Chapter 1: Conceptual Basis

Section 3

V 2.3 23rd/Mar/2022

Based on textbook *Conceptual Computer Networks* by:

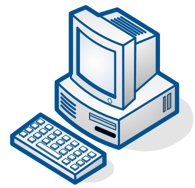
2

Sharing connectivity

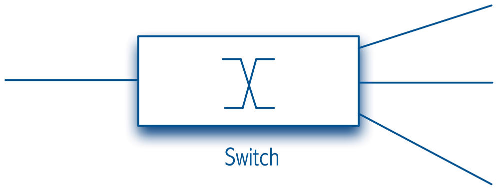
How to share a link, a network among multiple users

Review of terminology

- **Hosts**: the computers that run the application programs
  - Clients
  - Servers



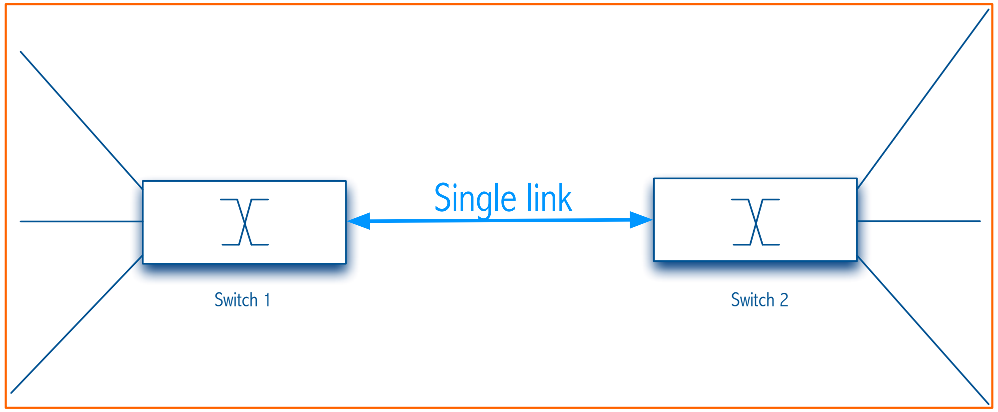
- **Network nodes**
  - DataComm equipment for building a network

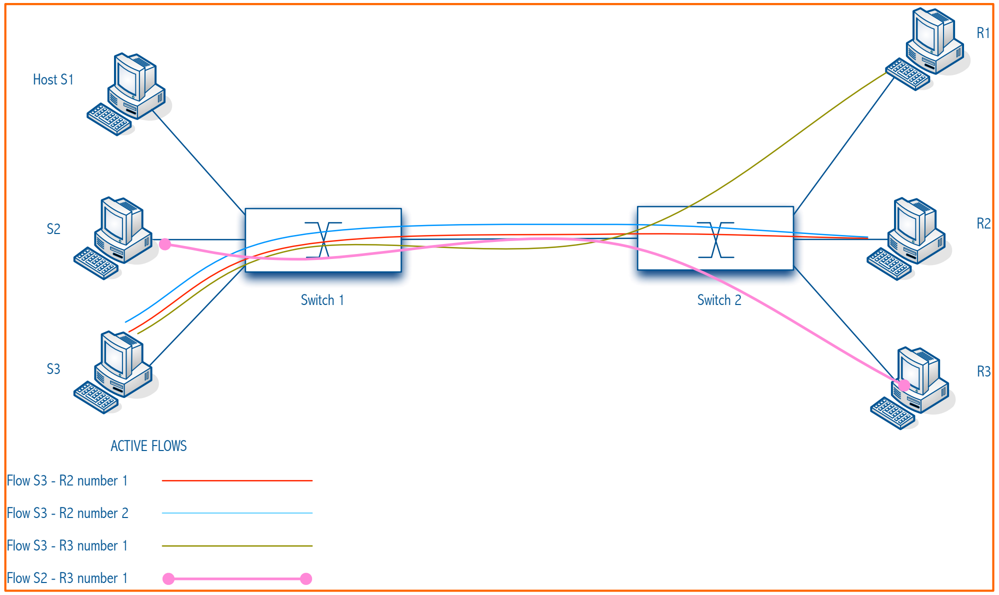


- **Links**:
  - The physical transmission media and the controlling protocol
    - Simplex
    - Half-duplex
    - Full-duplex
  - Radio waves (WiFi), Twisted Pair cables, Optical Fibers, etc

Multiplexing = sharing

4



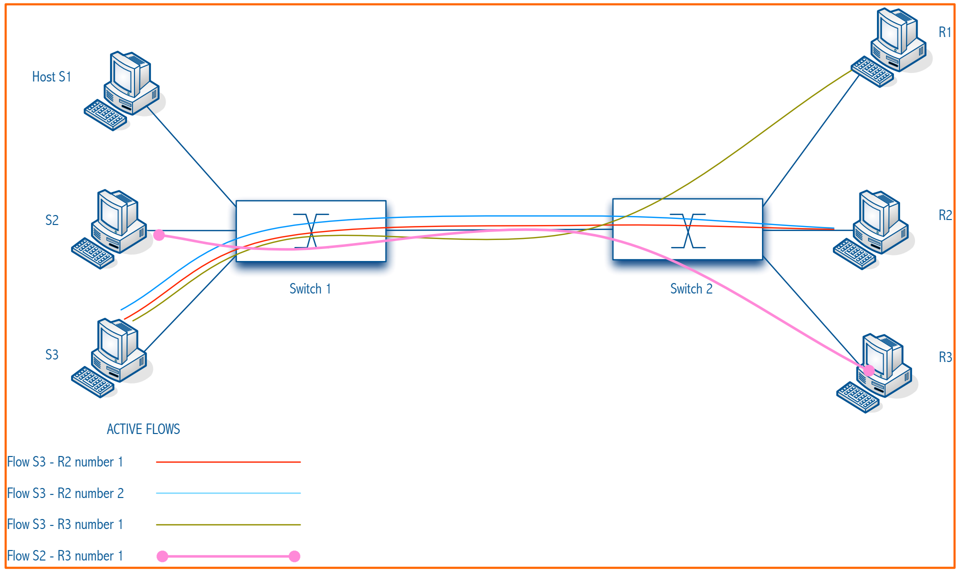


- Switch1 and Switch2 are linked by a single link
- How can that link be shared among the hosts?
- How can that sharing be done?
  - By multiplexing the flows of packets over the link that connects the switches

