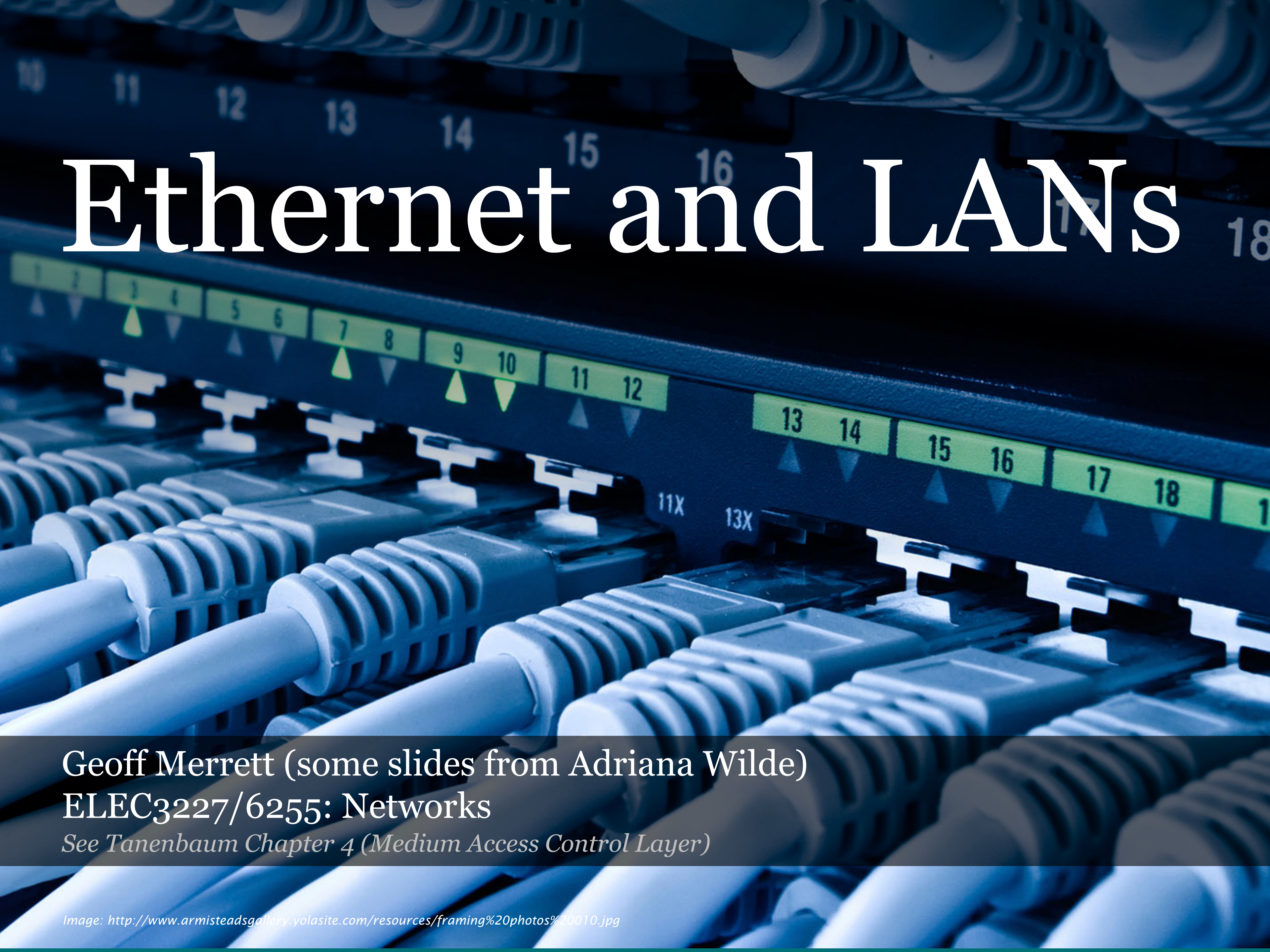
Ethernet and LANs

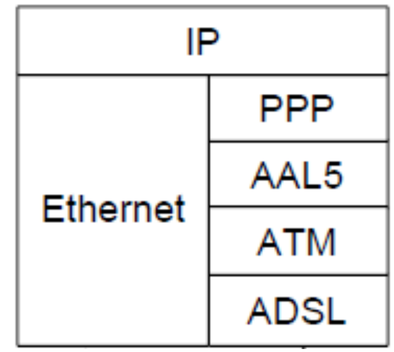


Geoff Merrett (some slides from Adriana Wilde)
ELEC3227/6255: Networks
See Tanenbaum Chapter 4 (Medium Access Control Layer)

Image: http://www.armisteadsgallery.yolasite.com/resources/framing%20photos%20010.jpg

Outline

- Ethernet
  - Classic Ethernet
  - Switched Ethernet
  - Fast Ethernet
  - Gigabit Ethernet
  - (10 Gigabit Ethernet)
  - (40/100 Gigabit Ethernet)
- LANs
  - Repeaters, hubs, bridges/sw
  - Spanning trees
  - 802.1Q and VLANs
- Wireless LANs



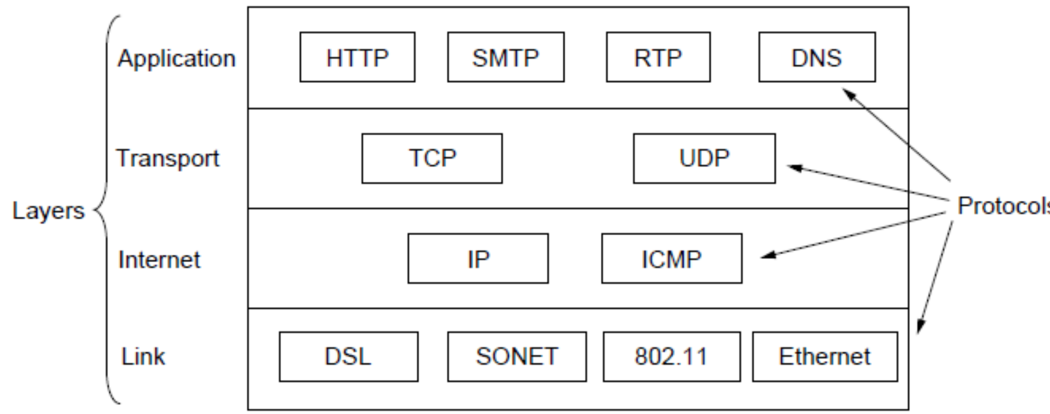


Image: CN5E by Tanenbaum & Wetherall, © Pearson Education-Prentice Hall and D. Wetherall, 2011

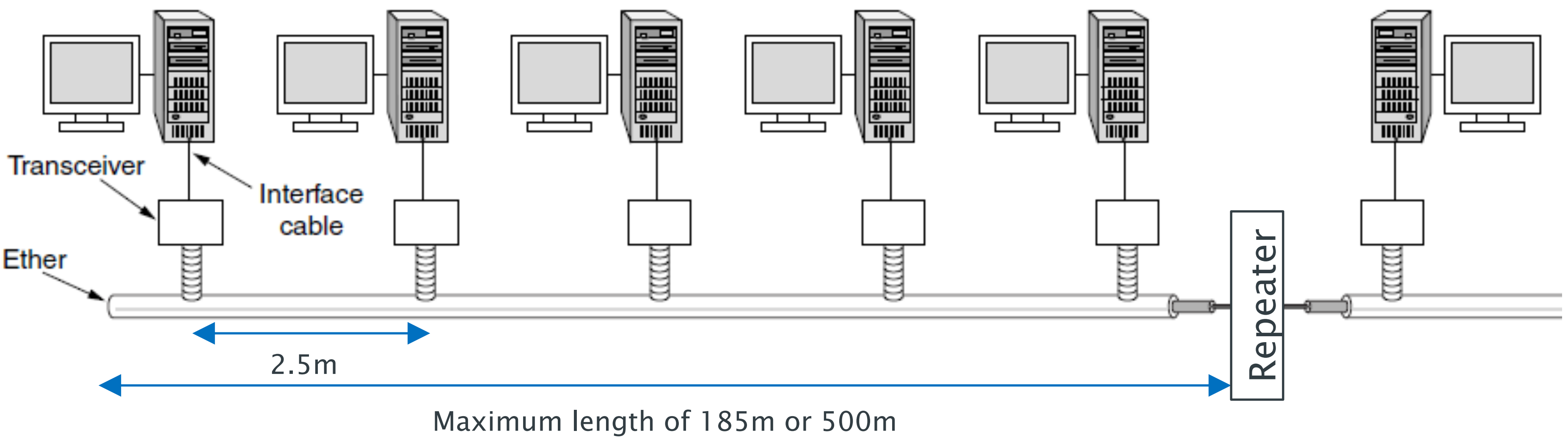
Ethernet/IEEE 802.3

- Used for Local Area Networks (LANs)
  - ECS has ~3000 wired Ethernet points
  - Multiple Ethernet LANs connected via IP routers
  - Connects to the University's ISP (JANET)

- Classic Ethernet
  - Historical (3-10 Mbps)
- Switched Ethernet
  - Widely used (100, 1000, 10000 Mbps)

Classic Ethernet

- Bus architecture – terminals 'tapped into' a single coaxial cable (the '*ether*')
- Maximum length of a single cable (due to signal attenuation)
- Repeaters amplify the signal, allowing longer cables to be used



