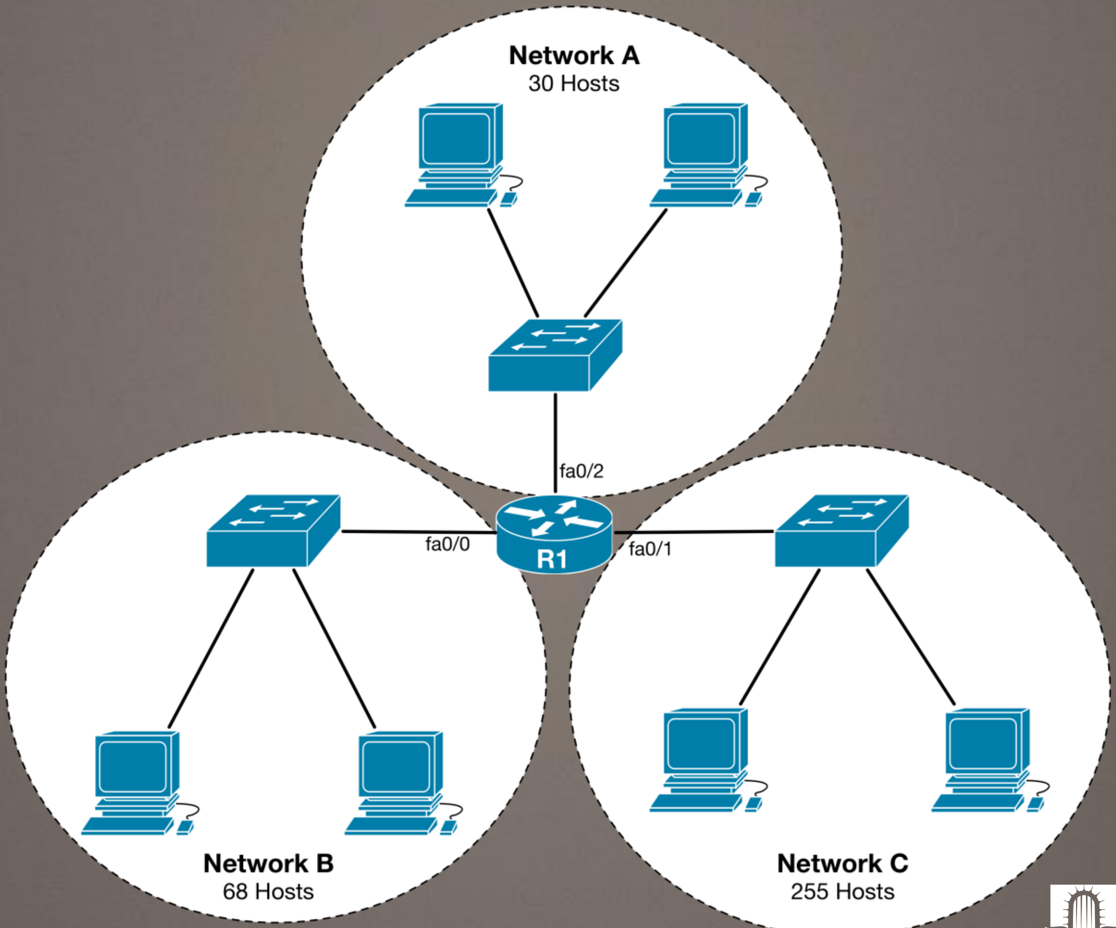
Review Question

Subnet the 145.123.0.0/22 network for the topology below



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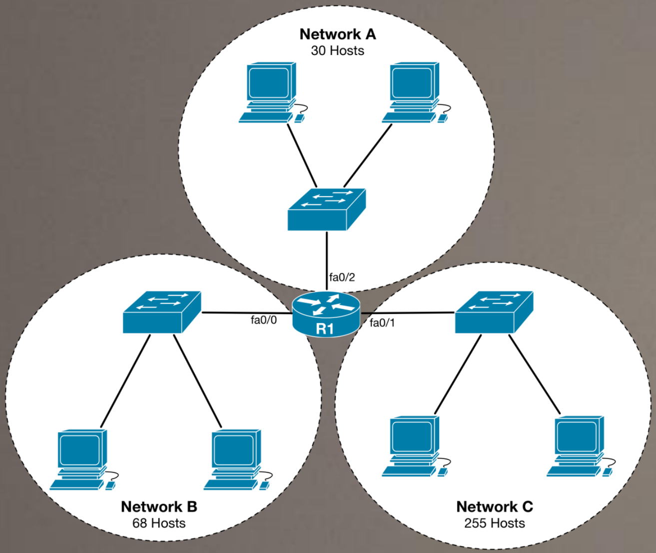
Review Question

Subnet the 145.123.0.0/22 network for the topology below



Host bits required:

255 hosts → 9 bits
68 hosts → 7 bits
30 hosts → 5 bits

C	145.123.0.0/23
B	145.123.2.0/25
A	145.123.2.128/27

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The Data Link and Physical Layers

ICT169

Foundations of Data Communications

Admin

- Participation quiz 2 deadline extended
  - Now due Monday, 20 August (day of this lecture)
  - Reminder about copying and pasting
- Additional lecture recordings showing up in Echo360; should only be 3 to-date
- Non-teaching week coming up (starting 27 August)

Reminder – Mid-Semester Test

- Runs during Session 6 (Week 7) during lab times, you **must** attend the lab you are enrolled in
- Online (LMS-based) test, 90 minutes
- **Closed book:** No aids allowed except note paper (provided)
- Covers topics from the lectures, labs and readings of sessions 1—5
- Your answers are entered online
    - Multiple choice
    - Short answer
    - Long answer
- Contributes 15% of your overall grade

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Mid-Semester Test – Possible Question Topics (1)

- Describe the difference between packet switched and circuit switched networks
- Describe why data networks break communications into packets
- Define network convergence, and identify challenges associated with it
- Describe a communications medium, giving three examples
- Differentiate between a LAN and a WAN
- Describe the purpose of the OSI model
- Name the layers of the OSI model and TCP/IP models
- Name some networking devices, and identify which layer of the OSI model they operate at

Mid-Semester Test – Possible Question Topics (2)

- Define the term ‘protocols’ and describe their purpose in data communications.
- Differentiate between units used to define network speeds and data storage
- Convert between units used to define network speeds and data storage
- Describe the Client/Server and Peer-to-Peer architectures
- Describe the purpose and operation of some widely used application layer protocols (eg. DNS, HTTP, FTP, DHCP)
- Describe the purpose of the OSI Transport layer
- Define ports with respect to the Transport layer

Mid-Semester Test – Possible Question Topics (3)

- Describe the operation of the Transmission Control Protocol and User Datagram Protocol
- Identify when it is appropriate to use each transport layer protocol
- Describe the purpose of the network layer
- Describe the operation of IPv4 (key properties and header fields)
- Describe the packet forwarding process
- Describe the different types of IP transmissions (unicast, multicast, broadcast)
- Describe the purpose of the subnet mask and subnetting
- Apply VLSM to subnet IP networks (and related questions):
  - Subnetting problems (see lab handout)
  - Size of subnets given subnet mask
  - Identify whether IP addresses belong to the same subnet
  - Convert between dotted decimal and slash notation

Mid-Semester Test – Possible Question Topics (4)

- Describe the role of the Data Link layer and the division of functions between the Logical Link Control (LLC) and Media Access Control (MAC) sublayers
- Describe the difference between Point-to-Point and Multi-Access links
- Differentiate between different approaches to MAC (CSMA/CD, TDMA, Token Ring)
- Describe the role and use of MAC addressing in data communications
    - End-to-end and hop-to-hop addressing
- Identify data link layer protocols
- Describe the purpose of the physical layer
- Identify different forms of physical media (copper, fibre, air) and the distances these mediums are used for
- Medium, medium access and topology for Ethernet, ADSL, Cable/DOCSIS

Mid-Semester Test – Possible Question Topics (5)

- List different topologies used by Ethernet networks
- Describe the operation of CSMA/CD
- Describe the role of MAC addresses in Ethernet networks
- Describe the operation of Ethernet switches
- Describe the role and operation of ARP
- Define and identify Collision and Broadcast domains
- Differentiate between a straight-through and crossover cable
- Identify the suitable cable type for connecting network devices
- Describe the Hierarchical Network Model
- Describe the role of Virtual Local Area Networks (VLANs) in switched networks
- Describe how traffic from different VLANs is identified and isolated
- Describe the purpose of a trunk link

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Subnetting Practice Resources

Introduction to Networks Activities (Requires NetAcad login)

9.1.3.6 - Network Addresses - http://bit.ly/2bbCVHU

9.1.3.7 - Number of Hosts - http://bit.ly/2bbD4ev

9.1.3.8 - Host Addresses - http://bit.ly/2bqhEYL

9.1.3.9 - Subnet Masks - http://bit.ly/2aYZ7HG

9.1.3.13 - Network Addresses II - http://bit.ly/2bmr8XE

9.1.3.14 - Number of Hosts II - http://bit.ly/2b0igGs

9.1.3.15 - Host Addresses - http://bit.ly/2bmqkCc

Practice Questions (subnetting.net) - http://bit.ly/2bm42lq

Lammle Subnetting Practice - http://bit.ly/2b0hBV6

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Last Week

- An in-depth look at the Network layer, focusing on IPv4 (the most common network layer protocol)
- We also looked back at the encapsulation process
- The packet forwarding process
- Binary maths
- IPv4 addressing and subnet masks
- Subnetting using VLSM