Physical-layer Multiplexing Techniques

1. Synchronous Time-division Multiplexing (STDM)

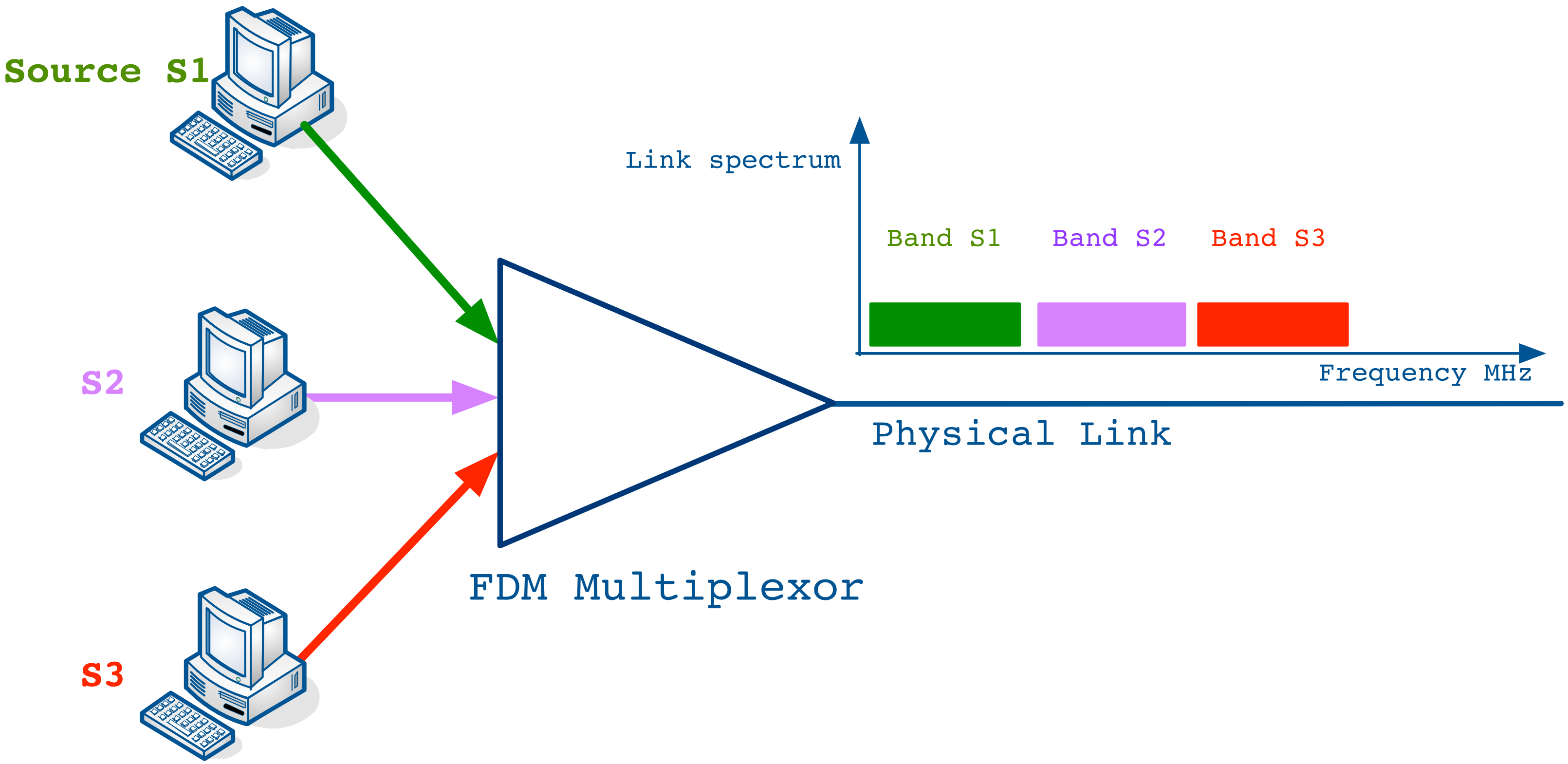
- Allocate a predetermined time slot to each flow
- Each flow avails the full bandwidth when transmitting
- Drawbacks
  - If a flow is not transmitting (idle), its slot remains allocated and is wasted