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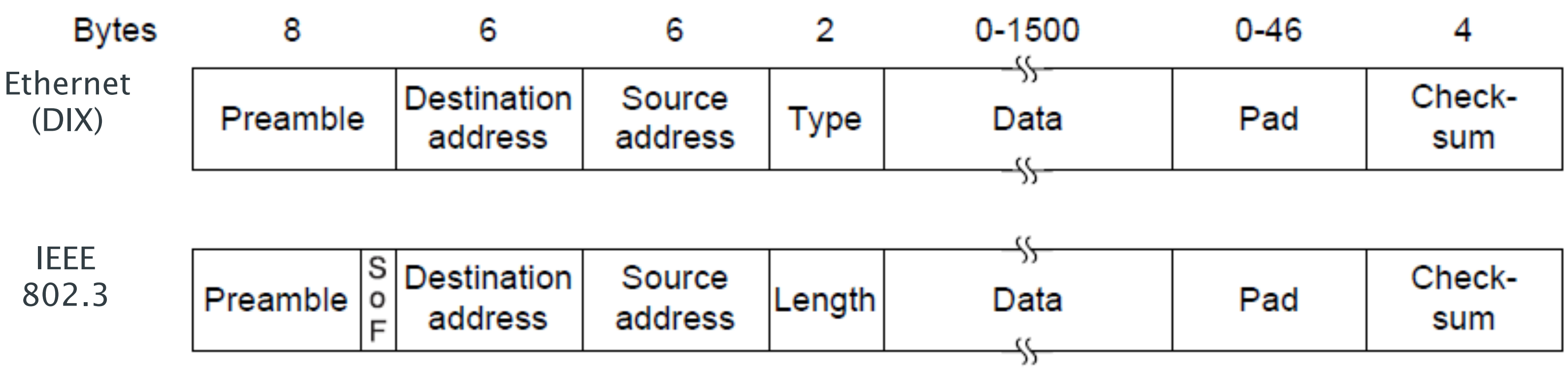
Frame Format

Ethernet / IEEE 802.3

Ethernet Frame Format

- IEEE standardised Ethernet as IEEE 802.3 (with a few tweaks)



- Uses Manchester encoding

- Frame format hasn't really changed with evolution of Ethernet – still pretty much the same today.

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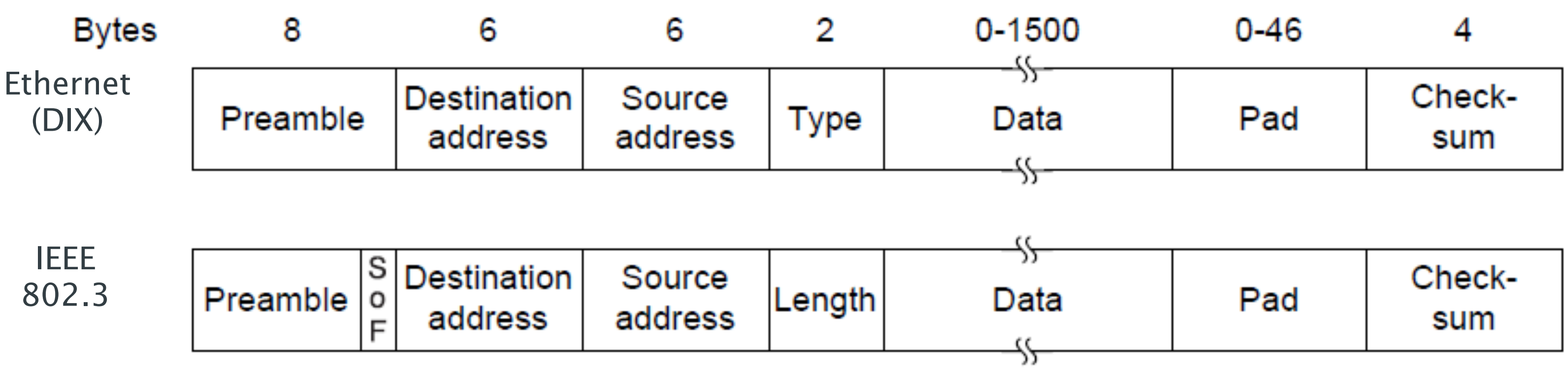
Ethernet Frame Format: Preamble

- 8 bytes



- First seven bytes = 10101010_2
- Eighth byte = 10101011_2 (802.3 refers to it as the start of frame delimiter, and indicates that the frame is about to begin)
- With Manchester encoding and 10Mbps, this creates a 10 MHz square wave for 6.4 us, allowing the receiver to synchronise with the transmitter.

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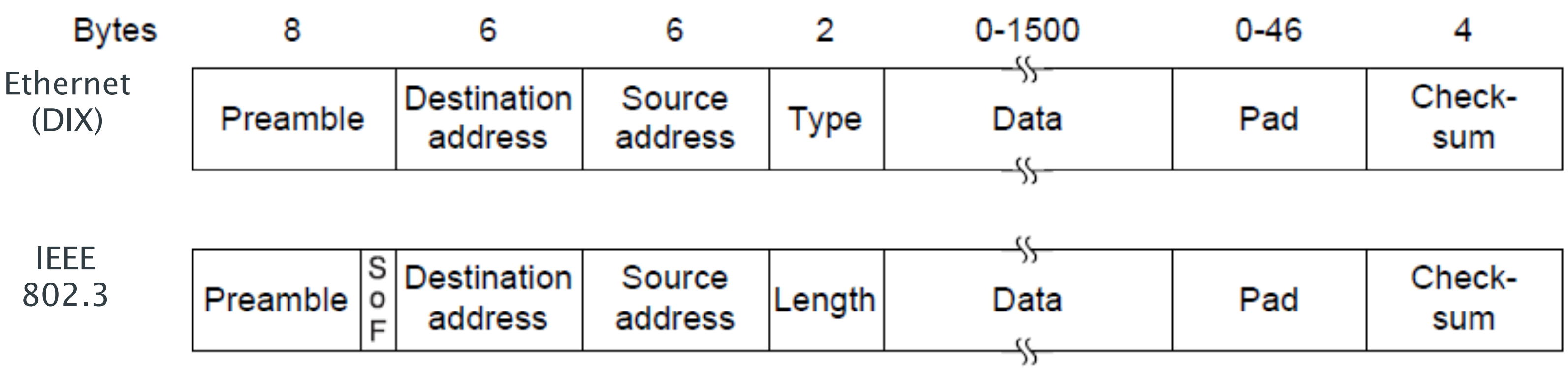
Ethernet Frame Format: Addresses

- 6 bytes (destination address) + 6 bytes (source address)

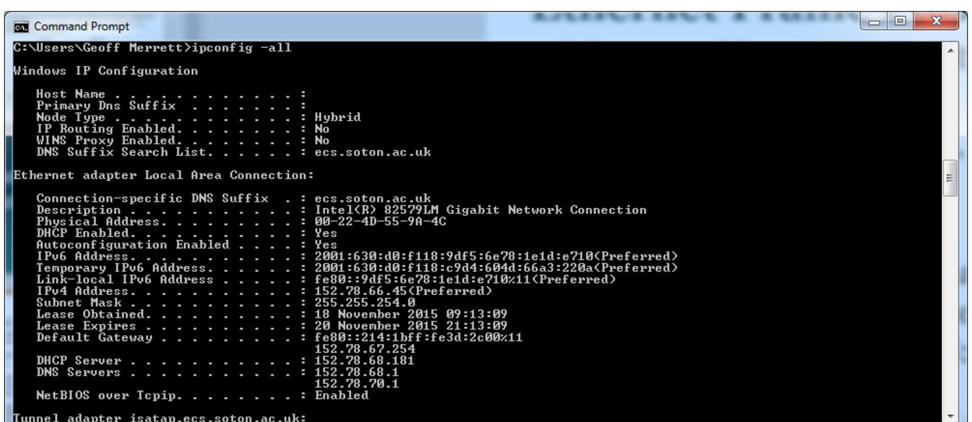


- Needed as, unlike PPP, Ethernet is not a point-to-point link (there can be multiple terminals on the network.
- Usually referred to as Level 2 or MAC (Media Access Control Layer) addresses

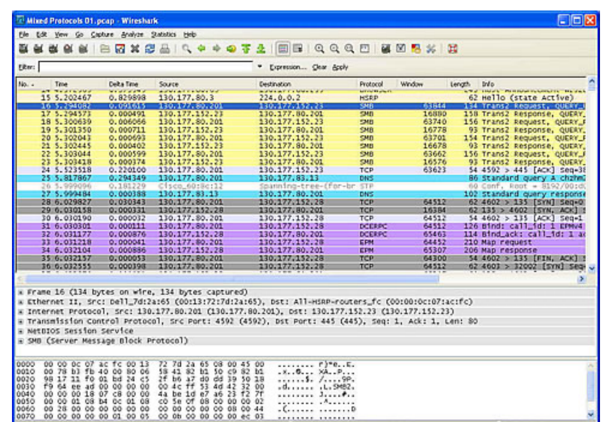
Image: CN5E by Tanenbaum & Wetherall, © Pearson Education-Prentice Hall and D. Wetherall, 2011

Ethernet Frame Format: Addresses

- 6-byte address is usually quoted as a series of 12 hexadecimal characters, with bytes separated by colons
  - E.g. `00-22-4D-55-9A-4F`
- Built into the hardware at manufacture, and are unique (assigned by IEEE)
  - `MM:MM:MM:SS:SS:SS` (`MM:MM:MM` is the OUI [manufacturer ID], `SS:SS:SS` is the board serial number)
- `FF:FF:FF:FF:FF:FF` is a special address, inferring a broadcast transmission (i.e. will be received by all nodes in the network)

