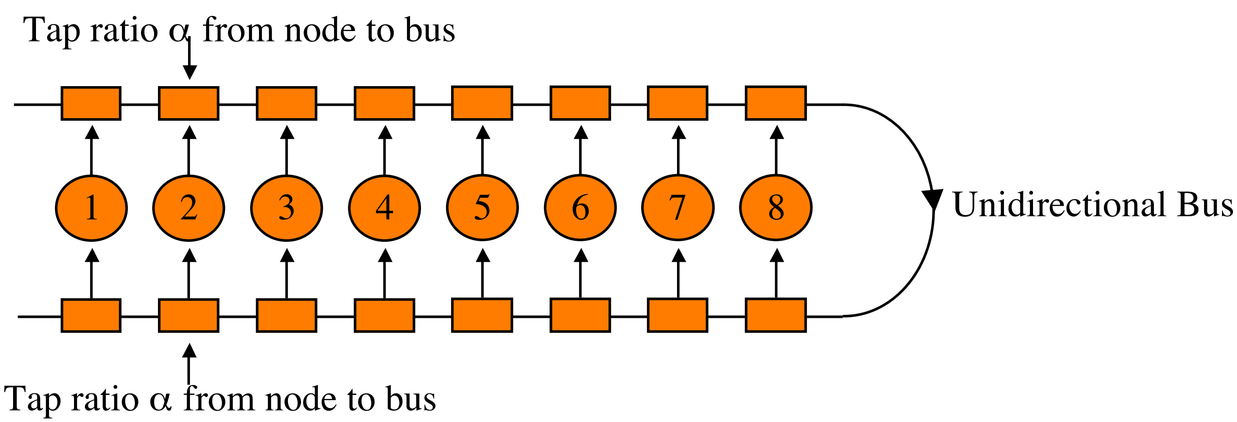


$$L_{bus} = \alpha^2 (1-\alpha)^{2N-3} \gamma^{2N-1}$$

$$L_{bus,opt} \approx \frac{e^{-2}\gamma^{2N-1}}{N^2} \approx 8.7 + 20\log_{10} N - (2N-1)10\log_{10}\gamma$$

where there is an optimal coupling the minimized L_{bus}

$$\alpha_{opt} = \frac{2}{2N-1}$$

Media Access Control (MAC) Protocols

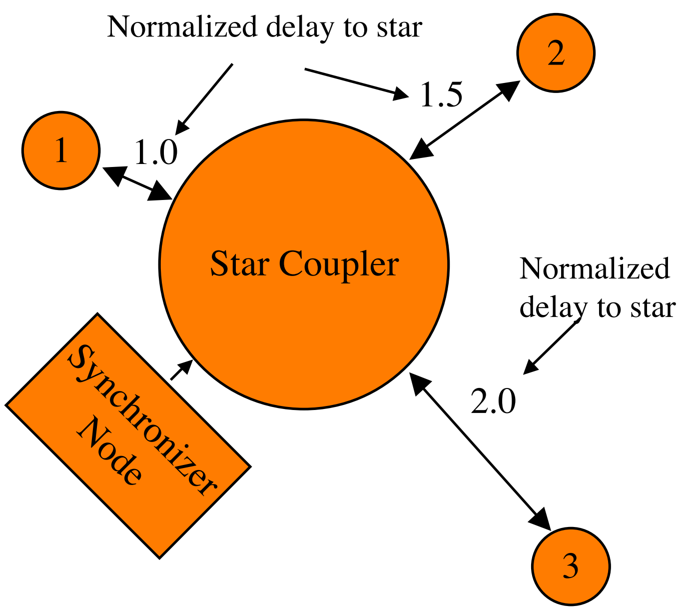
- In a B&S network, each node sends messages to all other nodes
- Each node must then select the desired signal for reception
- MAC protocols are designed to mediate access between the users and the network bandwidth
- MAC protocols are designed to perform best for a certain application
- MAC protocols for circuit switching will allocate the complete bandwidth from a wavelength to a single user
- MAC protocols that allow users to share the bandwidth of a wavelength typically assume packets are transmitted in time slots on each wavelength