Physical-layer Multiplexing Techniques

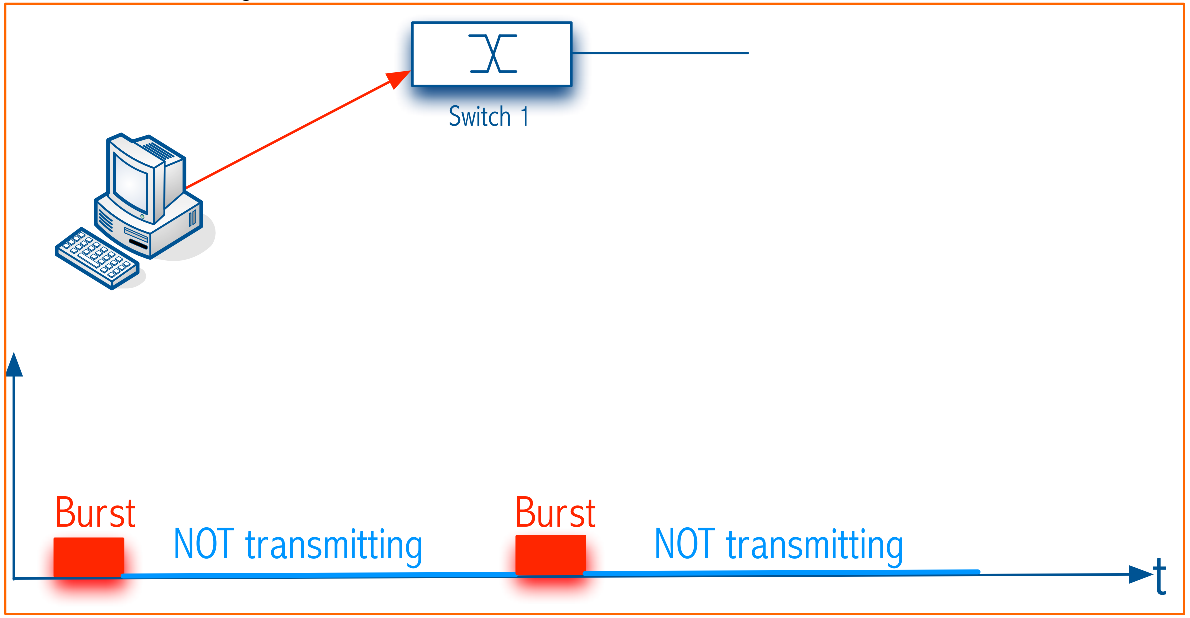
2. FDM: Frequency Division Multiplexing

- *Similar* to FM radio
- Each flow is assigned a portion (a band) of the link spectrum
- Each portion is the same size (bandwidth)
- Cable TV, certain Cellular Telephony (Slots of 30 kHz each), etc



Physical-layer Multiplexing Techniques

3. Statistical Multiplexing
   - Sources are supposed to be bursty
   - The bandwidth of the shared link is a fraction of the peak aggregated bandwidth of the other links
   - If two or more bursts overlap, then the multiplexor must queue them until ready for transmitting them