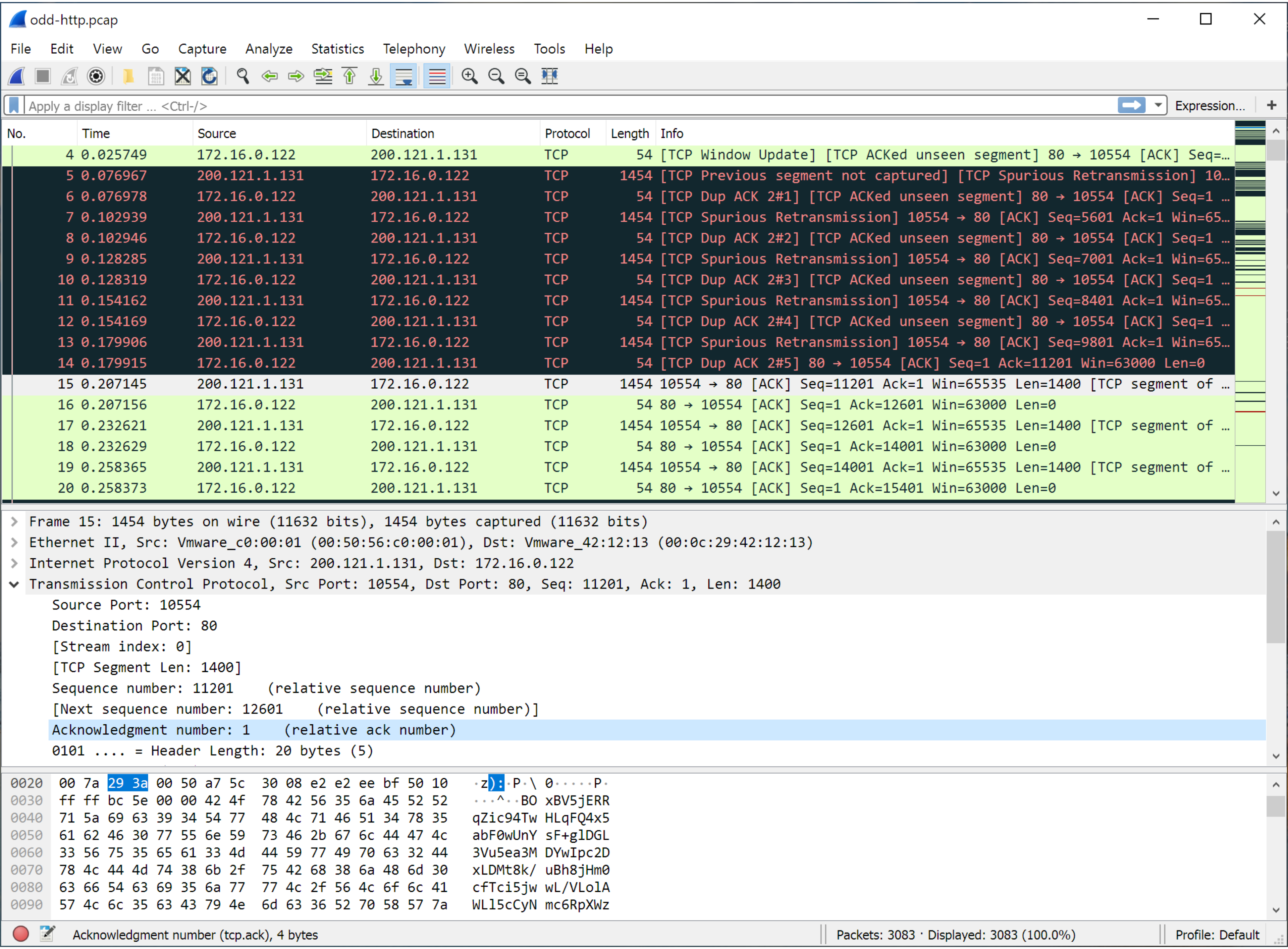


ipconfig (or ifconfig)



wireshark

OUI List: http://standards.ieee.org/develop/regauth/oui/oui.txt



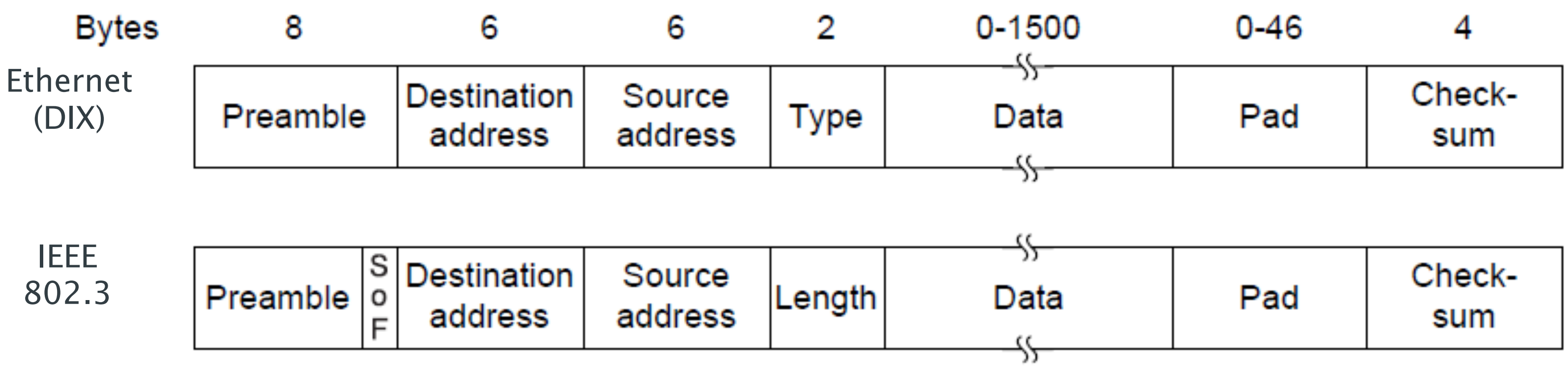
odd-http.pcap
File Edit View Go Capture Analyze Statistics Telephony Wireless Tools Help
Apply a display filter ... <Ctrl-/>
Expression...
No. Time Source Destination Protocol Length Info
4 0.025749 172.16.0.122 200.121.1.131 TCP 54 [TCP Window Update] [TCP ACKed unseen segment] 80 → 10554 [ACK] Seq=…
5 0.076967 200.121.1.131 172.16.0.122 TCP 1454 [TCP Previous segment not captured] [TCP Spurious Retransmission] 10…
6 0.076978 172.16.0.122 200.121.1.131 TCP 54 [TCP Dup ACK 2#1] [TCP ACKed unseen segment] 80 → 10554 [ACK] Seq=1 …
7 0.102939 200.121.1.131 172.16.0.122 TCP 1454 [TCP Spurious Retransmission] 10554 → 80 [ACK] Seq=5601 Ack=1 Win=65…
8 0.102946 172.16.0.122 200.121.1.131 TCP 54 [TCP Dup ACK 2#2] [TCP ACKed unseen segment] 80 → 10554 [ACK] Seq=1 …
9 0.128285 200.121.1.131 172.16.0.122 TCP 1454 [TCP Spurious Retransmission] 10554 → 80 [ACK] Seq=7001 Ack=1 Win=65…
10 0.128319 172.16.0.122 200.121.1.131 TCP 54 [TCP Dup ACK 2#3] [TCP ACKed unseen segment] 80 → 10554 [ACK] Seq=1 …
11 0.154162 200.121.1.131 172.16.0.122 TCP 1454 [TCP Spurious Retransmission] 10554 → 80 [ACK] Seq=8401 Ack=1 Win=65…
12 0.154169 172.16.0.122 200.121.1.131 TCP 54 [TCP Dup ACK 2#4] [TCP ACKed unseen segment] 80 → 10554 [ACK] Seq=1 …
13 0.179906 200.121.1.131 172.16.0.122 TCP 1454 [TCP Spurious Retransmission] 10554 → 80 [ACK] Seq=9801 Ack=1 Win=65…
14 0.179915 172.16.0.122 200.121.1.131 TCP 54 [TCP Dup ACK 2#5] 80 → 10554 [ACK] Seq=1 Ack=11201 Win=63000 Len=0
15 0.207145 200.121.1.131 172.16.0.122 TCP 1454 10554 → 80 [ACK] Seq=11201 Ack=1 Win=65535 Len=1400 [TCP segment of …
16 0.207156 172.16.0.122 200.121.1.131 TCP 54 80 → 10554 [ACK] Seq=1 Ack=12601 Win=63000 Len=0
17 0.232621 200.121.1.131 172.16.0.122 TCP 1454 10554 → 80 [ACK] Seq=12601 Ack=1 Win=65535 Len=1400 [TCP segment of …
18 0.232629 172.16.0.122 200.121.1.131 TCP 54 80 → 10554 [ACK] Seq=1 Ack=14001 Win=63000 Len=0
19 0.258365 200.121.1.131 172.16.0.122 TCP 1454 10554 → 80 [ACK] Seq=14001 Ack=1 Win=65535 Len=1400 [TCP segment of …
20 0.258373 172.16.0.122 200.121.1.131 TCP 54 80 → 10554 [ACK] Seq=1 Ack=15401 Win=63000 Len=0
Frame 15: 1454 bytes on wire (11632 bits), 1454 bytes captured (11632 bits)
Ethernet II, Src: Vmware_c0:00:01 (00:50:56:c0:00:01), Dst: Vmware_42:12:13 (00:0c:29:42:12:13)
Internet Protocol Version 4, Src: 200.121.1.131, Dst: 172.16.0.122
Transmission Control Protocol, Src Port: 10554, Dst Port: 80, Seq: 11201, Ack: 1, Len: 1400
Source Port: 10554
Destination Port: 80
[Stream index: 0]
[TCP Segment Len: 1400]
Sequence number: 11201 (relative sequence number)
[Next sequence number: 12601 (relative sequence number)]
Acknowledgment number: 1 (relative ack number)
0101 .... = Header Length: 20 bytes (5)
0020 00 7a 29 3a 00 50 a7 5c 30 08 e2 e2 ee bf 50 10 ·z):·P·\ 0·····P·
0030 ff ff bc 5e 00 00 42 4f 78 42 56 35 6a 45 52 52 ···^··BO xBV5jERR
0040 71 5a 69 63 39 34 54 77 48 4c 71 46 51 34 78 35 qZic94Tw HLqFQ4x5
0050 61 62 46 30 77 55 6e 59 73 46 2b 67 6c 44 47 4c abF0wUnY sF+glDGL
0060 33 56 75 35 65 61 33 4d 44 59 77 49 70 63 32 44 3Vu5ea3M DYwIpc2D
0070 78 4c 44 4d 74 38 6b 2f 75 42 68 38 6a 48 6d 30 xLDMt8k/ uBh8jHm0
0080 63 66 54 63 69 35 6a 77 77 4c 2f 56 4c 6f 6c 41 cfTci5jw wL/VLolA
0090 57 4c 6c 35 63 43 79 4e 6d 63 36 52 70 58 57 7a WLl5cCyN mc6RpXWz
Acknowledgment number (tcp.ack), 4 bytes
Packets: 3083 · Displayed: 3083 (100.0%)
Profile: Default