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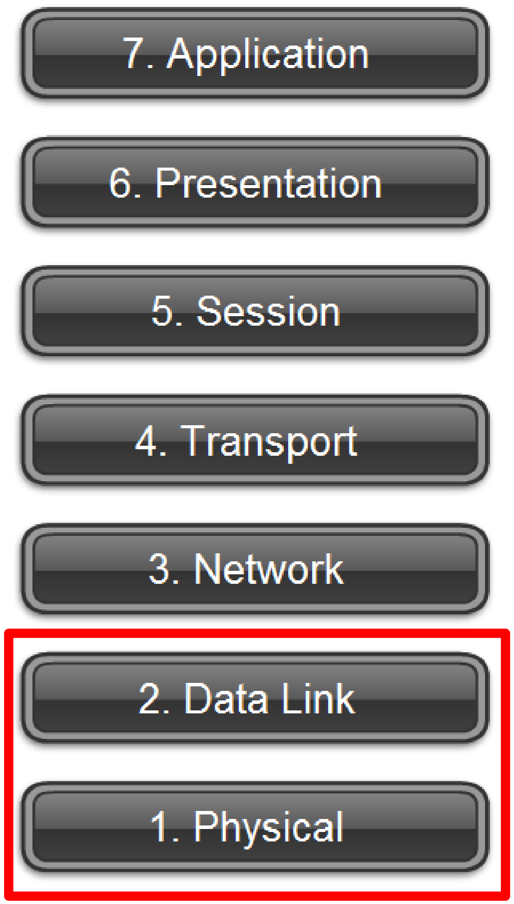
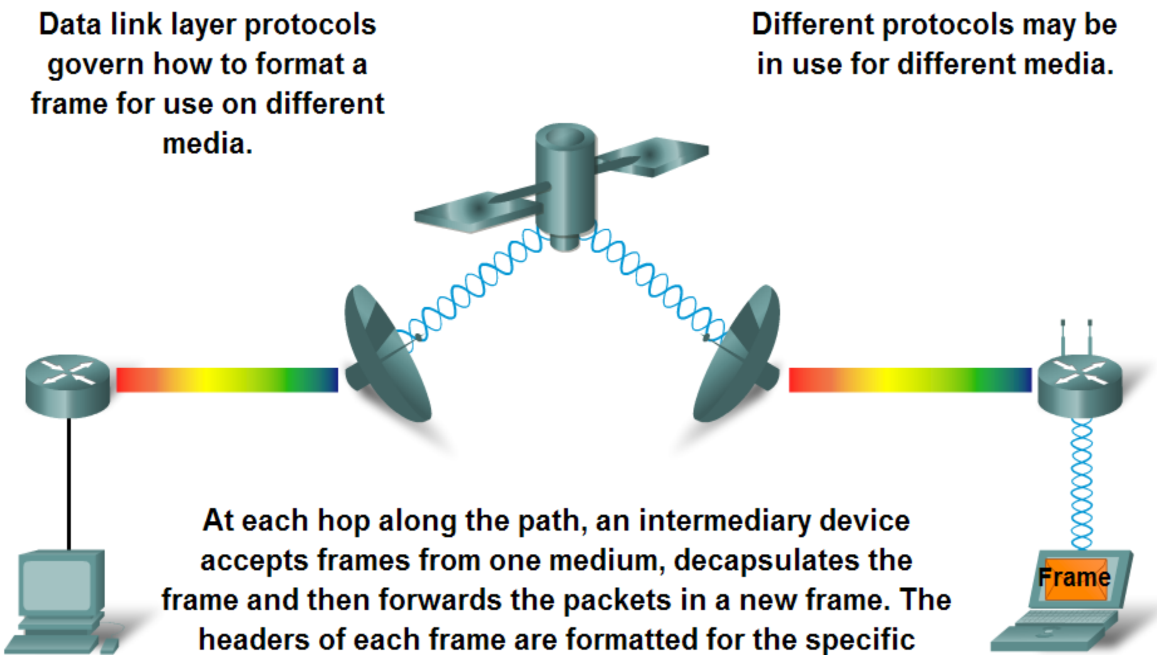
Lecture Overview

- The role of the Data Link and Physical layers in data communications
- Sub-layers of the Data Link Layer
- Link layer technologies
- Media access in shared environments
- Link layer addressing and differences to the upper layers
- Different media used for transmission of data
- Encoding of bits at the physical layer
- Current broadband technologies



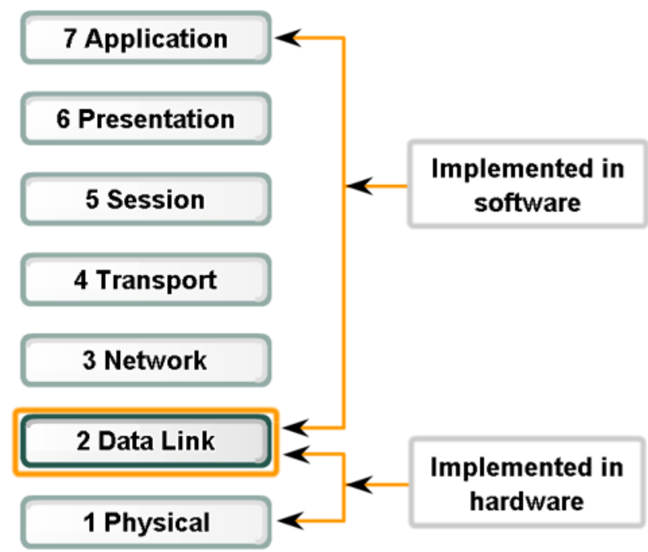
The Data Link Layer

- Remember, the upper layers (Network, Transport and Application) are responsible for end-to-end delivery of data
- Data must still traverse each link one hop at a time, which is the role of the Data Link Layer



The Data Link Layer (cont.)

- The link layer must control how data is transmitted over specific mediums, and must make accommodations for the medium
- Difficult to separate discussions of the link layer from the physical layer, so we will end up examining both concurrently



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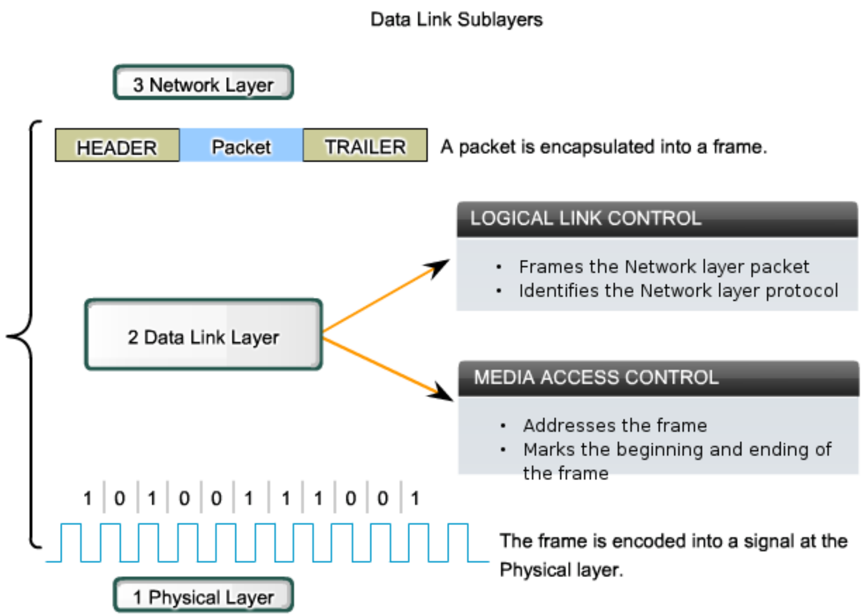
Data Link Sub-Layers

- Data link layer is divided into two sub layers known as Logical Link Control (LLC) and Media Access Control (MAC)
- LLC is the upper half of the link layer, which interacts with the network layer
- MAC is the lower half of the link layer, which interacts with the physical layer



Logical Link Control (LLC)

- LLC **encapsulates** network layer data in **frames**
- LLC informs the receiver which network layer protocol is being encapsulated
    - Most commonly IPv4 and IPv6

```
> Frame 6: 610 bytes on wire (4880 bits), 610 bytes captured (4880 bits)
v Ethernet II, Src: AsustekC_49:f1:55 (00:0e:a6:49:f1:55), Dst: Intel_e7:bc:21 (00:02:b3:e7:bc:21)
  > Destination: Intel_e7:bc:21 (00:02:b3:e7:bc:21)
  > Source: AsustekC_49:f1:55 (00:0e:a6:49:f1:55)
    Type: IPv4 (0x0800)
> Internet Protocol Version 4, Src: 136.186.229.138, Dst: 136.186.229.139
> Transmission Control Protocol, Src Port: 80, Dst Port: 58960, Seq: 1, Ack: 413, Len: 544
> Hypertext Transfer Protocol
> Line-based text data: text/html (13 lines)
```

Media Access Control (MAC)

- Handles most of the link layer functions
- Describes how frames should be formatted for transmission
- Governs **media access** and **addressing**

```
> Frame 6: 610 bytes on wire (4880 bits), 610 bytes captured (4880 bits)
v Ethernet II, Src: AsustekC_49:f1:55 (00:0e:a6:49:f1:55), Dst: Intel_e7:bc:21 (00:02:b3:e7:bc:21)
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> Transmission Control Protocol, Src Port: 80, Dst Port: 58960, Seq: 1, Ack: 413, Len: 544
> Hypertext Transfer Protocol
> Line-based text data: text/html (13 lines)
```
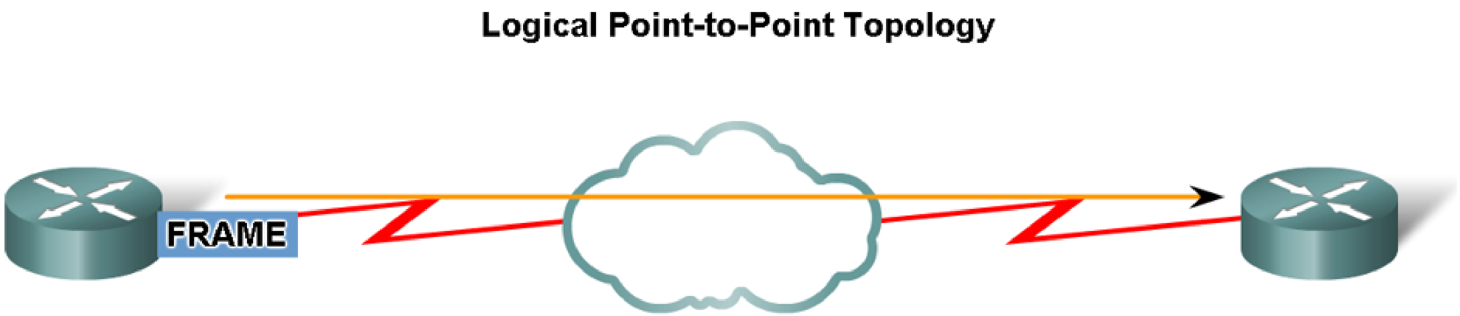

MAC sub-layer (Destination, Source)

LLC sub-layer (Type)