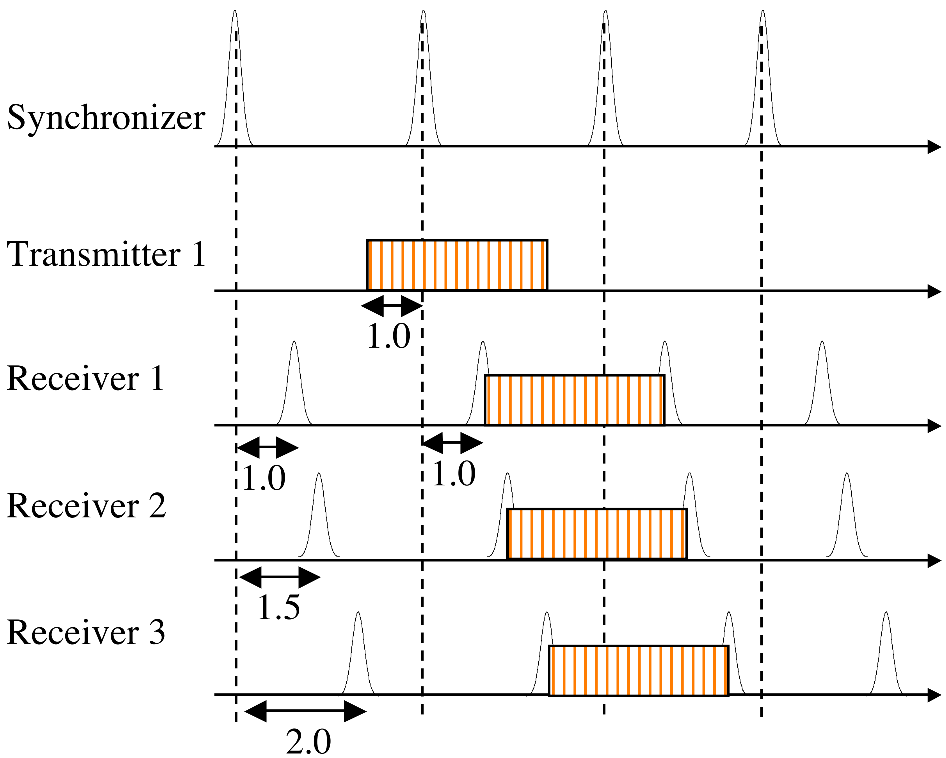
  - Two important measures of performance for a packet network are
    - **Throughput** (the fraction of the transmission capacity that carries useful data)
    - **Latency** (the delay a packet experiences from the output queue of a node to the final destination

Synchronization in Optical B&S Packet Networks

- Certain packet architectures utilize synchronization to avoid "collisions" of data at a destination
- These networks also tend to utilize a "control channel" to transmit information about packets that are transmitted

Case Study:



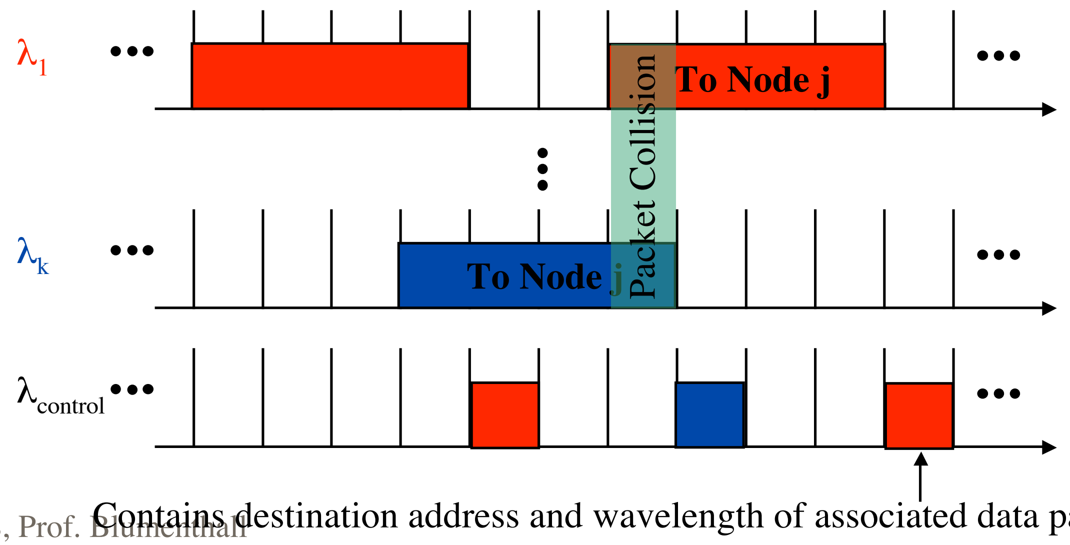


Slotted Aloha/Slotted Aloha MAC Protocol

⇨ Historically, it was assumed that the number of wavelength available to a WDM network would be limited.