Ethernet Frame Format: Type/Length

Bytes	8		6	6	2	0-1500	0-46	4
Ethernet (DIX)	Preamble		Destination address	Source address	Type	Data	Pad	Check-sum
IEEE 802.3	Preamble	SoF	Destination address	Source address	Length	Data	Pad	Check-sum

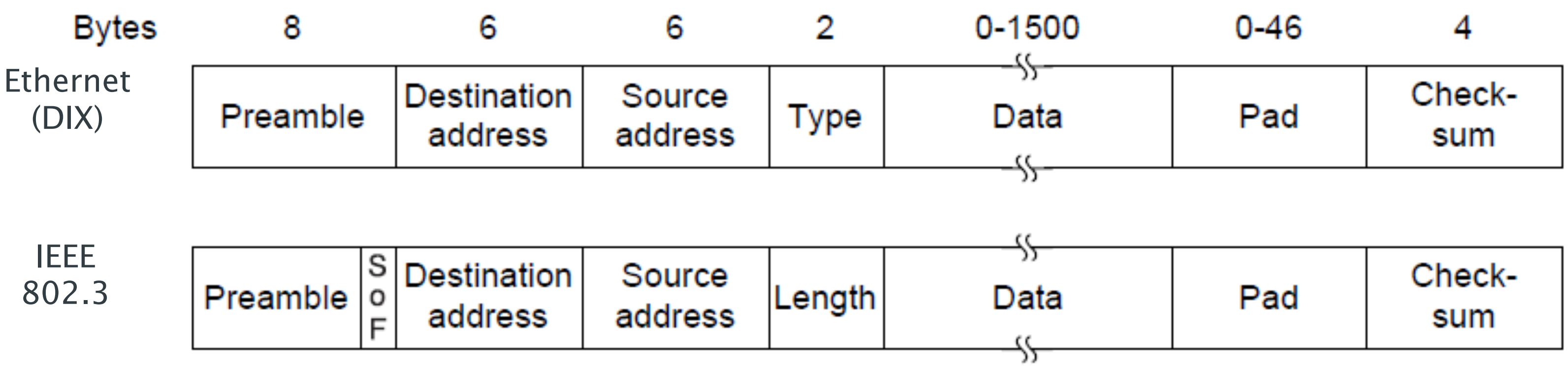
- Ethernet uses this 2 byte field for *type*
  - Indicates the type of NET packet that is contained in the payload, i.e. which NET protocol it needs to pass it to
  - E.g. `0x0800` means it's an ipv4 packet
- 802.3 changed this to indicate the payload length (type inferred elsewhere)
- Not a popular change, 802.3 revised…
  - Values in this field < `0x0600` are interpreted as lengths
  - Values in this field > `0x0600` are interpreted as types

Ethernet Frame Format: Data + Pad



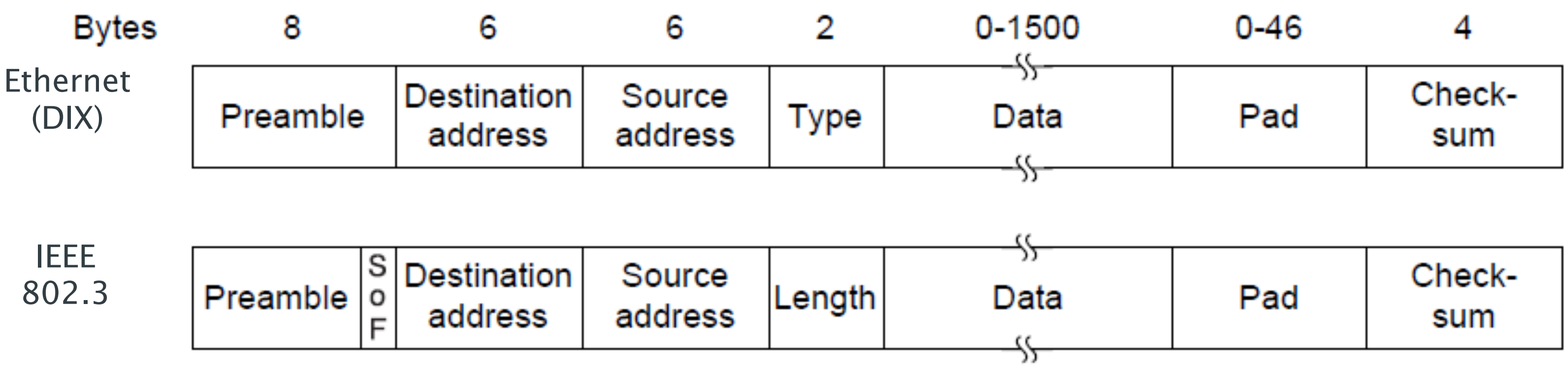
- Data has a maximum length of 1500 bytes (reasonably arbitrarily chosen)
  - Means that packets may need to be broken down into smaller chunks
- Frames also have a minimum length of 64 bytes (more on this later)
  - Therefore, the payload (*data* + *pad*) must be at least 46 bytes
  - If there is <46 bytes of *data*, the remaining bytes can be ‘padded’ using the *pad* field

Ethernet Frame Format: Checksum



- 32-bit CRC
  - Frames are dropped if an error is detected (no acknowledgements are used)

End of Frame Detection



- Managed by the PHY
  - Can indicate the end of a frame by the loss of the carrier signal
  - or, e.g. Gigabit Ethernet, uses a special symbol before and after a frame that are not used by the 8B/10B encoding scheme
- Also, after sending a frame, the transmitter must wait a minimum of 96 bit-periods (i.e. the time that would be taken to send 12 bytes) before transmitting the next frame

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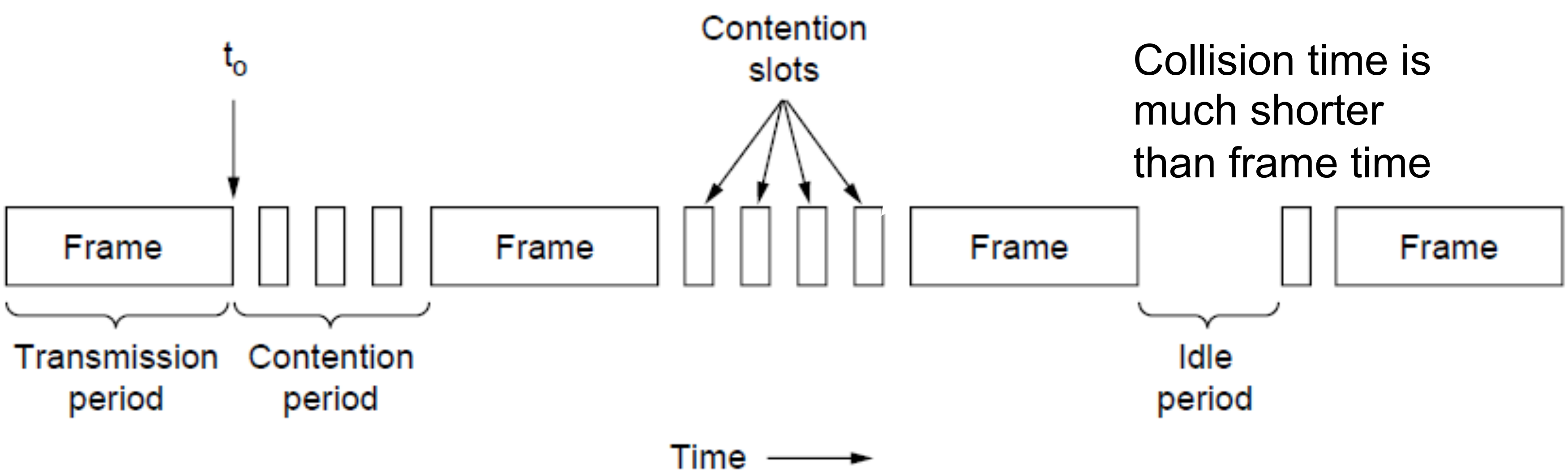
MAC Protocol

Ethernet / IEEE 802.3

CSMA–CD

- CSMA/CD = CSMA with Collision Detection
- CSMA/CD improvement is to detect/abort collisions



Collision time is much shorter than frame time

- CSMA/CD can be in a contention, transmission, or idle state.