Link Types

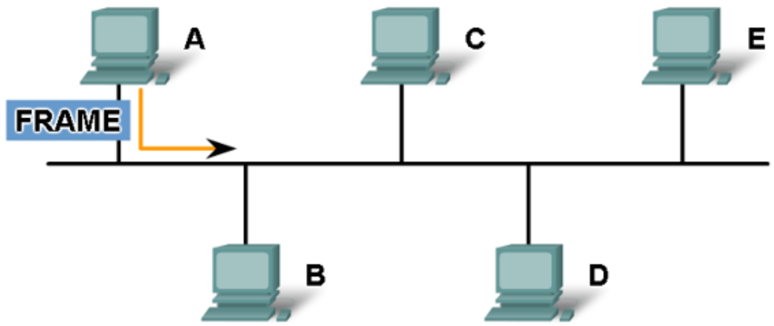
- Two major types of links you can expect to encounter: **Multi-Access** and **Point-to-Point**
- In Point-to-Point links, a frame only has one possible destination (the other ‘point’), making addressing redundant
- The same does not hold true for Multi-Access links, so hosts must be addressed



MAC Addressing

- In multi-access networks, a frame can have multiple possible destinations, so we need an addressing scheme
- The most common of these schemes is MAC addresses which consist of 48-bits
    - Used by Ethernet and WiFi
- MAC Addresses are typically unique, but are only significant within the local network
- **Example:** 12:34:56:78:9A:BC

Logical Multi-Access Topology



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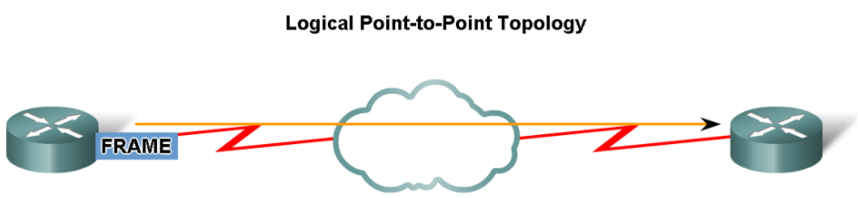
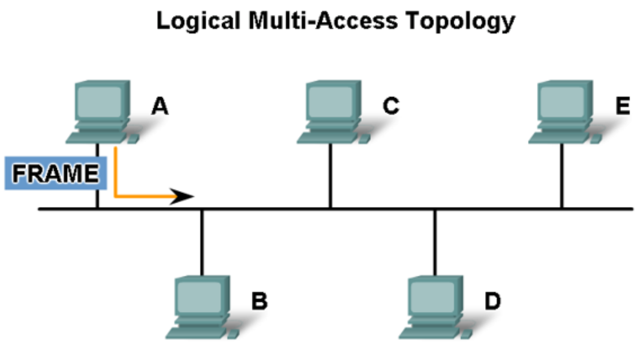
Media Access Control

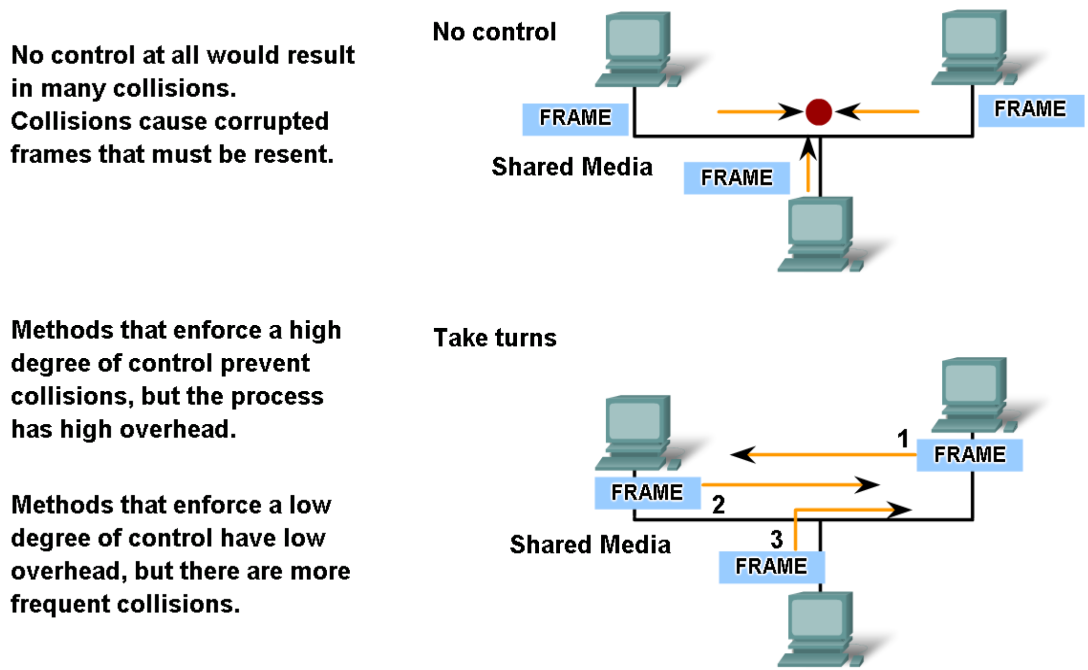
- In multi-access networks, devices must be careful about how and when they transmit - **avoiding collisions** is important
- Failure to do so can result in collisions, rendering the transmitted data unusable (and wasting available bandwidth)





Collisions

- Two devices transmitting at the same time causes a collision, requiring the message to be re-sent
- Similar to a conversation between two people; when two people speak at once, you can't understand either of them
- Transmitting devices must take turns, but how?



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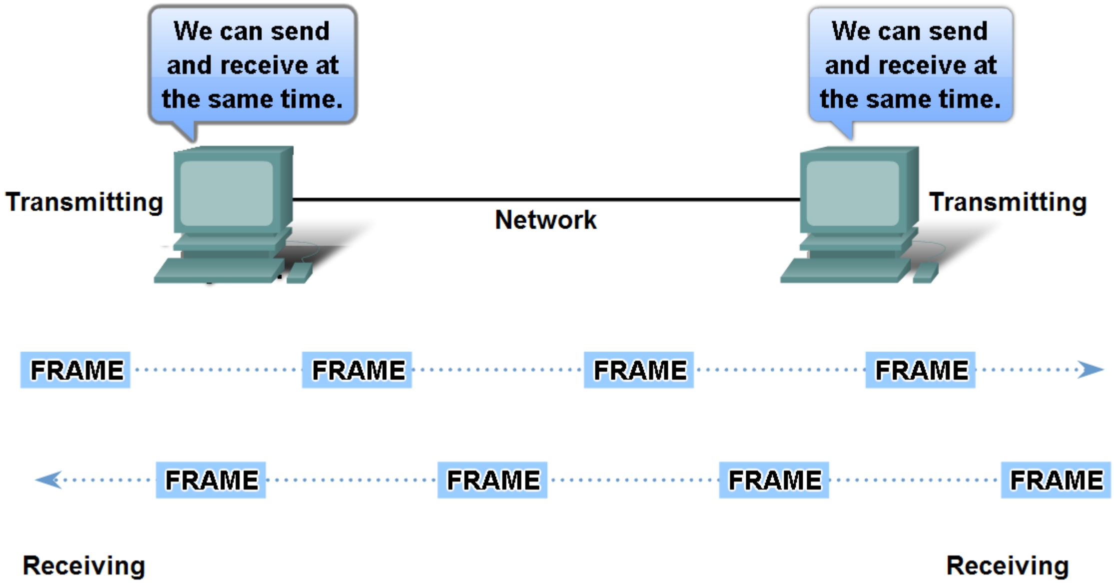
Duplexing

- Some communications media can only support transmission in a single direction at a time; this is known as **half-duplex**
- Half-duplex is especially common in wireless networks (WiFi, 3G) but some wired protocols (10Mbps Ethernet, Fibre) can also fall into this category
- **Full-duplex** can support simultaneous transmission in both directions, and is more common in wired networks (like modern Ethernet)



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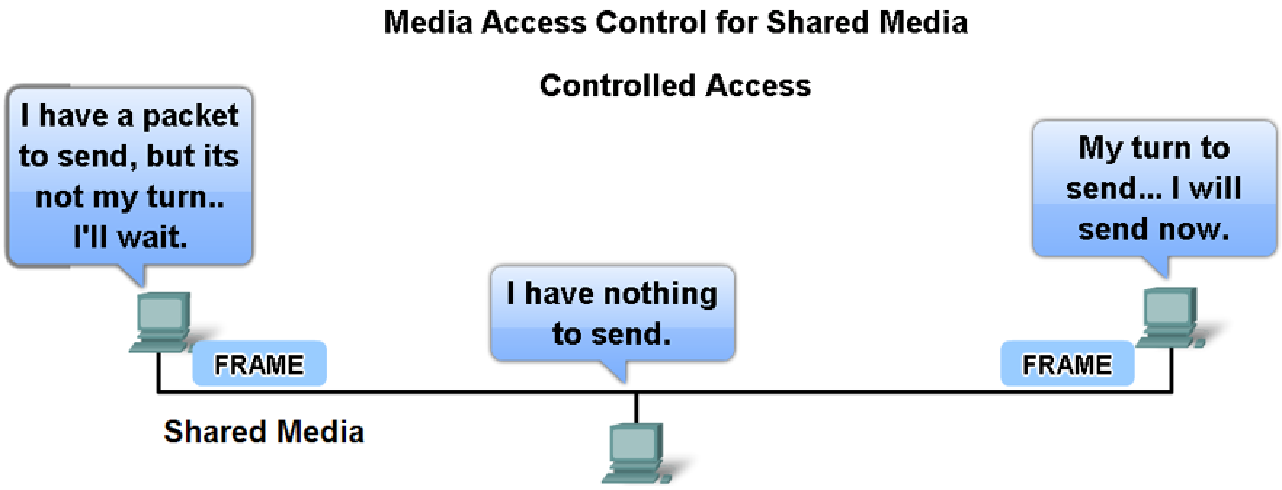
Approaches to MAC

There are two common approaches to controlling transmissions over a multi-access network:

- Controlled access
    - Token-based (Token Ring, FDDI)
    - Time Division Multiple Access (GPON, DOCSIS, 3G, HSDPA, LTE)
- Contention-based access
    - Carrier Sense Multiple Access (Ethernet / WiFi)