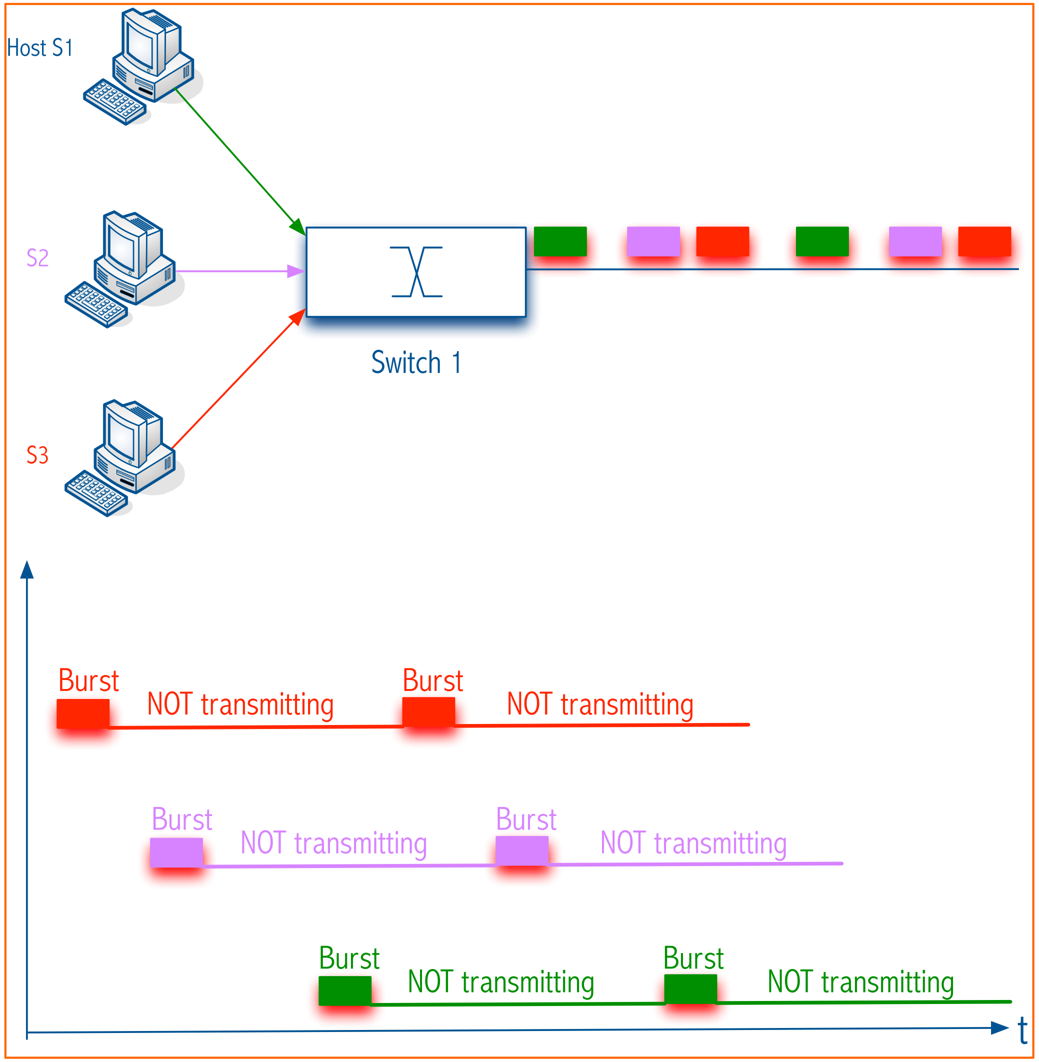
A bursty source

Multiplexing techniques

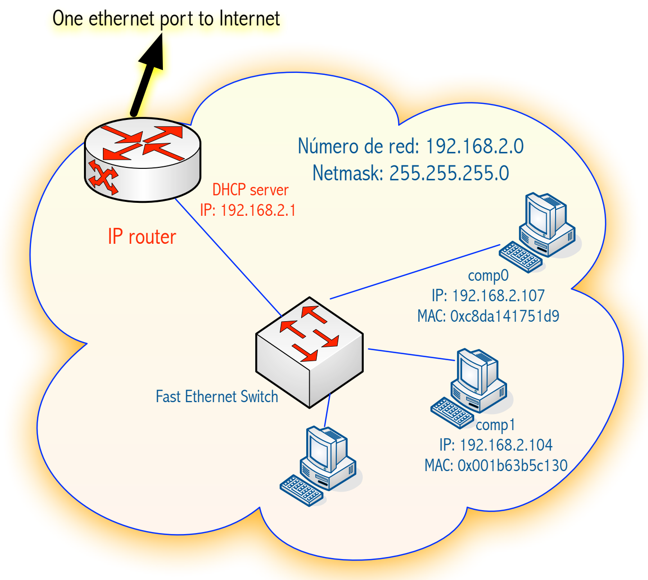
8

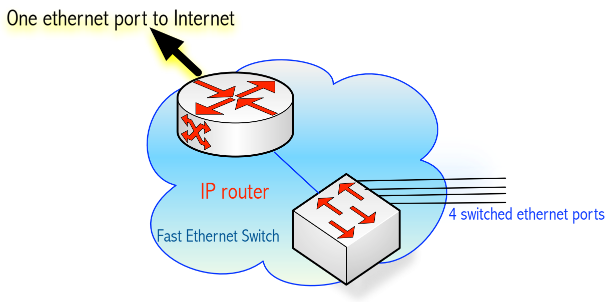
3. Statistical Multiplexing

- Packet queueing means delays packets
- Queue length
- Mean delay
- Statistical Multiplexing Gain
- FIFO, Round Robin, etc.
- Some switches may apply QoS (Quality of Service):
  - Priorities
  - WFQ, etc
- Congestion



Traditional types of networks





According to their geographical extent and their goals

- LAN : Local Area Network
  - Ethernet
- MAN: Metropolitan
  - WiMax
- WAN: Wide
  - X.25
- SAN (System Area Networks)
  - Interconnect hard disks, network storage
  - High speed

Network Reliability

Types of errors that may occur in the Internet

- Single bits are lost
  - Bit errors (1 to a 0, and vice versa)
  - Burst errors – several consecutive errors
- Whole packets are dropped (Congestion causes buffer overflows at the output queues)
- Links and Node failures
- Packets are delayed
- Packets may be delivered out-of-order
- Third parties eavesdrop

Network Management

- Network management
  - Manage the daily operation of networks
- Guarantee uptime
  - Times at which the network is available
- In real time
  - Monitor networks
  - Change configurations
  - Traffic engineering
- An automated process
  - Specific software “Network Management System”
  - Protocols: SNMP
  - Data structures: RMON, MIBs
- Home networks: Plug and play
- All this is quickly moving towards Software Defined Networking (SDN)

12

Network Performance: Networks must be fast

What are the essential network performance metrics: bandwidth and latency

Transmission media AS systems

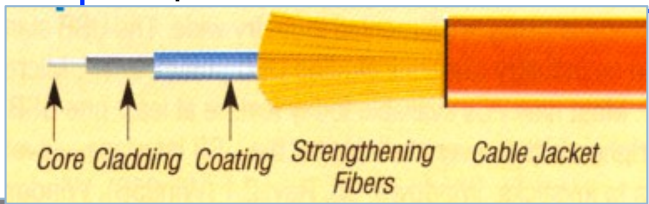
Input signal f(t)

Has bandwidth B

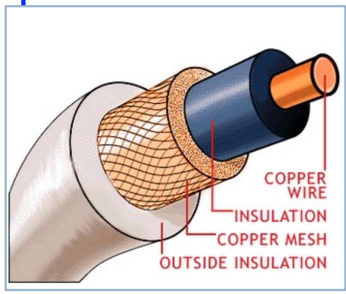
System with H(**ω**)

Output signal g(t)