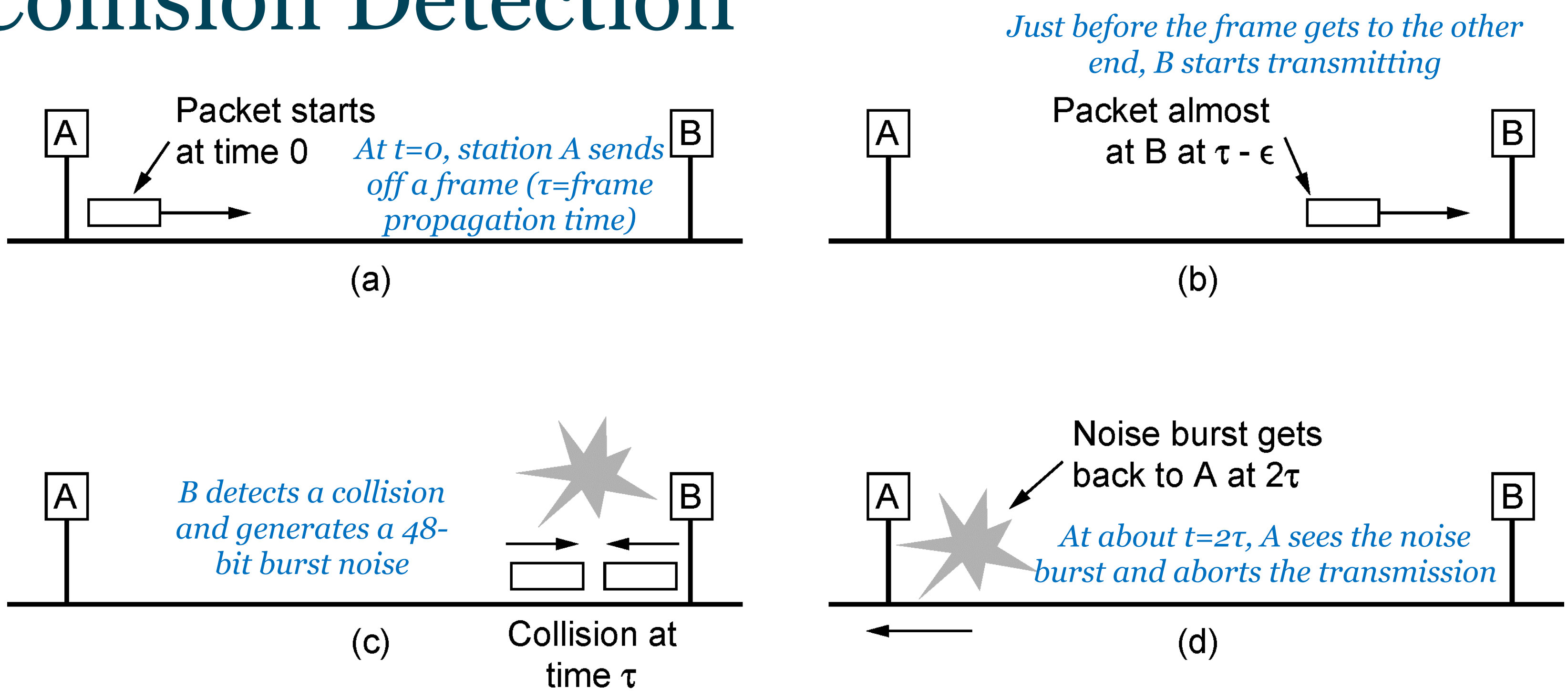
CSMA-CD

- Essentially the same as a group of people holding a conversation:

1. Listen to see if the channel is busy
2. If it is, transmit (*talk*) but continue to listen to detect a collision (*someone else talking*)
3. If there is a collision while you're talking (*someone else starts talking*), stop transmitting (*talking*) immediately and wait a period of time before trying again.
4. If the channel wasn't free (*someone was already talking*), wait before trying again.

Video: https://www.youtube.com/watch?v=DYu_bGbZiiQ

Collision Detection



- It may take a time period equal to 2τ before a collision is detected
- There are no acknowledgements, hence if a collision isn't detected, it's assumed to have been received correctly
- If a frame was very short, it may have been completely transmitted before a collision was able to be detected. Hence the minimum frame length.

Minimum Frame Size

- The ability to detect a collision before a frame is completely transmitted dictates the minimum frame size allowed
  - 10 Mbps Ethernet, maximum length of 2500m and 4 repeaters
  - Round Trip Time of ~50 us
  - At 10Mbps, a single bit is transmitted every 0.1us
  - Therefore, 500 bits must be transmitted (rounded up to 512 bits, or 64 bytes)

Exponential Backoff

- If a collision is detected, CSMA-CD has to backoff of a period of time before trying again

- The basic concept of the Exponential Backoff Algorithm is that the wait time is doubled at every attempt

- Of course, this is deterministic, and wouldn't help (each node that collided would be in 'sync' at every reattempt and continue to suffer collisions

Exponential Backoff

- The answer is to introduce some non-determinism (randomness)
  - each node selects a random delay from a number of possible delays.
- On the 1st attempt, the choice is:

$$0 \text{ or } 2\tau$$

- On the 2nd attempt, the choice is:

$$0, 2\tau, 4\tau \text{ or } 6\tau$$

- On the 3rd attempt, the choice is:

$$0, 2\tau, 4\tau, 6\tau, 8\tau, 10\tau \text{ or } 12\tau$$

- On the nth attempt, the choice is:

$$(2^0 - 1)\bullet 2\tau, (2^1 - 1)\bullet 2\tau, \ldots, (2^{n-1} - 1)\bullet 2\tau, (2^n - 1)\bullet 2\tau$$

- n is limited to a maximum of 10, and transmission is aborted after 16 attempts
- Dynamically adapts to the number of stations wanting to transmit

Exponential Backoff

- With two terminals wishing to communicate, the probability of repeated collisions are (i.e. the chance of both making the same choice):
  - 1st retransmission (1 in 2) 50%
  - 2nd retransmission (1 in 4) 25%: cumulative probability = 12.5%
  - 3rd retransmission (1 in 8) 12.5%: cumulative probability = 1.5%
  - 4th retransmission (1 in 16) 6.25%: cumulative probability = 0.1%
  - 5th retransmission (1 in 32) 3.125%: cumulative probability = 0.003%
  - 6th retransmission (1 in 64) 1.5%: cumulative probability = **less than 1 in 10^6**

ELEC3222 17/18 Exam Question

Ethernet uses CSMA/CD (*Carrier Sense Multiple Access with Collision Detection*), with an exponential back-off.

- **Explain** what happens if a collision is detected on transmitting a packet. Why is this useful?
- **Explain** why Ethernet necessitates the use of a minimum frame size.
- **Explain** why CSMA/CD is not needed in Switched Ethernet

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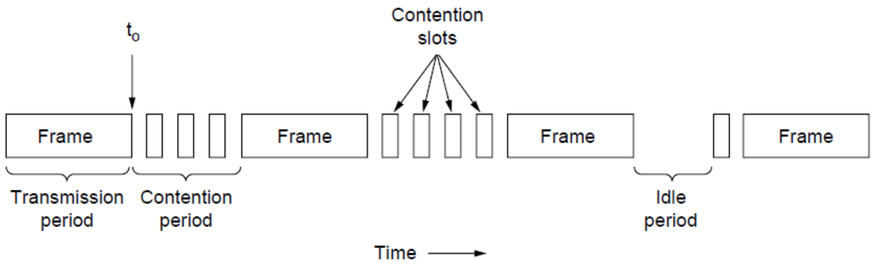
Channel Utilization

Ethernet / IEEE 802.3

Channel Utilisation

- CSMA-CD can be in one of three states
  - Transmitting (transmission period T_t)
  - Contention (contention period T_c)
  - Idle (idle period T_i)



$$Utilisation = \frac{T_t}{T_t + T_c + T_i}$$

Channel Utilisation

$$Efficiency = \frac{T_t}{T_t + T_c + T_i}$$

- T_t can be calculated as a function of the frame length L and data rate R

$$T_t = \frac{L}{R}$$

- Ideally, T_i is zero (although this may an invalid assumption!)
- T_c is difficult to estimate (and makes lots of assumptions), but a worst-case mean value under an 'optimum' heavy load can be modelled (refer to textbook):