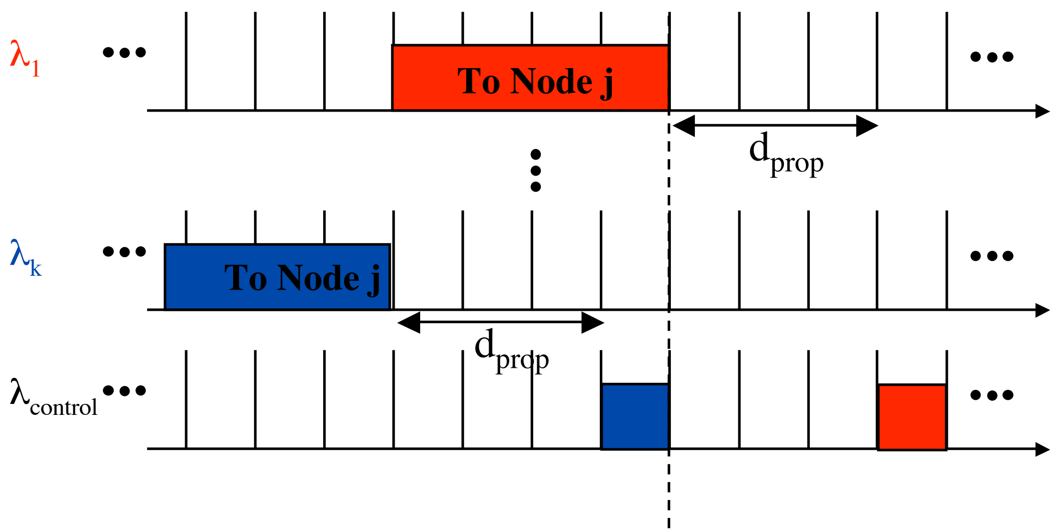
⇨ This led to the concept of **“wavelength bandwidth sharing”** through TDM or through another concept called “**wavelength reuse**”

- Aloha assumes that there are W wavelengths used to transmit data to N nodes where W << N
- There is also a common W+1 control wavelength channel
- Each node has a wavelength tunable transmitter and a wavelength tunable receiver
- Each node has a transmitter and receiver that work with the fixed control channel wavelength
- This is a “tell and go” protocol where packets are sent as soon as they are ready at the output queue
- Both data and control packets must be collision free in order for successful transmission



Modified SA/SA MAC Protocol

- The Slotted Aloha/Slotted Aloha protocol can be modified to avoid collisions by using a"**wait and see**" approach
- In this scheme we are will to trade the potential increase in delay to transmit a packet for an improvement in the overall throughput



λ_1 transmits the data packet if there are no colliding control packet request within d_{prop} of initially sending its control packet

Through-Latency Characteristics of SA/SA and Modified SA/SA MAC Protocol

- Assume a probability *p* that any slot is occupied by a packet, independently of all other slots
- Assume a large number of nodes *N* compared to the number of wavelengths *W*
- Assume that a data packet is equally likely to be transmitted in any on of the *W* channels

- The expected number of packets available in each transmission slot follows a Poisson distribution

$$\text{Prob}(G = k) = e^{-G}\frac{G^k}{k!}, k \geq 0$$

Throughput-Latency for SA/SA

- Define the **Throughput (T)** per data channel
  - as the expected number of data packets on a given channel at an arbitrary point in time that will be successfully received
- Define **L** as the number of control slots per data slot
- Define **W** as the number of wavelengths

For SA/SA

$$T(G) = \frac{LGe^{-G}}{W}\left(e^{-G/W}\right)^{2(L-1)}$$

For Modified SA/SA

$$T(G) = \frac{LGe^{-G}}{W}\left(1 - Ge^{-G}/W\right)^{2(L-1)}$$