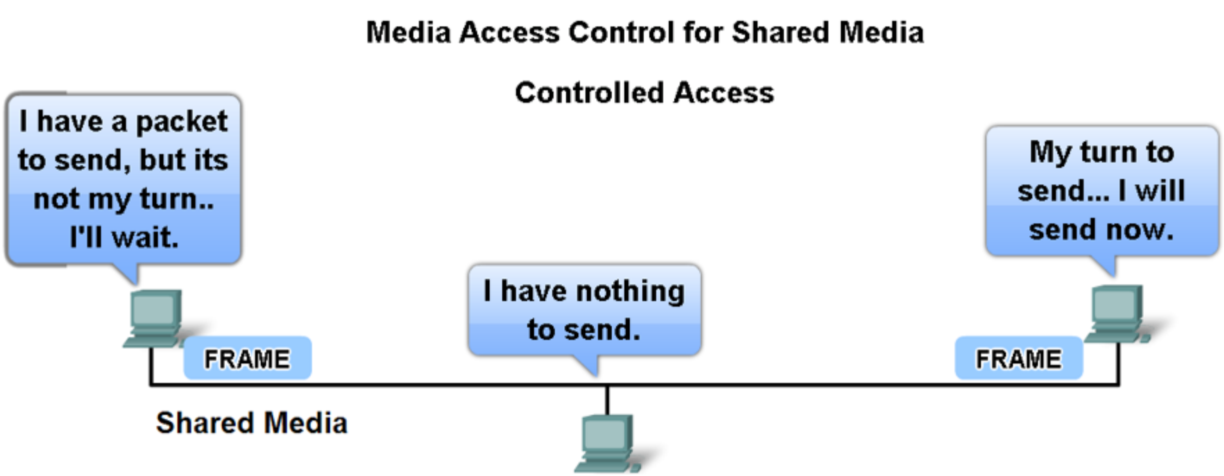
Controlled Access

- Controlled Access MAC avoids collisions entirely by ensuring that only one device can transmit at any given time
- This is usually achieved by having devices pass a **token** or sharing time slices
- Controlled Access can be viewed as fairer than Contention-based MAC as each device gets a predictable ‘turn’



Controlled Access – Token Ring

- Allows devices to transmit when they hold a token
- Devices pass the token around continuously the group
    - Devices with nothing to transmit simply pass the token along immediately
    - Receiving devices must wait until they hold the token before responding
- Fairer than the mechanism used by Ethernet, but no longer really used

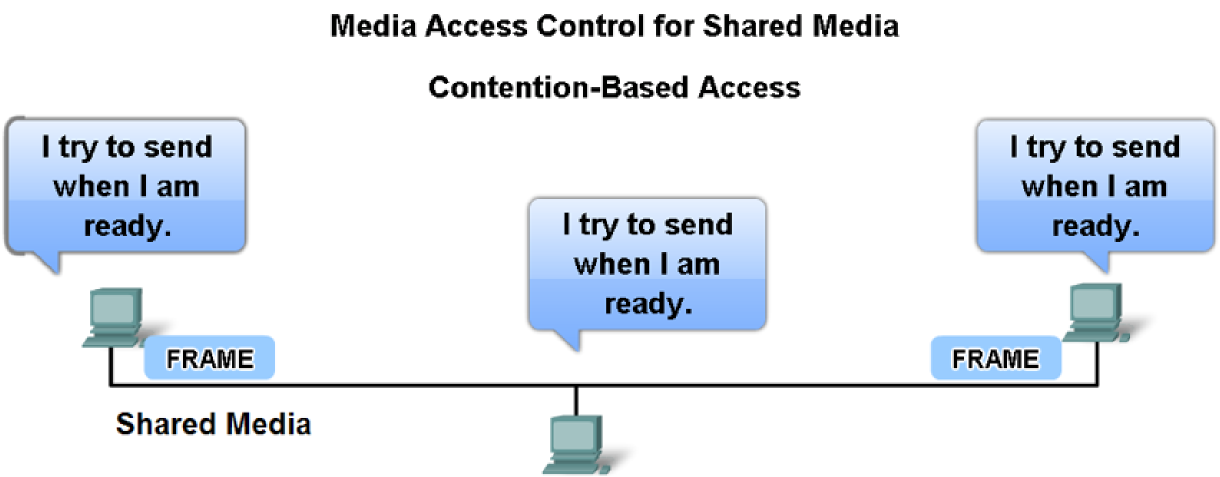


Controlled Access – Time Division Multiple Access

- Used when devices are further away from one another as time required to pass token is high
- Transmission time is divided into slots controlled by a central node
    - Allocation can be based on policies, demand, etc
- Used in mobile wireless networks (3G, HSDPA, LTE)

Contention-based Access

- In contention-based media access control, devices can transmit at (almost) any time
- Usually requires that devices listen for other transmissions before transmitting
- If a device hears an ongoing transmission, it should wait until that transmission is complete before transmitting

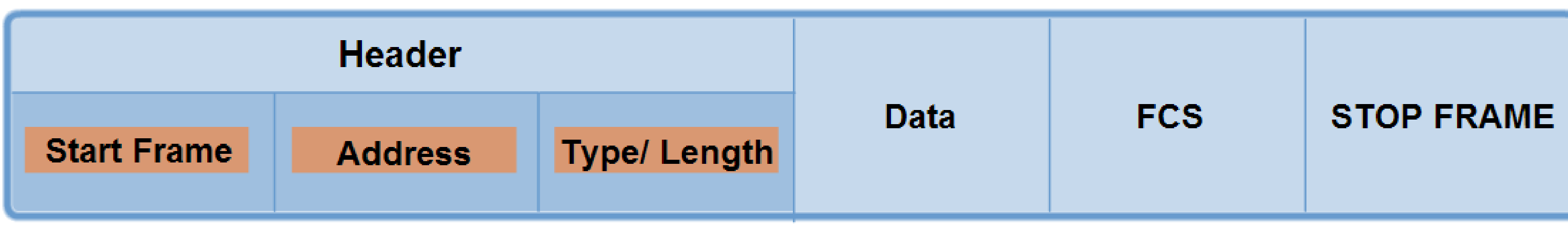


Contention-based Access – Carrier Sense Multiple Access

- Ethernet used CSMA/CD (Collision Detection) while CSMA/CA (Collision Avoidance) is used by WiFi
- Both variations follow the same basic principle discussed in the previous slide; major difference is in how they deal with collisions
- In CSMA/CD, devices will transmit a jamming signal when a collision occurs, forcing the devices to cease transmitting and wait for a short period of time (known as the **backoff period**)
- CSMA/CA is still used in WiFi (more on this in the Wireless Networks lecture)

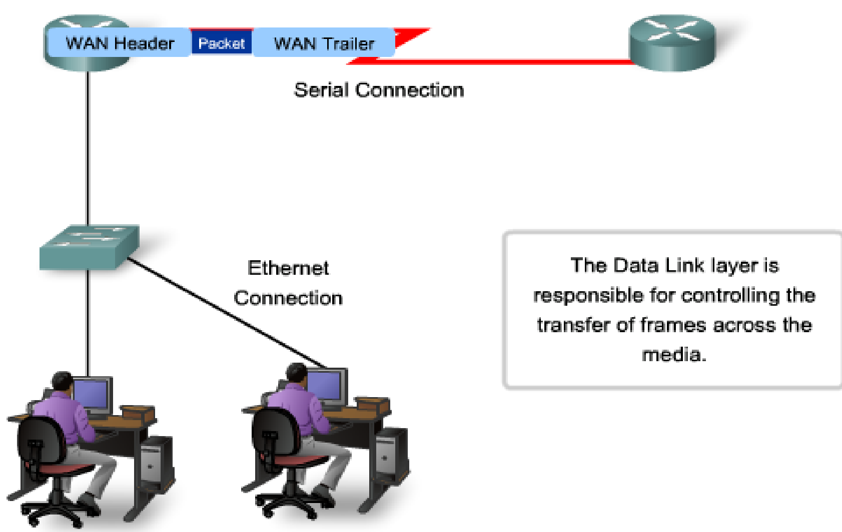
Link Layer Protocol Headers

- Link layer protocols share a number of common header fields, with variation based on other requirements:
  - Multi access vs. point-to-point
  - Reliability
  - Security (authentication, encryption)
- For example, not every protocol requires MAC addresses (this would be redundant for point-to-point technologies)



Link Layer Addressing

- Recall that the network and transport layers deal with end-to-end delivery of data
  - IP addresses and ports don't change
- Given differences between link layer protocol headers, this wouldn't be practical at the link layer
- Link layer headers and trailers are re-written at every hop



Break

When we return: Communications media and Link layer technologies

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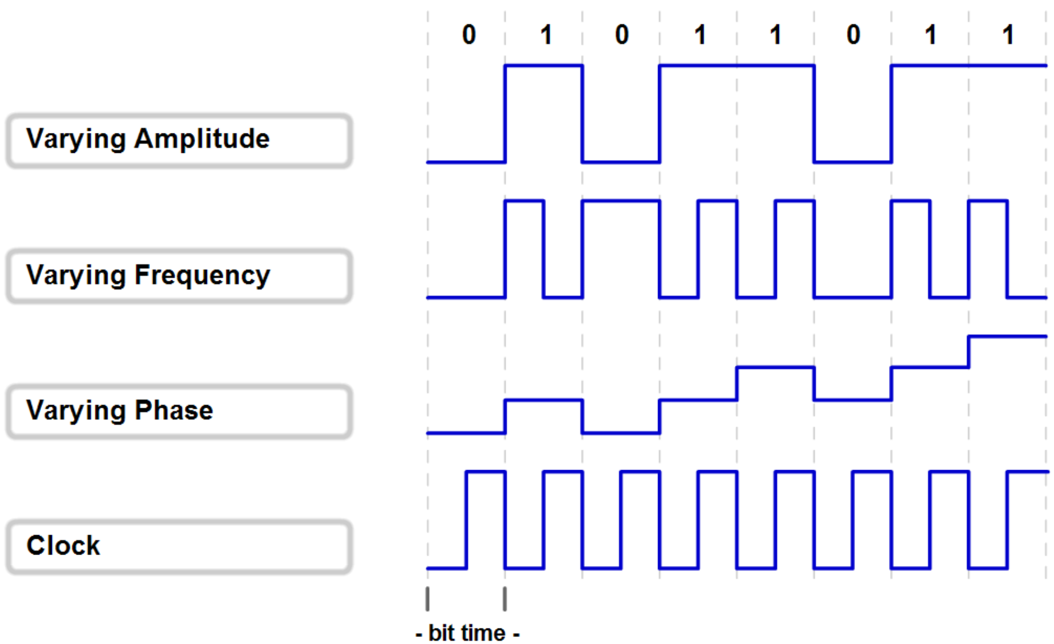
The Physical Layer

- Encodes binary bits (0s and 1s) into signals that can be carried across the physical medium
- Specifies the physical connectors and cables to be used

Encoding Techniques

- Bits can be encoded on the physical medium in different ways:
  - Amplitude
  - Frequency
  - Phase