$$T_c = \frac{e2D}{v}$$

- Where D is distance and v is velocity

Channel Utilisation

- Therefore, the channel utilisation becomes

$$Efficiency = \frac{T_t}{T_t + T_c + T_i}$$

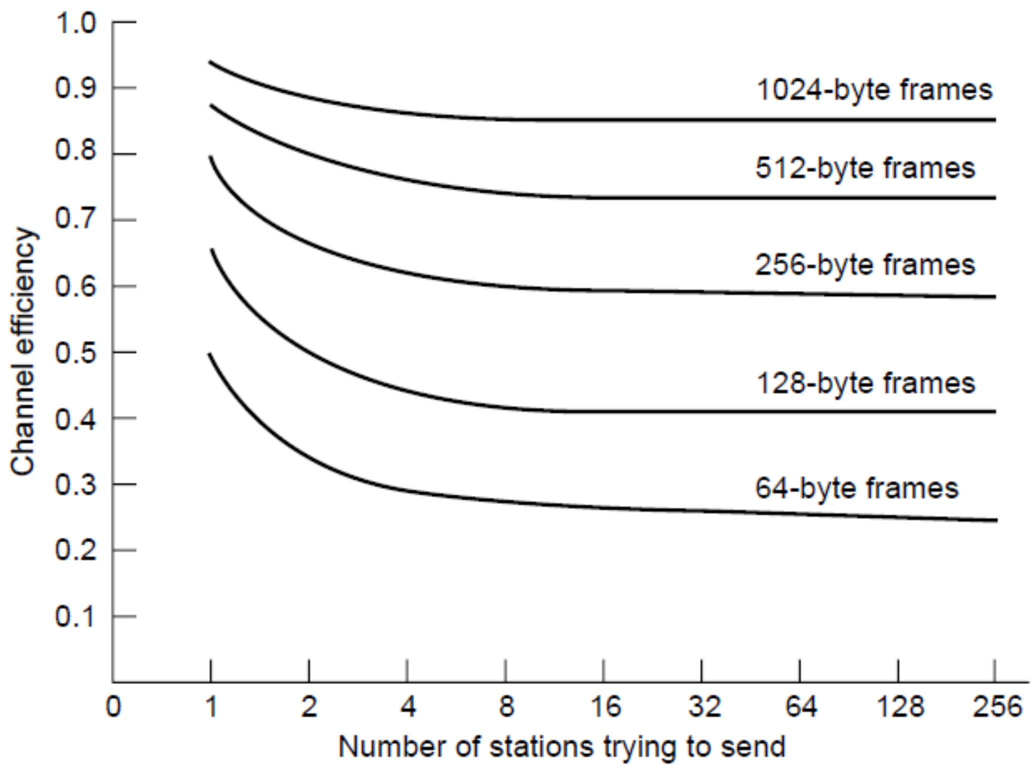
$$= \frac{\frac{L}{R}}{\left(\frac{L}{R} + \frac{e2D}{v} + 0\right)}$$

$$= \frac{1}{\left(1 + \frac{e2DR}{Lv}\right)}$$

- This indicates that increasing the frame length L increases utilisation
- However, the market wants increased distances (D) and data rates (R)
  - Thus decreasing utilisation

Classic Ethernet – Channel Utilisation

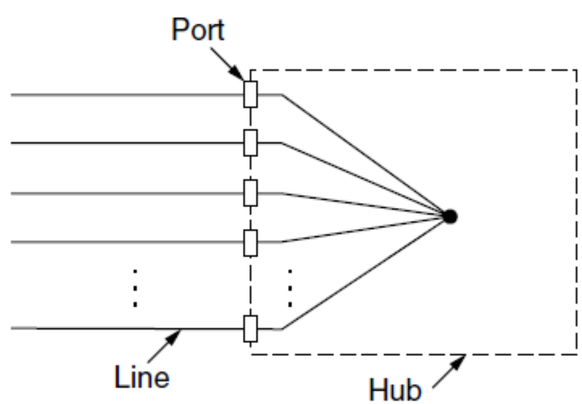
- Efficient for large frames, even with many senders
  - Degrades for small frames (and long LANs)



10 Mbps Ethernet,
64 byte min. frame

Ethernet Hubs

- The shared cable became problematic
  - e.g. finding breaks in the cable
- Moved to a topology where every station has its own wire
- All the individual cables connect to different ports on a **hub**
- Inside the hub, all the wires are connected together; i.e. operates at the PHY



- Easier to add additional stations, locate problems
- But still logically equivalent to single-long-cable (single CSMA-CD domain)

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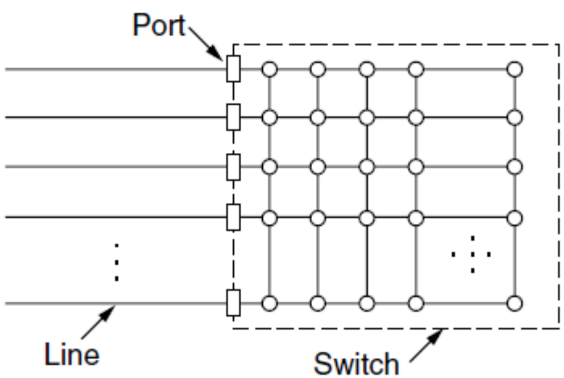
Switched Ethernet

Ethernet / IEEE 802.3

Ethernet Switches

- Switched Ethernet gets over this problem
- All the individual cables connect to different ports on a **switch**
- Inside the switch, frames are inspected, i.e. operates at the DLL
  - Interrogates the frame's destination address
  - Only forwards a frame to the port(s) for which it is destined

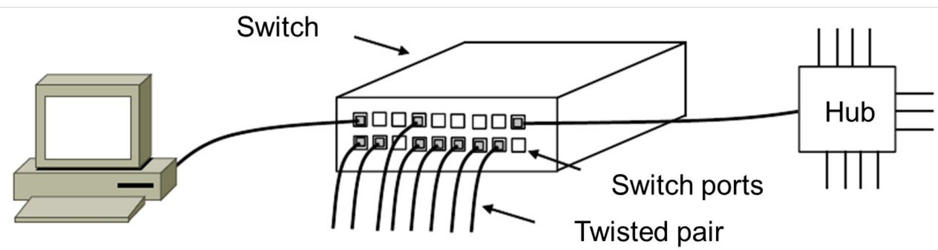


  - As interrogating the DLL, can also detect errors (check the CRC) before forwarding

Image: CN5E by Tanenbaum & Wetherall, © Pearson Education-Prentice Hall and D. Wetherall, 2011

Ethernet Switches

- Each port is now in its own CSMA-CD collision domain
  - If half-duplex, will still need CSMA-CD to manage access between a pair of stations
  - Provided the cable is full-duplex, there is now no need for CSMA-CD (redundant!)
  - Two stations might be trying to transmit to the same station at the same time, in which case the switch will need to buffer the frame (store-and-forward)
- Switched Ethernet
  - Improves performance: chance of collisions is reduced
  - Improves throughput: many frames sent simultaneously (by different senders)
  - Improves security: harder to snoop on frames across an entire LAN
- Can connect:
  - Multiple stations to a hub
  - The hub to a switch



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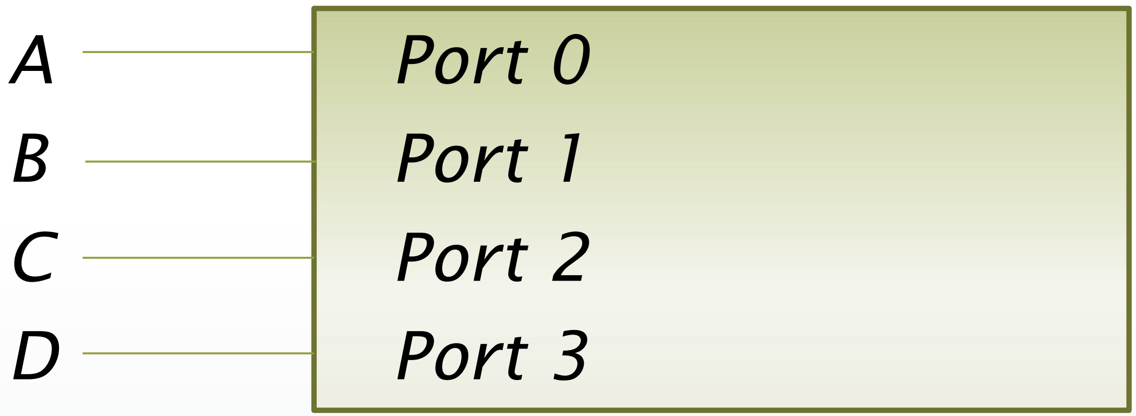
Frames in Ethernet Switches

- Consider a four-port switch, connected as below:



- When the switch receives a frame, it must decide what to do with it.

Frames in Ethernet Switches

- The switch inspects the address field of the frame
  - Is the destination address FF:FF:FF:FF:FF:FF (broadcast)?
    - If so, the frame is flooded, i.e. forwarded on every port (this frame has to go everywhere, so there is no choice)
  - Else, is the destination address known?
    - If so, filter the frame, i.e. transmit only on the port connected to the destination address
    - If not, flood the frame, i.e. transmit on every port
- How do we know the location of the destination address?

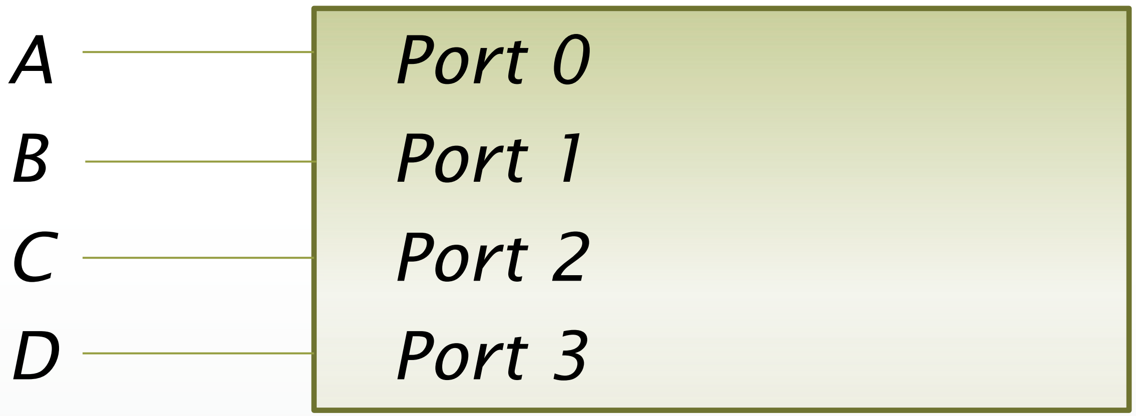
Frames in Ethernet Switches

- How do we know the location of the destination address?