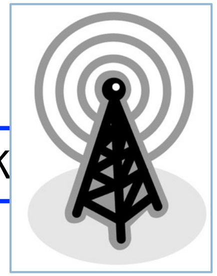
An optical fiber: B = 100 GHz



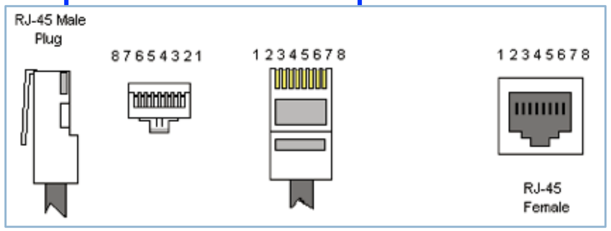
Coaxial cable: B = 3 GHz



WiFi radio link



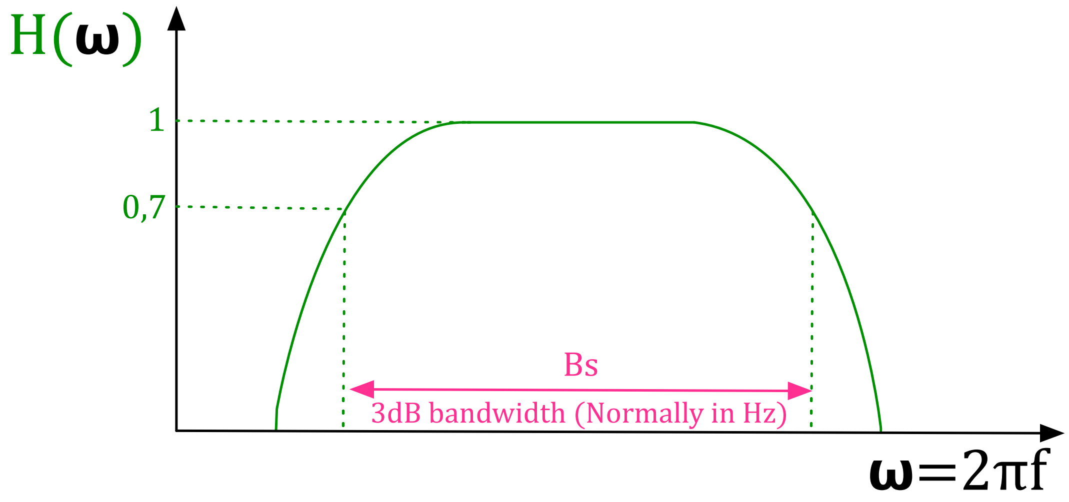
Twisted Pair

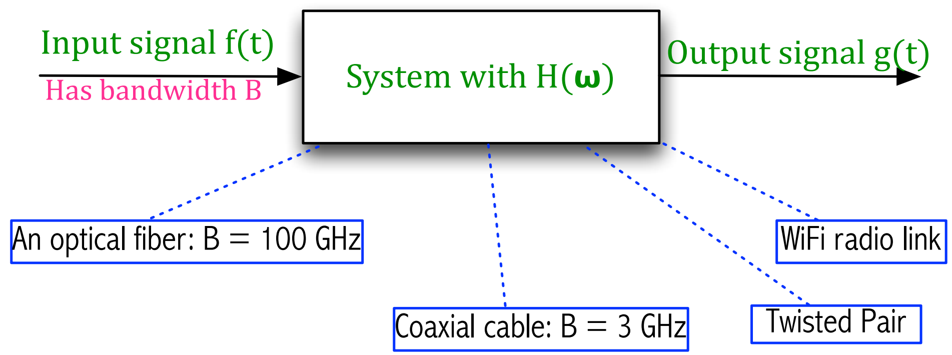


Bandwidth is a property of every system

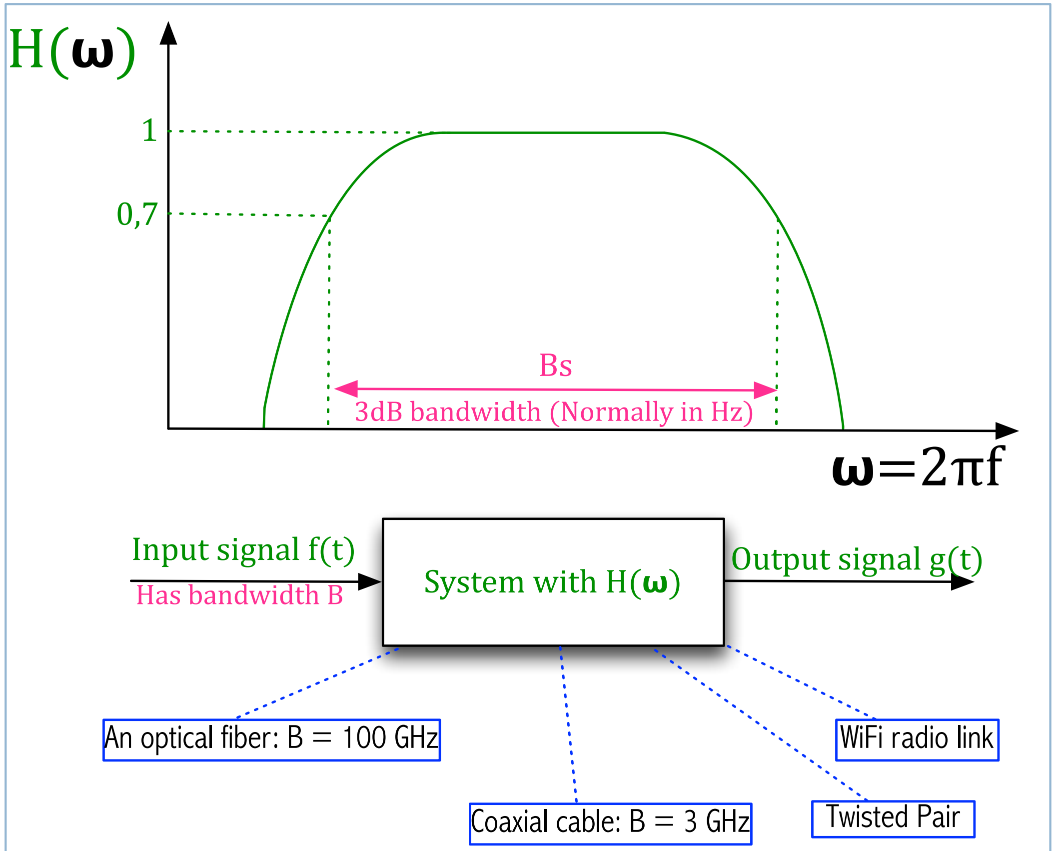
The width of the accepted frequency band

- Measured in Hz = 1/s
- In networking bps means bits per second
  - bits/s
  - bits · Hz
- Often, bandwidth and transmission speed are proportional





Bandwidth and transmission speed



If B > Bs => output will have big distortion
If Bs > B => output will have little distortion

- If the band can hold the signal, it passes cleanly on to the output
- Bs in Hz is the inverse of the signaling SPEED in seconds
- High bps needs high bandwidth => high speed demands high bandwidth
- High bandwidth permits high speed transmission

Performance

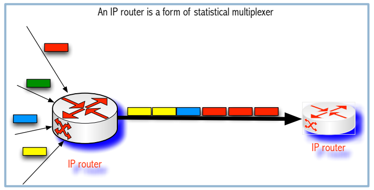
- **Bandwidth**
  - Width of a frequency band
  - Number of bits per second that can be transmitted over a communication link in a given period of time
  - The inverse of Bw is the time it takes to transmit one bit
    - 1Mbps = 1M bits/s = 10^6 bits/s → T_{transm}1 bit = 10^{-6} s/bit · 1bit = 1µs
  - Higher bandwidth (speed) means shorter transmission times
- Multipliers used in expressing speeds (ratios)
  - 1Kbps = 1K bits/s = 10^3 bits/s
  - 1Mbps = 1M bits/s = 10^6 bits/s
  - 1Gbps = 1G bits/s = 10^9 bits/s