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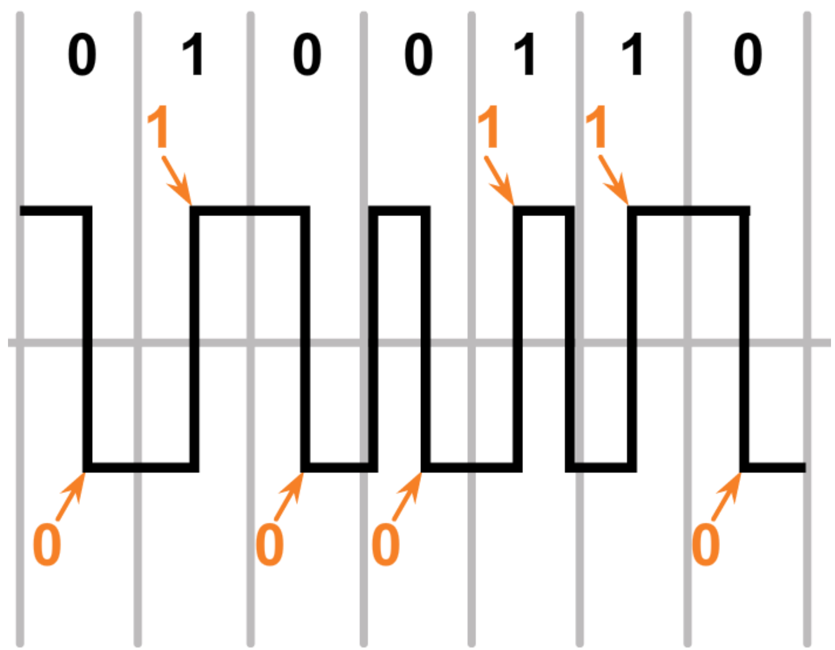
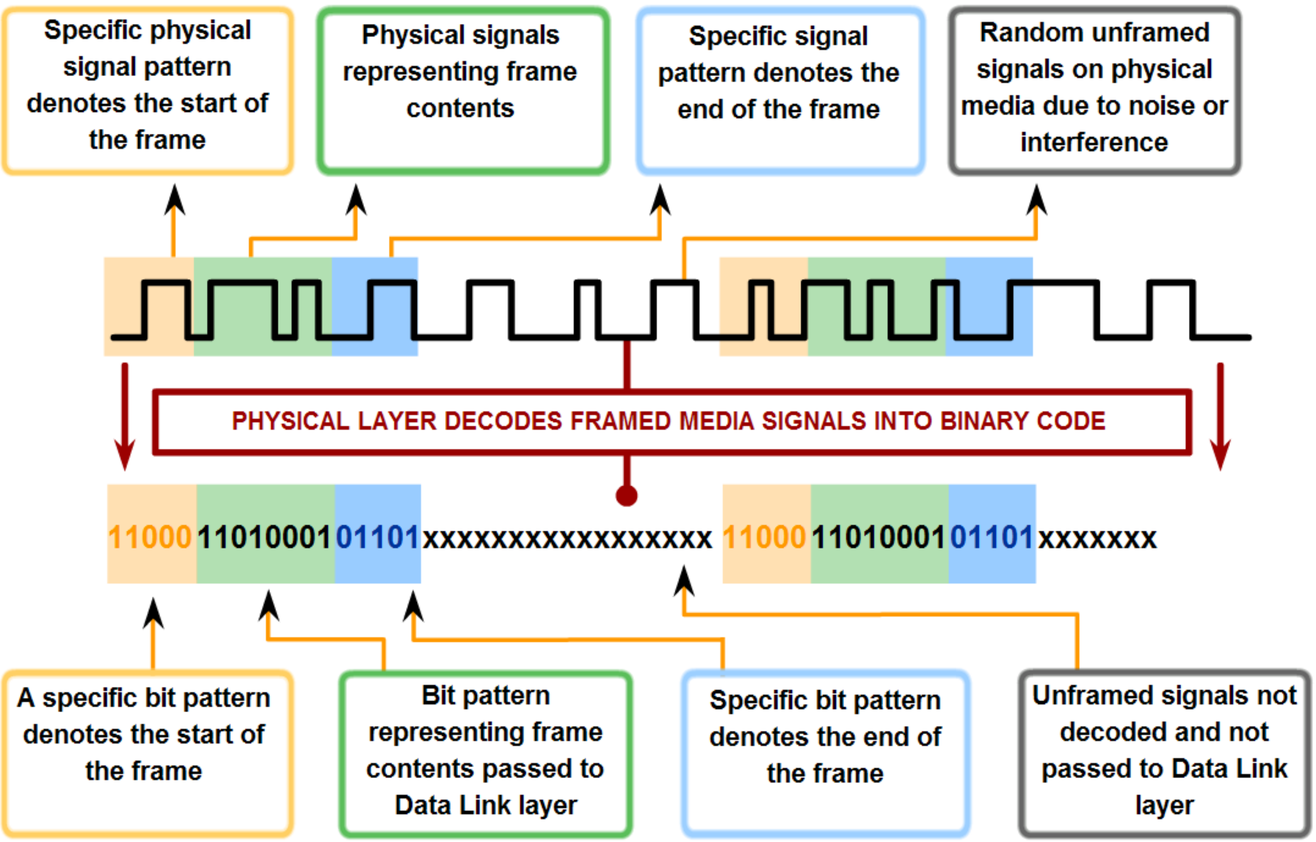
Encoding Techniques – Manchester Encoding

- A relatively simple encoding technique used by 10Mbps Ethernet
- Newer Ethernet standards use more complex techniques
- Bits encoded by frequency transition in middle of each period



Encoding Techniques – Demarcating Frames

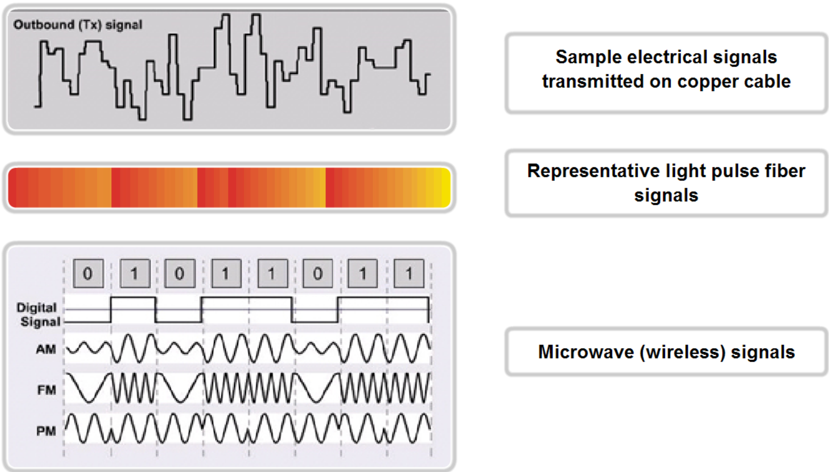
- Encoding techniques often use specific signal patterns to denote the start and end of a frame



Communications Media Revisited

- Remember that data communications can occur over different media
- The most common of which are copper, fibre optics and wireless
- The major difference is how data is represented on these media:
    - Copper – Electrical Signals
    - Fibre – Light Pulses
    - Wireless – Digital Signals

Representations of Signals on the Physical Media



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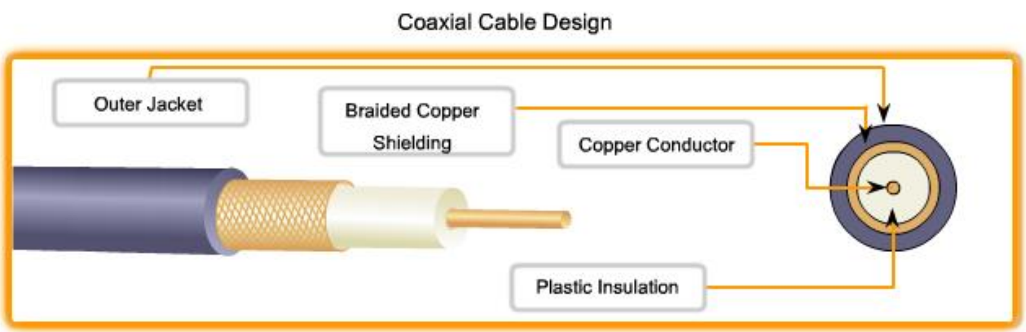
Communications Media – Coaxial Cable

- Copper cable traditionally used for TV networks, but can also be used to deliver broadband
- More commonly referred to as "Coax"
- Used for 10Base2 and 10Base5 Ethernet
- Performs poorly compared to twisted pair cabling



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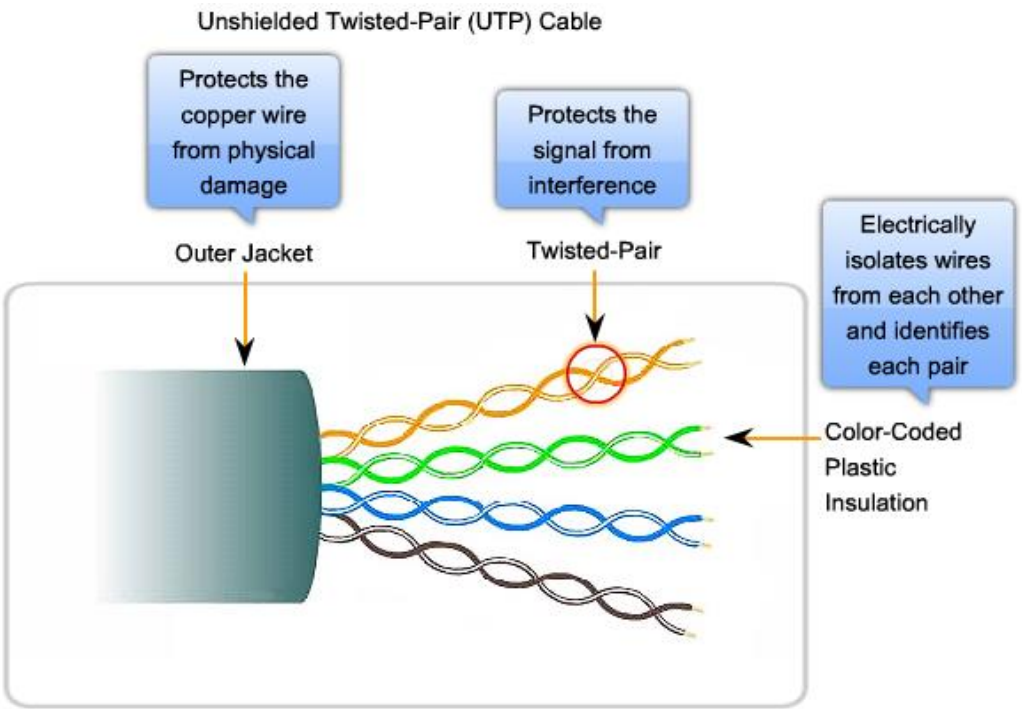
Communications Media – Twisted Pair

- Twists colour-coded pairs of copper wire to reduce the impact of interference



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Communications Media – Twisted Pair (cont.)