- A look-up table on the switch is used; this relates a port to a MAC address
  - Initially, the table is empty
  - It is not actively populated…
  - Instead, it examines the traffic passing through the switch
  - It inspects the source address of every frame, and updates the table with the address and port it was received on
  - Entries in the table are removed after a timeout period…
  - …to ensure that changes to physical connections get updated in the table

Frames in Ethernet Switches

- Consider an example:



- After reset, a frame is sent from ***A*** to ***B***
  - This is flooded onto ports *1*,*2* and *3*
- Next a frame is sent from ***D*** to ***A***
  - The switch is now aware of the port needed to reach ***A***
  - Therefore, this frame is filtered (only transmitted on port *0*)

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Fast Ethernet

Ethernet / IEEE 802.3

Switched/Fast Ethernet

- Fast Ethernet extended Ethernet from 10 to 100 Mbps
  - Backwards compatible (100 Mbps switches negotiate with 10/100 Mbps stations)
- Hubs and switches only (no more tapping into a single cable)
- Supports three different physical layers:

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps (Cat 5 UTP)
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

- 100Base-T4: Manchester coding, 4x Cat3 UTP cables
- 100Base-TX: 4B/5B coding, 2x UTP cables (1up, 1 down)
- What does increasing the data rate affect?
  - think about the time required to transmit a frame…

Switched/Fast Ethernet

- Increasing the data rate by 10x reduces the round trip time by 10x
- Therefore, in order to detect collisions, we need to…
  - Either reduce the maximum distance by a factor of 10
  - Or increase the minimum frame size by a factor of 10
- 100Base-T4 and 100Base-TX reduced the maximum segment size to 100m
  - as seen on the table below
- 100Base-FX doesn’t support hubs
  - must use full-duplex links and switches

Name	Cable	Max. segment	Advantages
100Base-T4	Twisted pair	100 m	Uses category 3 UTP
100Base-TX	Twisted pair	100 m	Full duplex at 100 Mbps (Cat 5 UTP)
100Base-FX	Fiber optics	2000 m	Full duplex at 100 Mbps; long runs

Gigabit Ethernet

- Full-duplex doesn't need CSMA-CD; hence the maximum cable length is a result of SNR rather than the round-trip-time
- Half duplex requires CSMA-CD; hence the increase in data rate necessitates us to either reduce the maximum distance or increase the frame size
  - Could reduce distance down to 25m
  - Instead, specified carrier extension (automatic padding) and frame bursting (piggybacking multiple frames) to allow a distance of 200m

Name	Cable	Max. segment	Advantages
1000Base-SX	Fiber optics	550 m	Multimode fiber (50, 62.5 microns)
1000Base-LX	Fiber optics	5000 m	Single (10 μ) or multimode (50, 62.5 μ)
1000Base-CX	2 Pairs of STP	25 m	Shielded twisted pair
1000Base-T	4 Pairs of UTP	100 m	Standard category 5 UTP

- To get 1Gbps rates over Cat5 cables is tricky!
  - All four UTPs are used for simultaneous bidirectional data transfer
  - One symbol carries 2 bits using 5 voltage levels (signal rate of 125Msymbols/sec)

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LANs

Repeaters, Hubs, Bridges/Switches and Routers

Hubs, Switches (Bridges), and Routers

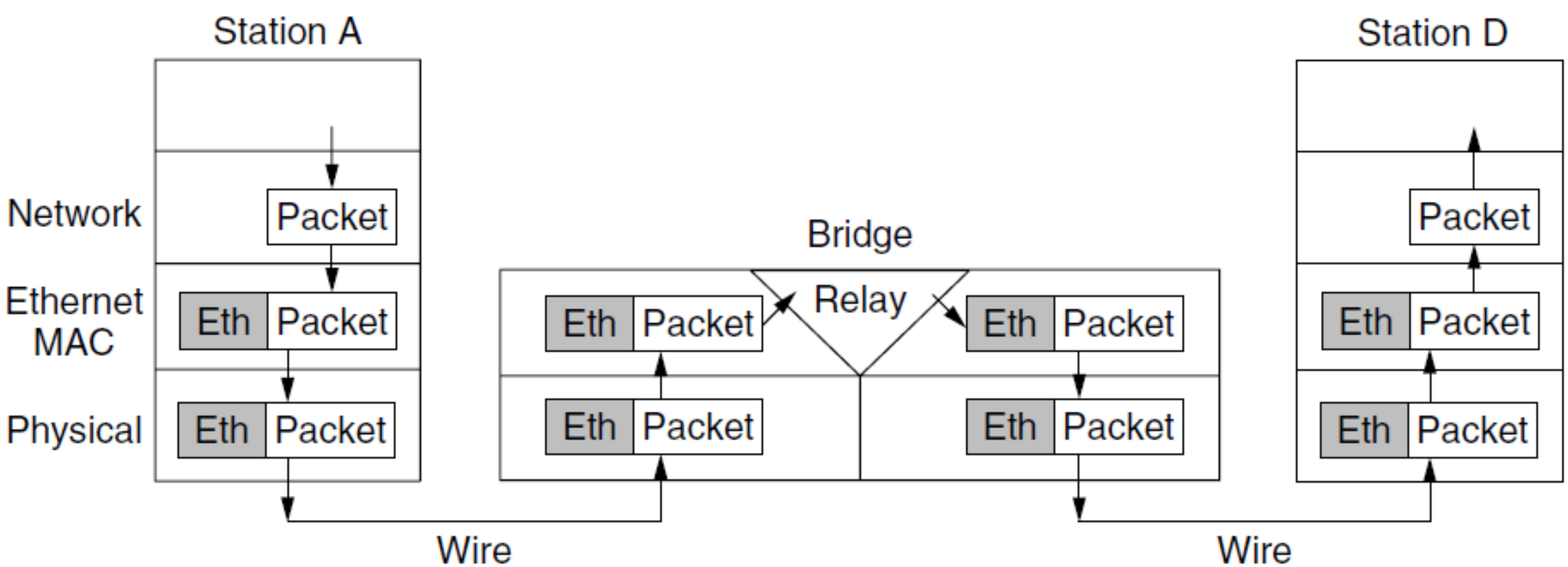
- Repeater
  - Operates at the PHYsical layer
- Hub
  - Operates at the PHYsical layer
- Switch (also known as a Bridge)
  - Operates at the Data Link Layer
- Router
  - Operates at the NETwork layer

Application layer	Application gateway
Transport layer	Transport gateway
Network layer	Router
Data link layer	Bridge, switch
Physical layer	Repeater, hub

- *Higher layers operate on an end-to-end basis*
  - *Transport gateway 'translates' connection-oriented protocols, e.g. SCTP to TCP*
  - *Application gateway 'translates' at the application level, e.g. SMS to eMail*

Bridges/Switches

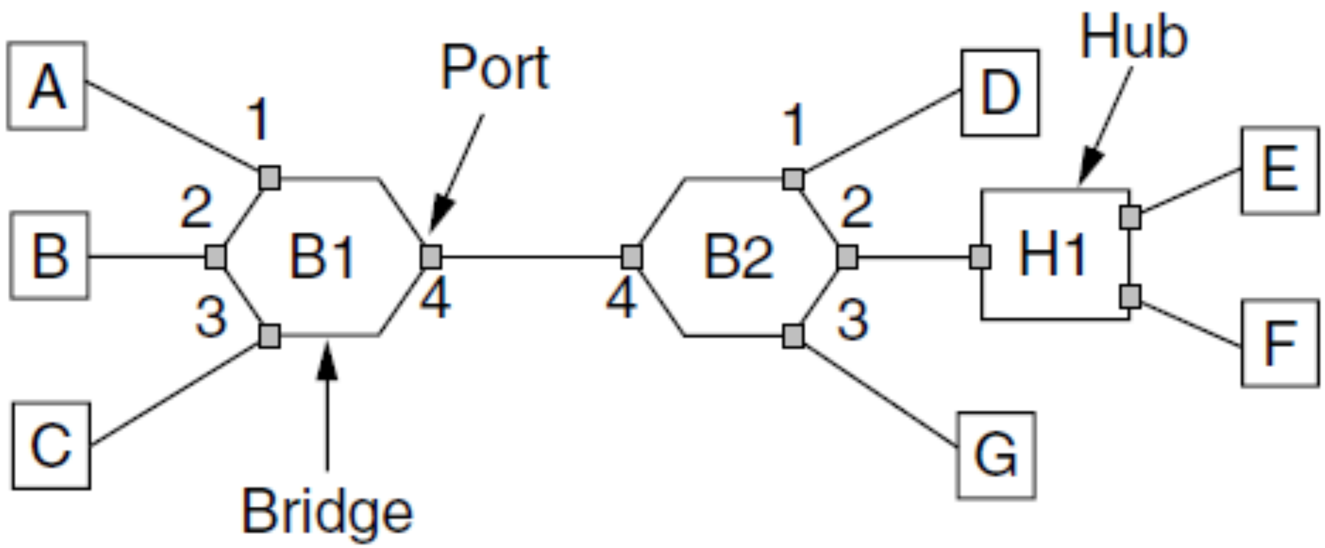
- Bridges extend the Link layer:
  - Use but don't remove Ethernet header/addresses
  - Do not inspect Network header



Ethernet LANs

- So far we've only really looked at switches/bridges as a way of supported *switch*ed Ethernet, - i.e. creating a single LAN
- Why do we need to be able to connect LANs?
  - **Distance**: We have maximum distances associated with LAN standards that add physical limits – but the diameter of the University is much bigger than this!
  - **Organisational**: Different departments may want their own LANs
  - **Capacity and Load Balancing**: The University has a lot of computers! Also, a classic Ethernet or Ethernet hub divides bandwidth between all computers attached.
  - **Broadcast Traffic**: All machines in a LAN are in the same *broadcast domain*, hence the more machines, the more broadcast traffic (e.g. ARP, DHCP, etc).
  - **Scalability**: The algorithms used in LANs wouldn't scale well (e.g. ARP, Spanning Tree, etc)
- A solution to this is to join LANs together using bridges, i.e. *bridge* two LANs

Ethernet LANs



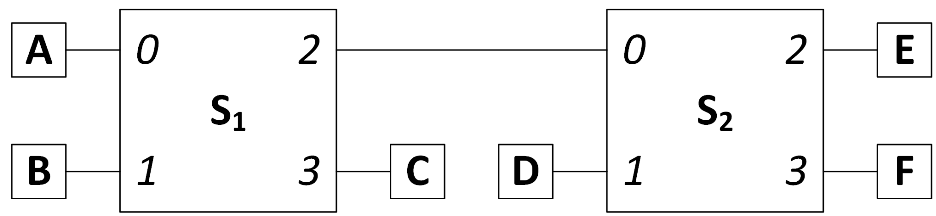
ELEC3222 16/17 Exam Question

The Switched Ethernet network shown in Figure 1 consists of six computers (A, B, C, D, E, F) and two 4- port Ethernet switches (S_1, S_2). Consider the following sequence of events:

i. Computer D sends a frame to F

ii. Computer E sends a frame to D

iii. Computer C sends a frame to E



Explain, in detail, the action of both switches. Your answer should include a MAC address table for both S_1 and S_2. Assume that all computers know the MAC addresses of all the others, and that the switches have just been reset.