Total time to transfer one packet onto a Point-to-Point connection

- Latency = Propagation + transmit + queue

- Propagation time = physical link distance/speed of light m / (m/s)
  - The time it takes for the signal corresponding to ONE BIT to travel from the sender through the receiver

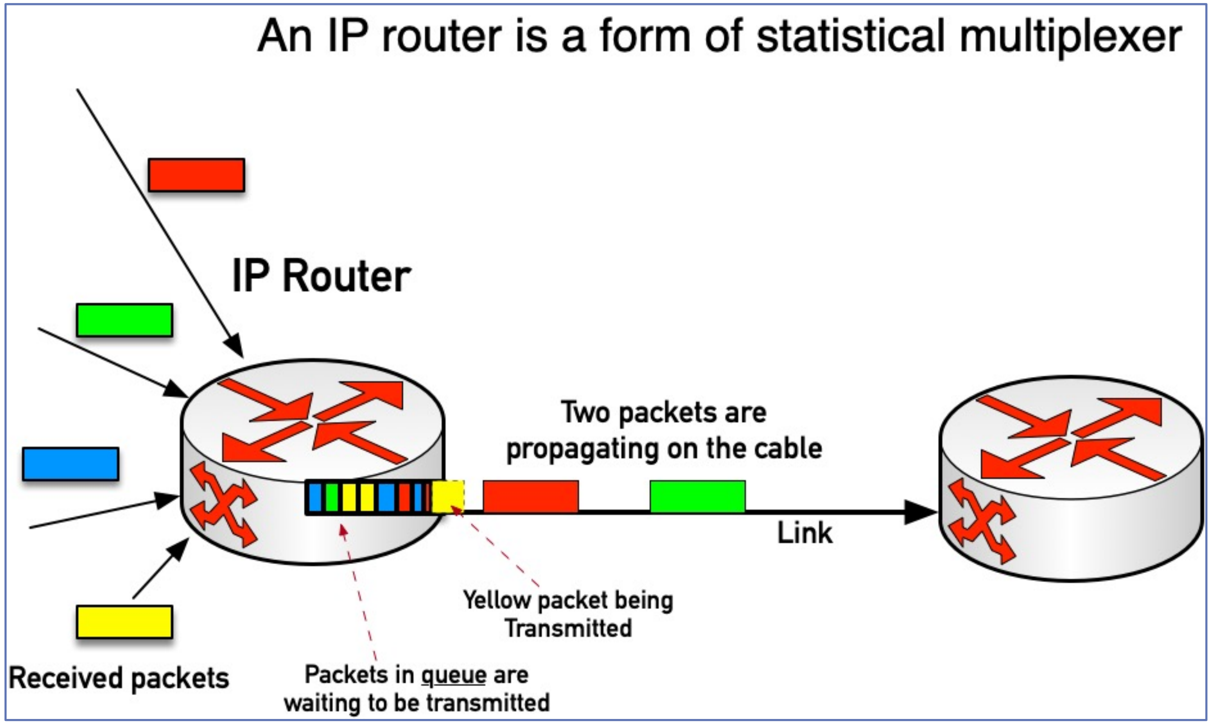
- Transmit time = packet size/bandwidth bits / (bits/sec)



- If only one bit is transmitted => propagation is important
  - Or a small amount of bits
- If the amount of bits transmitted is large => bandwidth is important

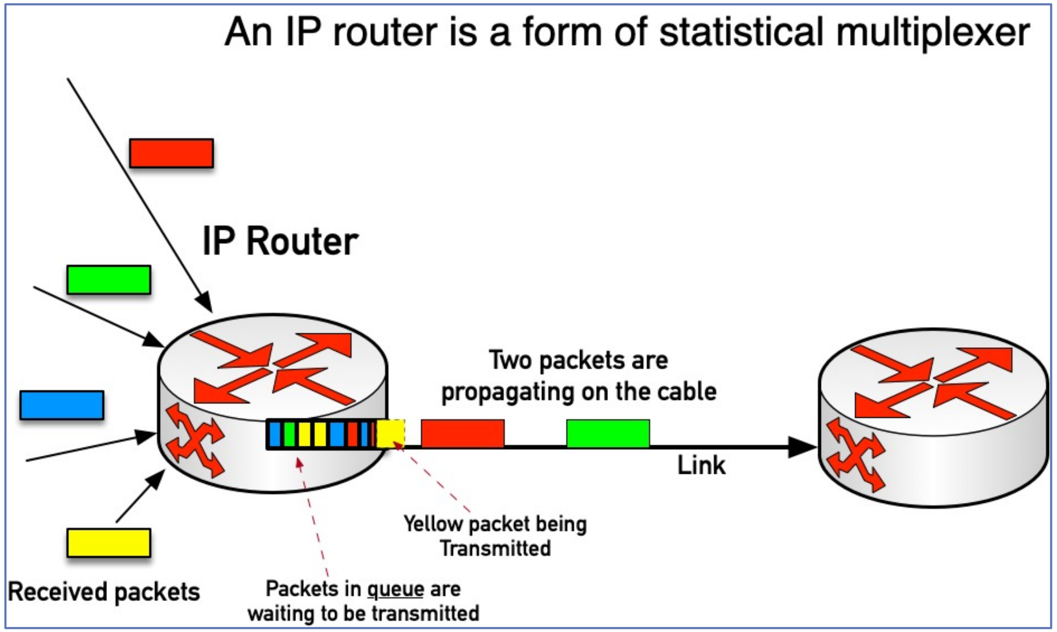
Queuing time

- Packets received while a packet is being transmitted must be enqueued
- Otherwise, they'll be lost