- Different categories of cables allow for different amounts of bandwidth:
  - Cat1: Previously used for voice telephone, ISDN, and doorbells
  - Cat2: Previously used for 4Mbps Token Ring
  - Cat3: Used for 10BaseT Ethernet
  - Cat4: Previous used for 16Mbps Token Ring
  - Cat5: Used for 100BASE-T Ethernet
  - Cat5e: Used for 1000BASE-T Ethernet
  - Cat6: Used for 1000BASE-T and 10GBase-T Ethernet
  - Cat6a: Used for 10GBase-T Ethernet

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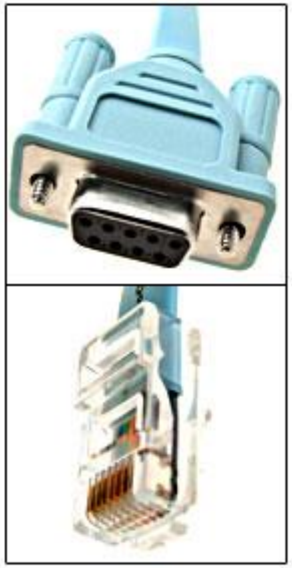
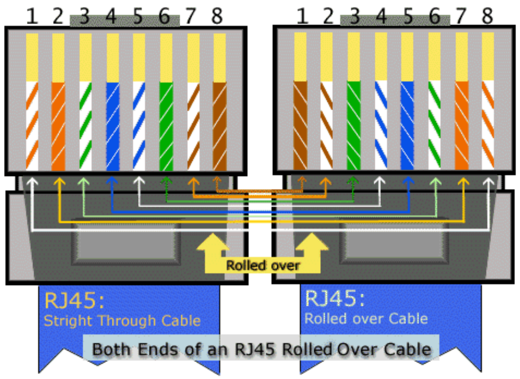
Communications Media – Serial Cable

- Copper cable typically used between a router and ISP as a WAN link
- Can be used for a variety of WAN technologies including ISDN, Frame Relay, ATM, Ethernet over Fibre

Communications Media – Rollover Cable

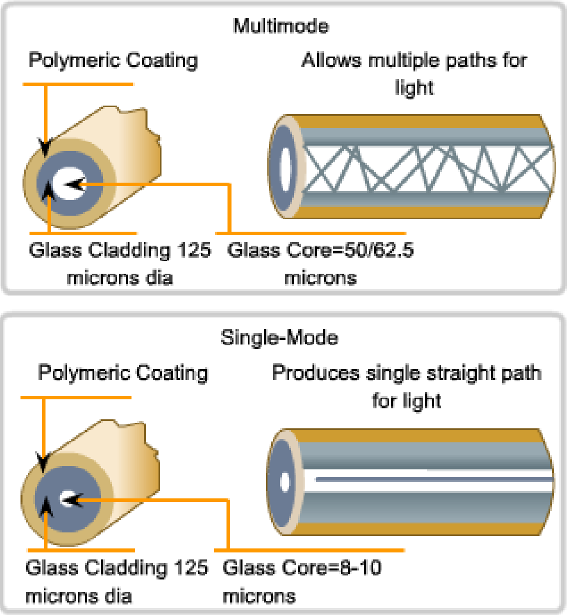
- Copper cable, also known as console cables
- Different pin configuration to Cat5, also lacks twisting for noise reduction
- Used for configuring network equipment (routers and switches)





Communications Media – Fibre

- Fibre Optic cable that uses lasers to transmit light along the fibre strand
- Single Mode Fibre
  - Core so small that light goes through in straight path, typically Laser as light source
  - More expensive to produce but it offers better performance
  - Use multiple concurrent colours / frequencies: Wavelength Division Multiplexing (WDM)
- Multi Mode Fibre
  - Larger core allows multiple paths for light, typically LEDs as light source
  - Cheaper but higher loss due to higher dispersion



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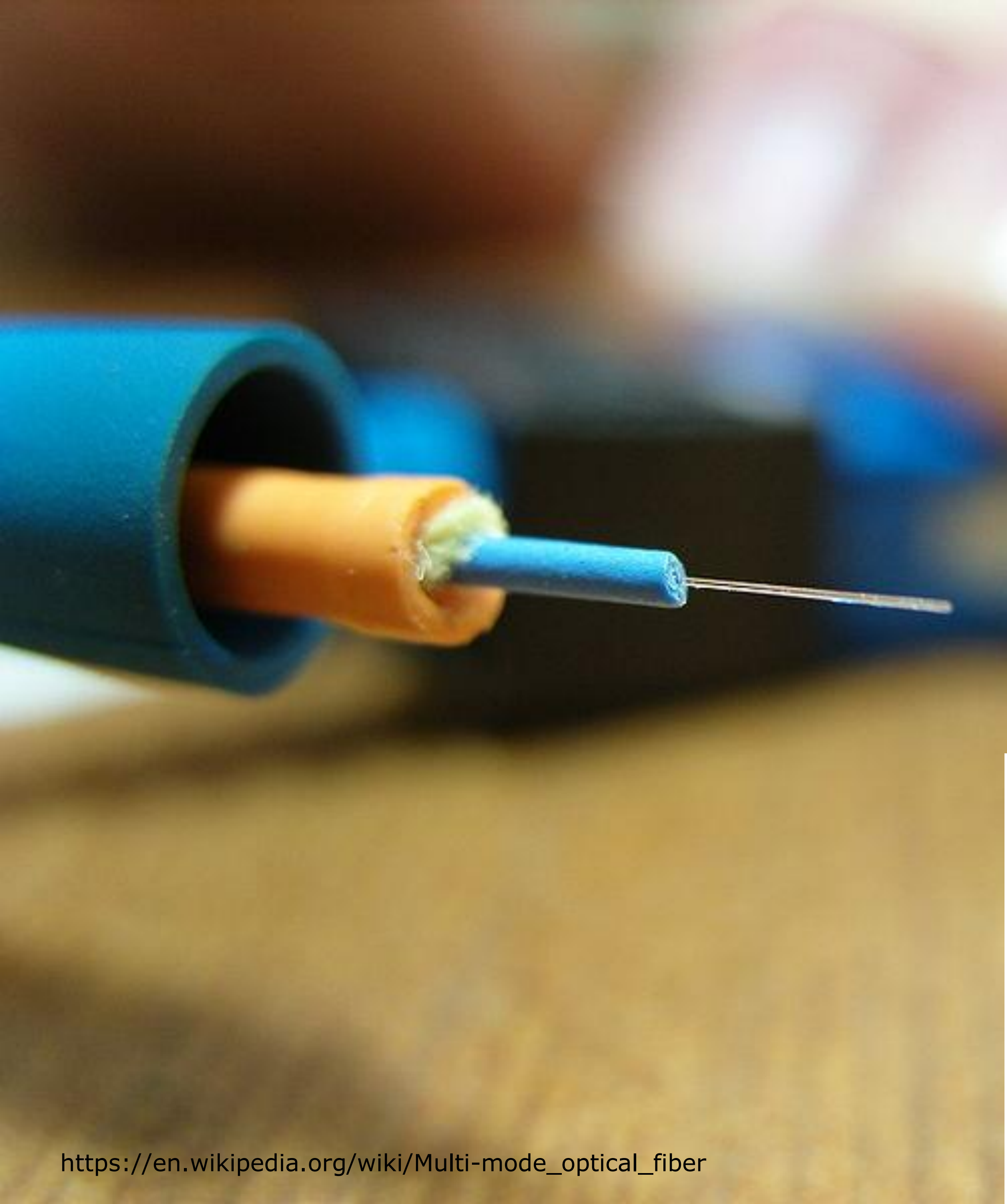
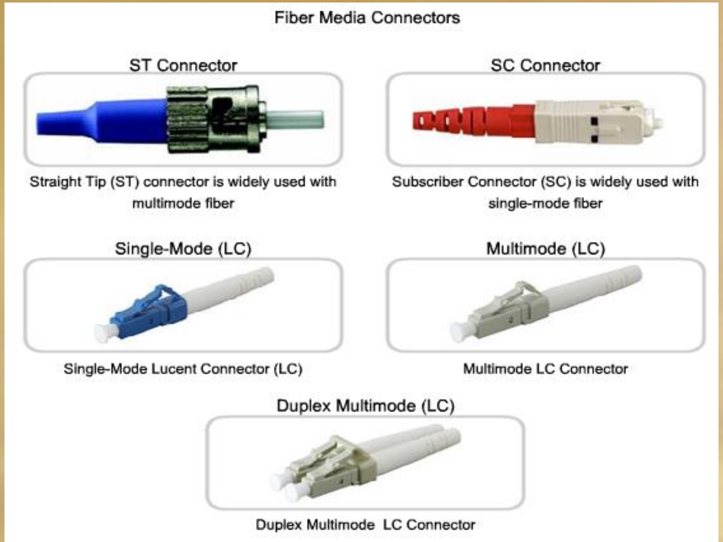
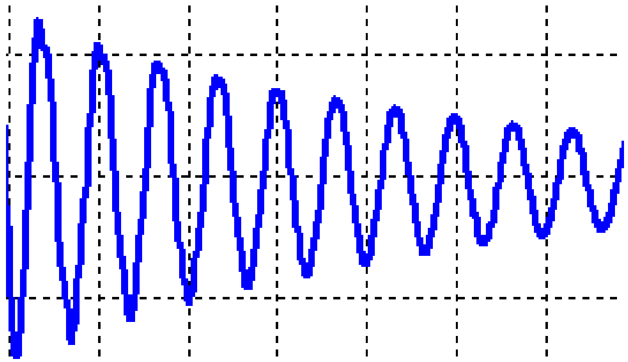