Transmission time

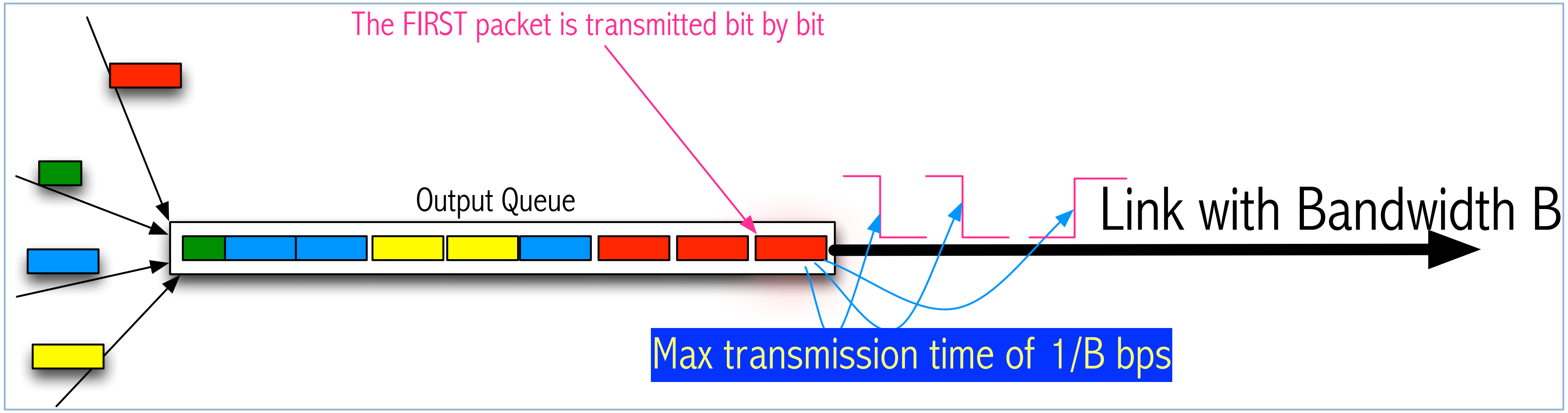
- The packet on the first position in Queue is transmitted
  - Packet bits are *encoded* into signals (Electrical, Electromagnetic, Optical)
  - 1 bit from packet -> 1 signal waveform
  - At which speed (bps = bits/s) can this be done?
  - High Bw => High speed



Transmission time

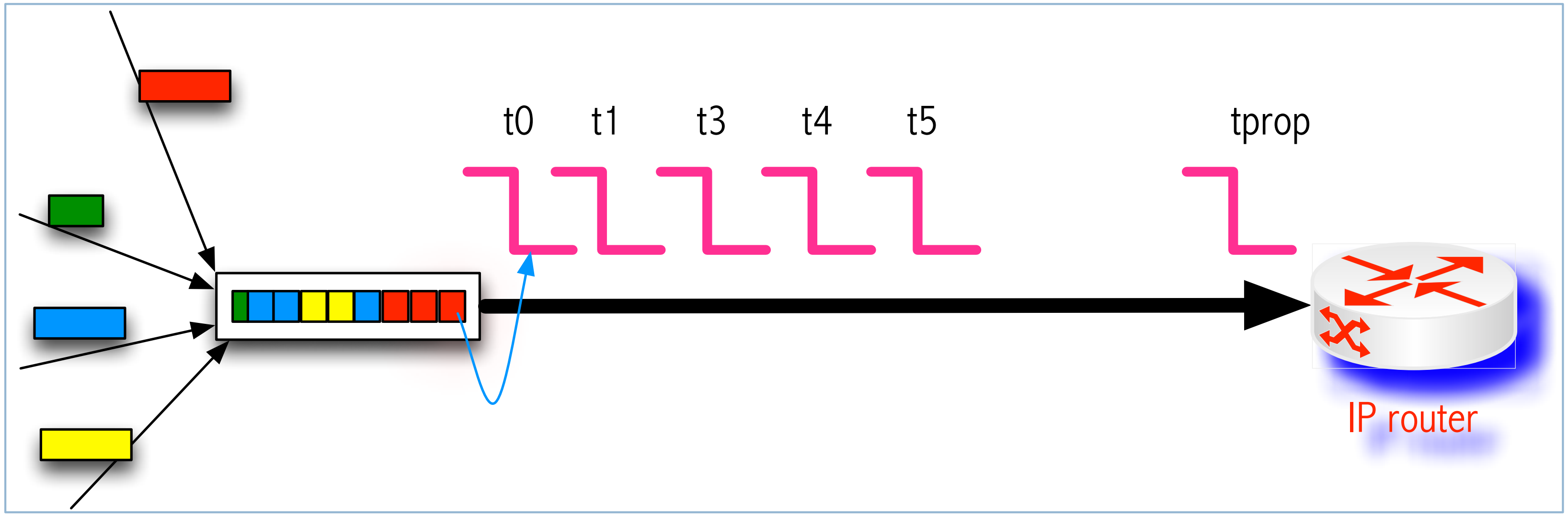
20

- The packet on the first position in Queue is transmitted
  - Packet bits are turned into signals (Electrical, Electromagnetic, Optical)
  - 1 bit from packet -> 1 signal
  - At which speed (bps = bits/s) can this be done?
  - High Bw => High speed



Propagation time (t_{prop})

- Now, each signal must propagate over the wire until it reaches the receiver
  - Speed of light in empty space c = 3×10^8 m/s
  - Speed of light in other media
    - Copper: $2{,}3 \times 10^8$ m/s
    - Optical fibers: $2{,}0 \times 10^8$ m/s



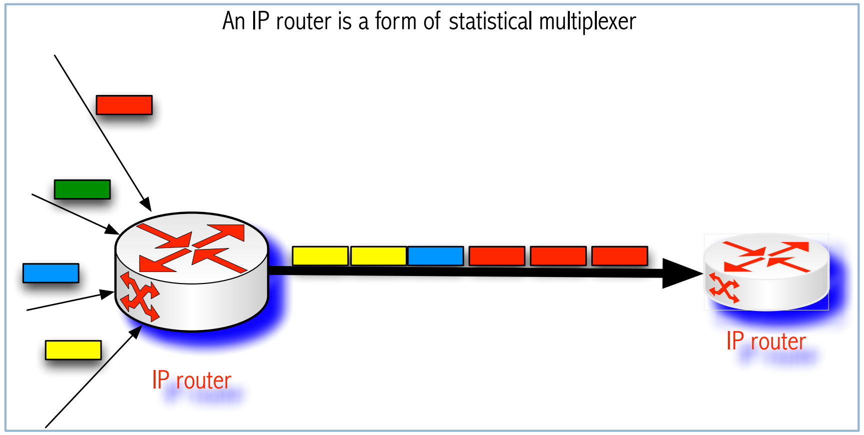
Latency = total time to transfer one packet

(Point-to-point connection)

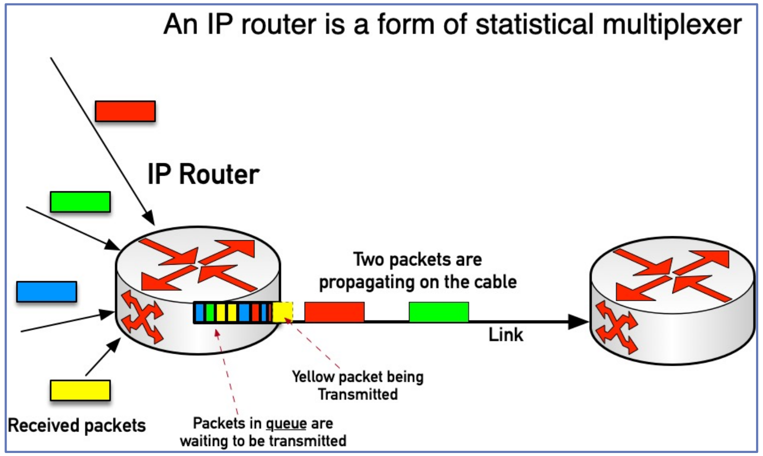
22

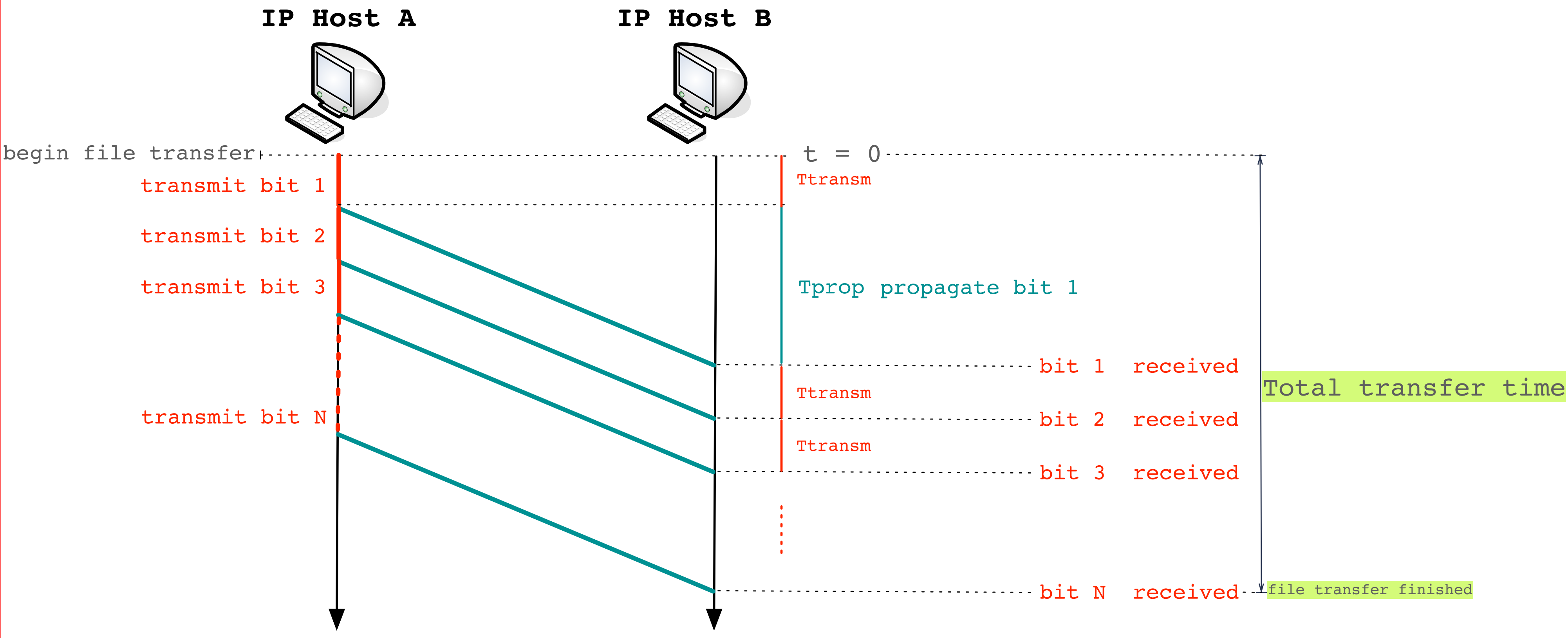
- Latency = Propagation + transmit + queue
- Propagation time = physical link distance/speed of light m / (m/s)
- Transmit time = packet size/bandwidth bits / (bits/sec)

- If only one bit is transmitted => propagation is important
  - Or a small amount of bits
- If the amount of bits transmitted is large => bandwidth is important



- **Latency = Propagation + transmit +** queue
- Propagation time = physical link distance/speed of light m / (m/s)
- Transmit time = packet size/bandwidth bits / (bits/sec)
- If only one bit is transmitted => propagation is important
  - Or a small amount of bits
- If the amount of bits transmitted is large => bandwidth is important





Total transfer time = Nbit x Ttransm + Tprop

End of Ch 1 Section 3