https://en.wikipedia.org/wiki/Multi-mode_optical_fiber

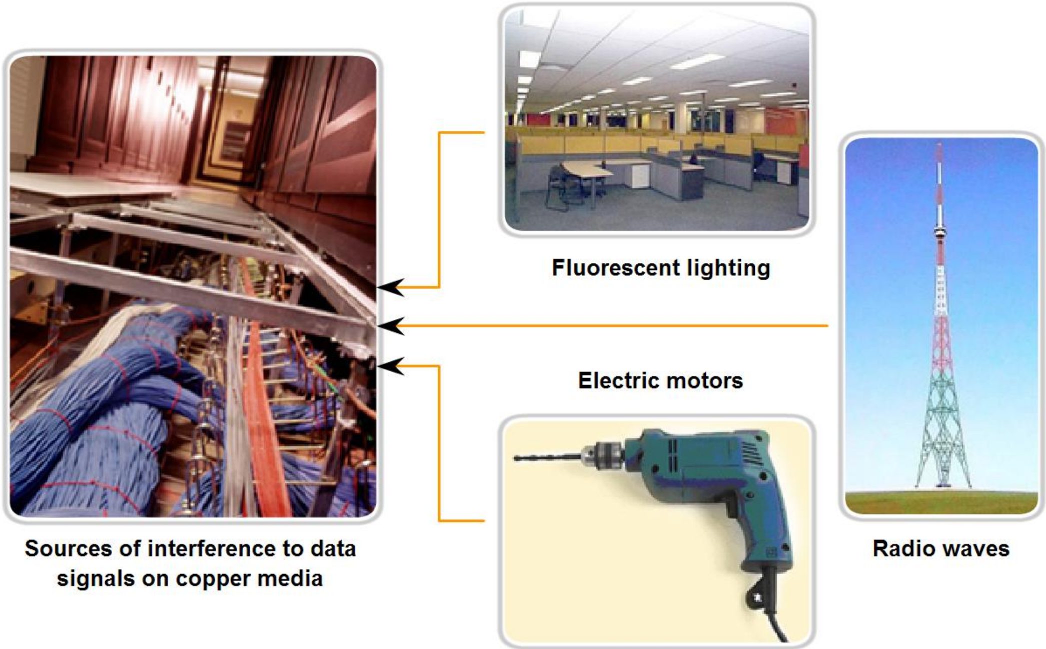
Attenuation

- Signals in all media attenuate with distance
  - LAN speeds (e.g. Ethernet) are always going to be faster than WAN speeds (e.g. ADSL)
  - Ethernet has maximum distance of 100m and must run on Cat5 cable or better while ADSL must work over many kilometers using 40 year old telephone cable
- Attenuation also depends on medium
  - Highest for wireless, followed by copper, followed by fibre
- Attenuation also depends on frequency
  - Higher for higher frequencies



Interference

- Interference is noise introduced into signal on medium by external factors
- Can cause errors in transmission; may render data unreadable
- For example, electromagnetic interference (EMI)



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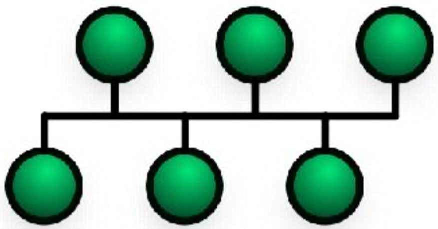
10Base2 and 10Base5 Ethernet

- Uses coaxial cable in a bus topology
- Theoretical maximum speed of 10Mbps
- Requires less cable to support the bus topology; new devices join on to the main cable
- Requires use of CSMA/CD
- Coaxial cable is difficult to route



http://en.wikipedia.org/wiki/Bus_network

http://en.wikipedia.org/wiki/10BASE2

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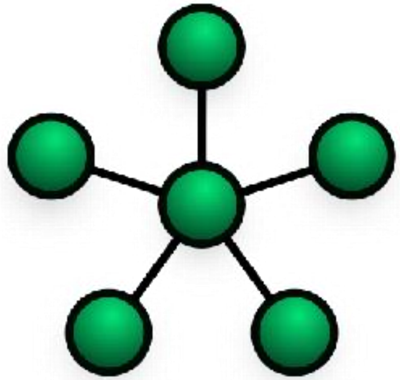
10BaseT Ethernet

- Uses twisted pair cables in a physical star topology
- Requires hubs or switches to connect devices
- Every transmission is sent to the hub or switch
- Hubs would then broadcast the transmission to devices connected to all other ports
- Switches forwards the transmission on to the intended destination only; no collisions



http://en.wikipedia.org/wiki/Star_network

http://en.wikipedia.org/wiki/Category_5_cable

Token Ring

- Cabled in a star topology, but uses a logical ring topology
- Supports speeds of 4Mbps – 16Mbps
- Hosts will pass a ‘token’ that allows them to transmit
- Early versions used coaxial cable, but twisted pair became available later

http://upload.wikimedia.org/wikipedia/commons/0/0d/Ibm_8228_mau.jpg

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802.3 Ethernet

- Typically uses Unshielded Twisted Pair (UTP) cable in a star topology
- Commonly supports speeds of 100Mbps (100BaseTX) and 1Gbps (1000BaseT) using Cat5e
- More recently, 2.5Gbps (2.5GBASE-T) over Cat5e and 5Gbps (5GBASE-T) over Cat6 standardised
- Higher speed variants exist for 10Gbps (using Cat6a) and 40Gbps or 100Gbps (fibre-based)

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802.11 (WiFi)

- Uses radio frequency (usually) with a wireless access point in a physical star topology
- Can also be used in a peer-to-peer architecture, which becomes a mesh network
- Supports speeds of 11Mbps – 2167Mbps
- Popular due to the convenience provided; hosts can now be moved at will as long as there is an access point within range

https://en.wikipedia.org/wiki/Wi-Fi

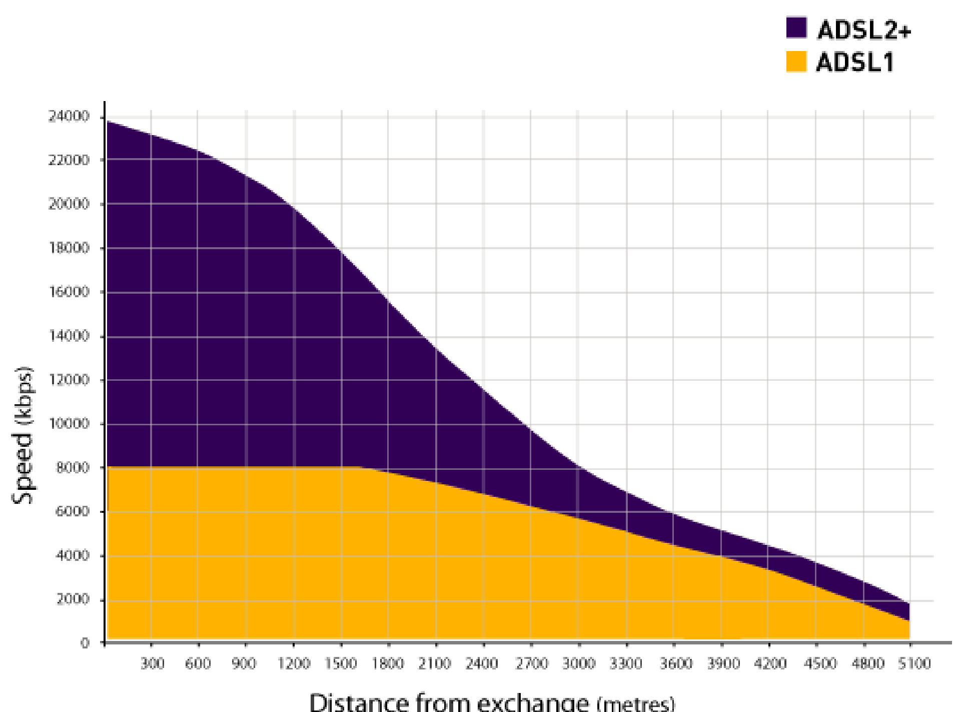
Asymmetric Digital Subscriber Line (ADSL)

- Common Internet connection option that uses physical star topology
- Uses DSL concentrators known as DSLAMs
- Modern ADSL typically supports speeds between 1.5Mbps and 24Mbps (depending on distance to DSLAM)
- Upload speed will usually be significantly slower than download
- Uses existing telephone cabling

https://en.wikipedia.org/wiki/Digital_subscriber_line

Asymmetric Digital Subscriber Line (cont.)

- Depending on cable quality distances between house and DSLAM can be up to 4 – 8 kms
- The closer DSLAM is, the less copper cable, therefore attenuation is reduced and higher speeds are possible
- Usually have a fibre connection from DSLAM to ISP



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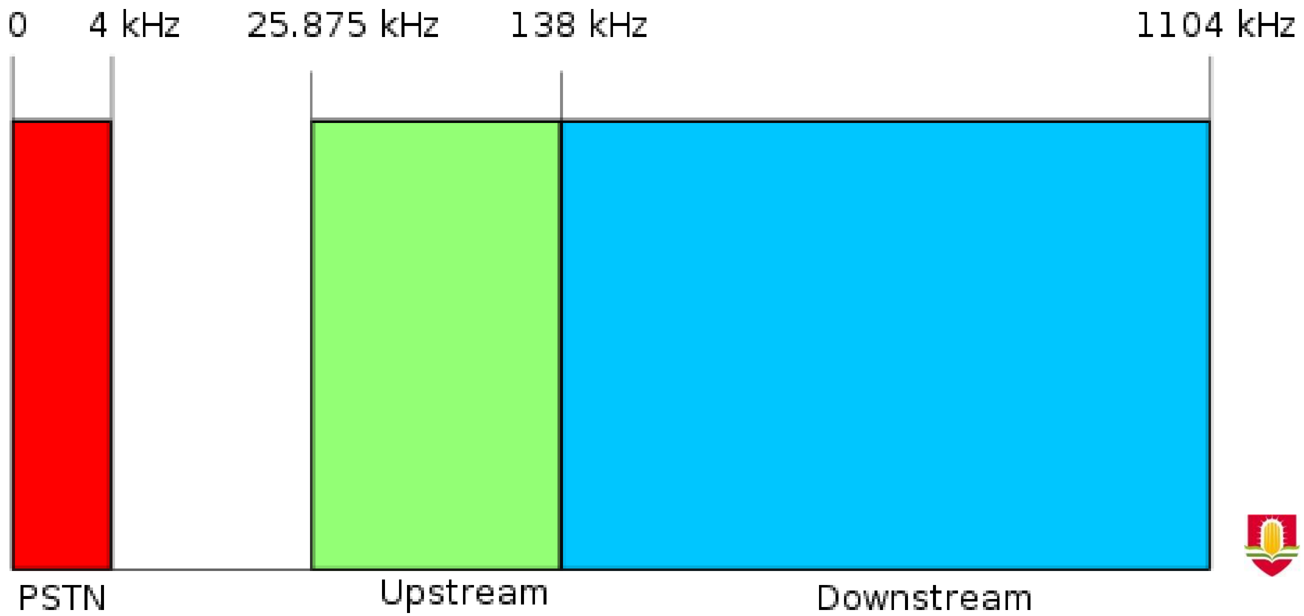
Asymmetric Digital Subscriber Line (cont.)

- Telephone services can continue to work simultaneously over Public Switched Telephone Network (PSTN)
- Most ADSL is full duplex - can send and receive at same time
- Copper medium is shared using Frequency Division Duplexing (FDD)



Very High Bit-rate DSL (VDSL)

- To implement VDSL, there must be less than 1km of copper cable, which significantly reduces attenuation; otherwise ADSL speeds
- VDSL2 degrades slower
- Wider and higher range of frequencies can be used in VDSL due to the reduced attenuation
- Used in many countries in the world already

Version	Standard name	Common name	Downstream rate	Upstream rate	Approved in
VDSL	ITU G.993.1	VDSL	55 Mbit/s	3Mbit/s	2004-06-13
VDSL	ITU G.993.2	VDSL2	100 Mbit/s	100 Mbit/s	2006-02-17

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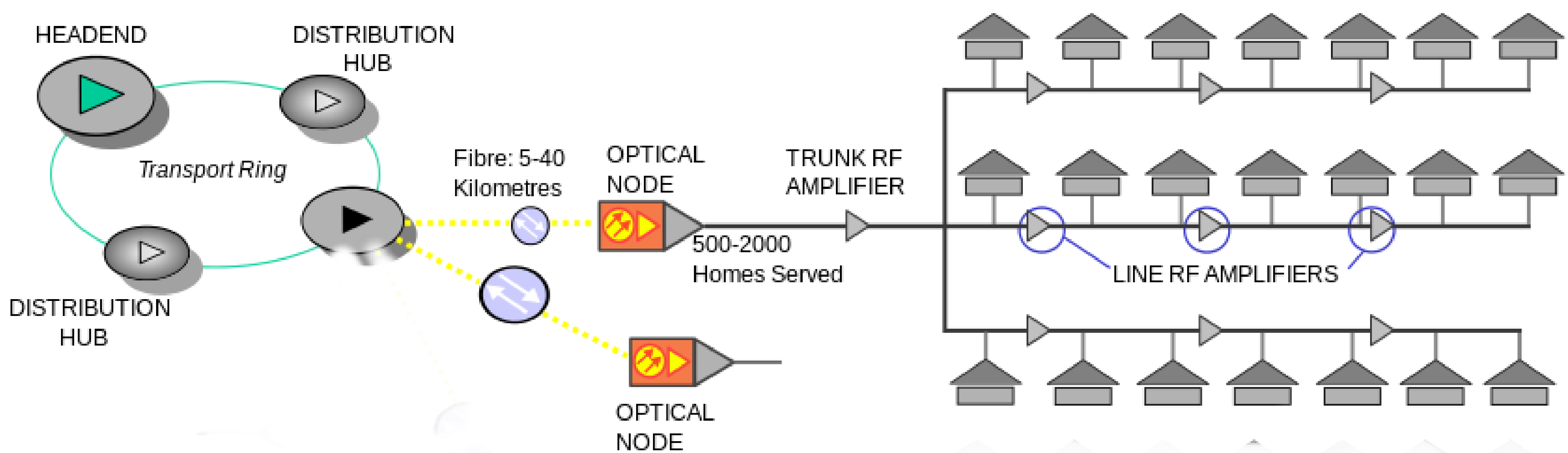
Data Over Cable Service Interface Specification (DOCSIS)

- Uses coaxial cable in a physical bus topology to deliver Internet connectivity
- Cable modem termination system (CMTS) at headend controls bus and acts as gateway
- Uses TDMA for media access

https://en.wikipedia.org/wiki/Cable_modem

Data Over Cable Service Interface Specification (cont.)

- Popular in countries where coaxial cable was already deployed for Cable TV
- Fibre is used to get closer to houses, so we have part-fibre part-coaxial networks referred to as **Hybrid Fibre Coax (HFC)**
- Less copper and fewer users sharing copper segment increases speeds



Data Over Cable Service Interface Specification (cont.)

- DOCSIS is shared medium so speeds can be higher when network is underutilised and slower when network is heavily utilised
- Just like ADSL, better speeds can be obtained by moving fibre closer to users
- Actual throughput also increased by having fewer users on each shared segment

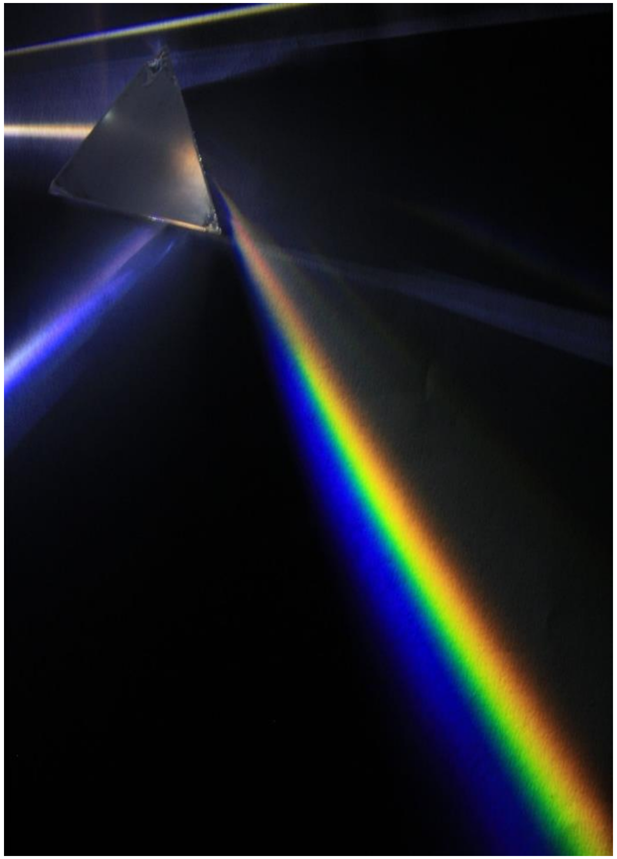
	UPSTREAM	Raw Bitrate	DOWNSTREAM	Raw Bitrate
DOCSIS 1.0 and 1.1	200 - 3200 kHz, QPSK or 16QAM	0.4 - 13 Mbps	QAM64 or QAM256	36 or 43 Mbps
DOCSIS 2.0	200 - 6400 kHz, QPSK - 128QAM	0.4 - 36 Mbps	QAM64 or QAM256	36 or 43 Mbps
DOCSIS 3.0	n * 200 - 6400 kHz, QPSK - 128QAM	max n * 36 Mbps	n * QAM64 or QAM256	36 to 172 Mbps (with 4 channels)

Direct / Point-to-Point Fibre

- Fibre is connected directly into premises all the way from main exchange
- Connection is one-to-one, with two fibres to every site (for uplink and downlink)
- Fibre has the lowest rate of attenuation, so very high speed is possible
    - Depends on provider offerings
- Very costly; only used for business areas

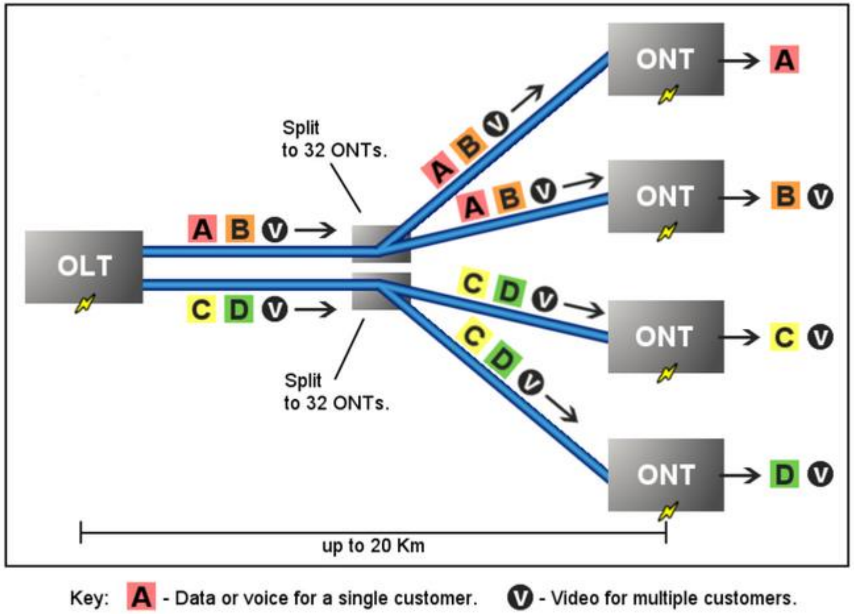
Gigabit Passive Optical Network (GPON)

- Connects one fibre to small street unit, which then splits light out to single fibres connected to homes
- WDM multiplexes up and downstream on single fibre
    - Connecting up to 32 or 64 premises
- GPON minimises fibre and electronics used (reduces cost)
- GPON simplifies deployment by using passive street-side splitters



Gigabit Passive Optical Network (cont.)

- Downstream signals are broadcast to all premises
- Upstream shared based on Time Division Multiple Access (TDMA)
- Encryption is used to prevent eavesdropping



Lecture Objectives

You should now be able to:

- Describe the role of the Data Link layer
- Discuss the division of Data Link layer functions between Logical Link Control (LLC) and Media Access Control (MAC)
- Describe the difference between Point-to-Point and Multi-Access links
- Describe the role of MAC addressing in data communications
- Describe data link layer protocols
- Differentiate between different approaches to MAC
- Describe the purpose of the physical layer
- Identify different forms of physical media
- Describe the effects of attenuation and interference

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Lecture Summary and the Week Ahead

- Today's lecture has completed our look at the OSI model layers by examining the roles of the Data Link and Physical layers
- We also discussed prominent layer 1 and 2 protocols
- The readings for this week are Introduction to Networks – Chapters 4 and 5
- In the labs: configuring Cisco networking devices

Next Week

- We’ve completed our look at the OSI model, so we move on to specific technologies
- Start with Ethernet; a very prominent link layer technology
    - Ethernet addressing and cabling
    - Switching and switch operation
    - Address Resolution Protocol
    - Virtual LANs
- Make sure you start preparing for the Mid-Semester Test!