Frames in Ethernet Switches (example)

Switch S_1

Ethernet Address	Port

Switch S_2

Ethernet Address	Port

Note: We are ignoring the timeout field here!

Ethernet LANs

- All stations on an Ethernet LAN can communicate with each other at the DLL

- To connect multiple LANs, we use a *Router* which operates at the NET.
  - Inspects the Packet in the Network layer
- To communicate beyond the LAN, a station transmits the frame to the router
  - The router then routes the packet
  - DLL Broadcasts not routed outside the LAN
- Router advertises the IP addresses within

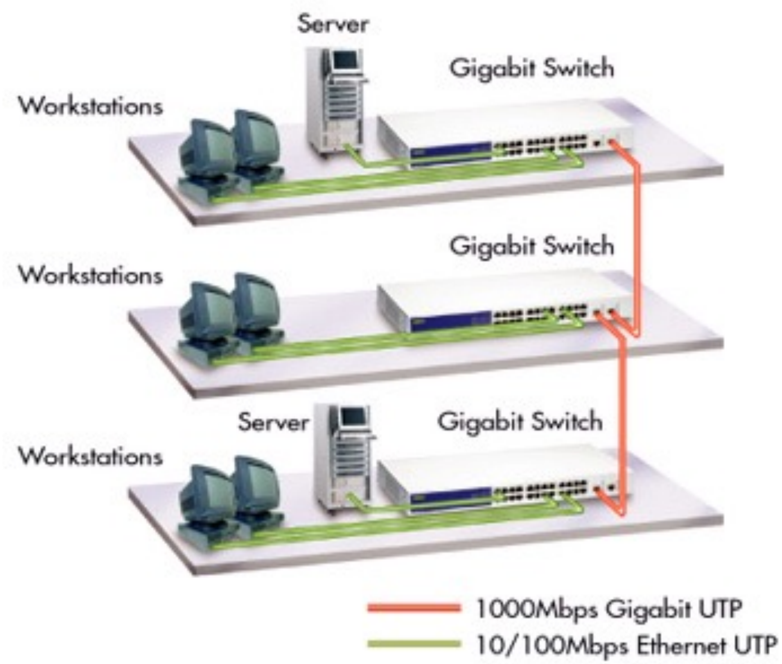


Image: http://www.eusso.com/models/gigabit/ugs5224-rx/ugs5224-rx.htm

Spanning Trees

- To increase reliability, multiple links may be made between switches
- This can cause infinite loops with backward learning of forwarding ports

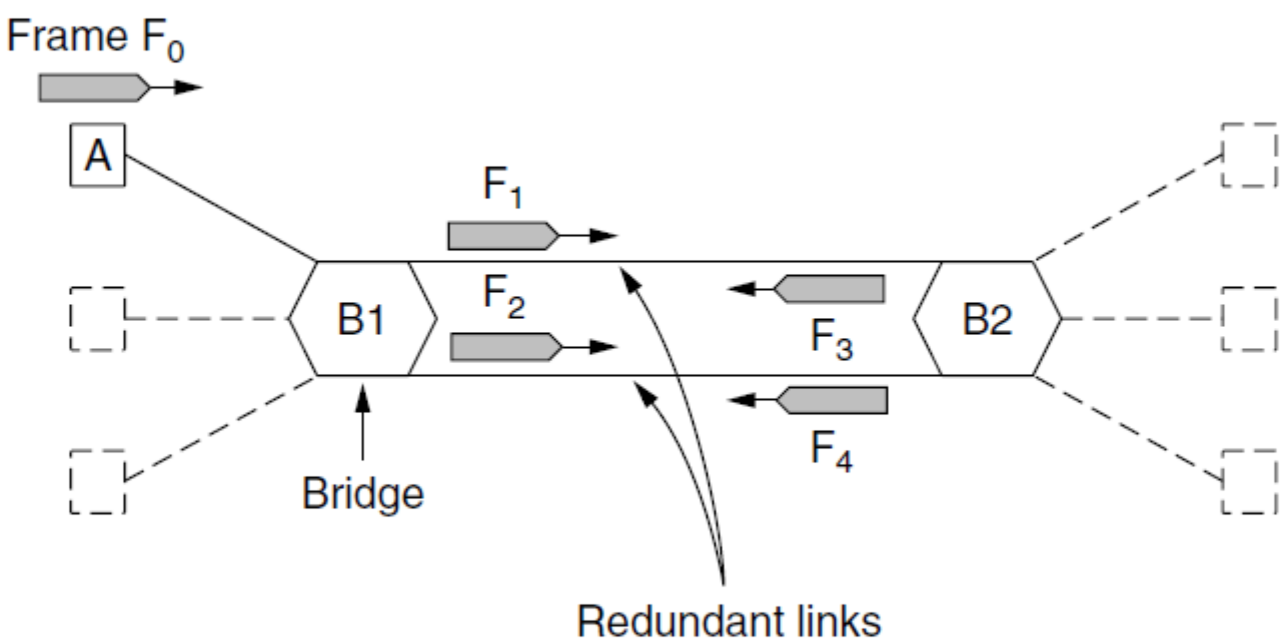
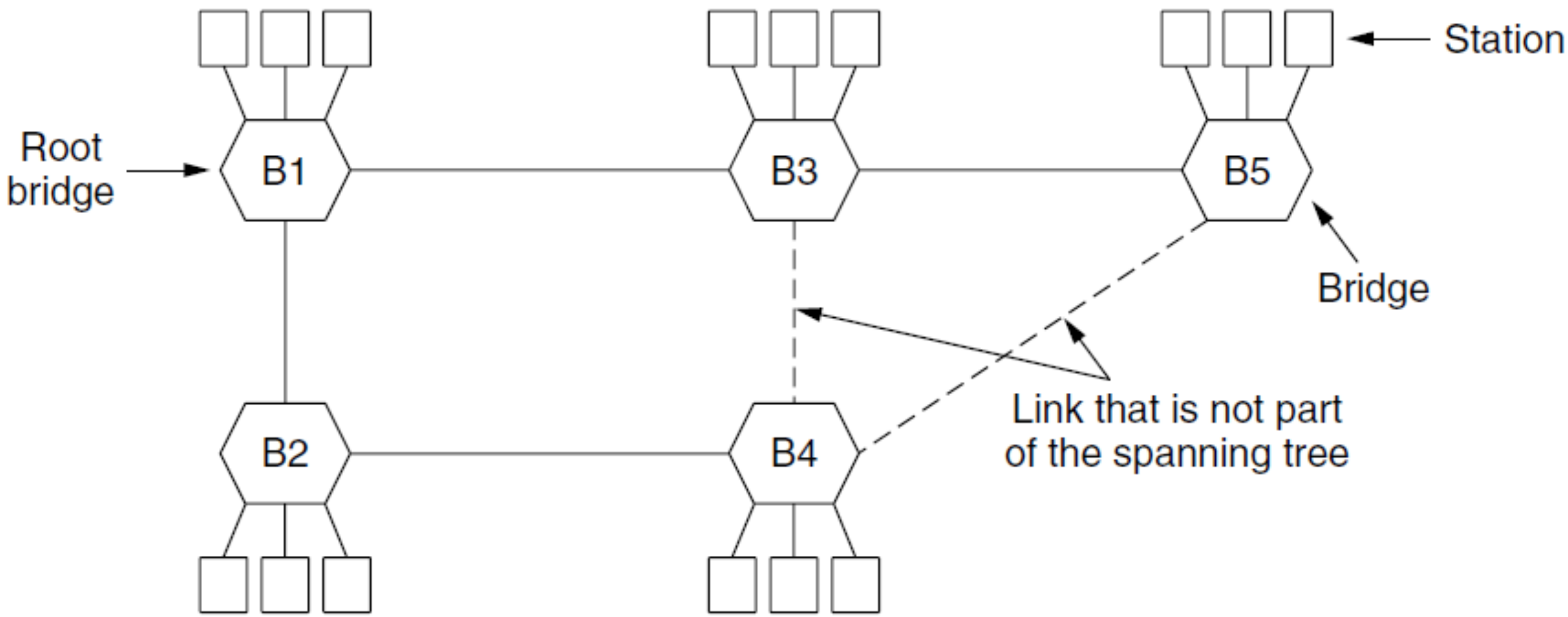


Image: CN5E by Tanenbaum & Wetherall, © Pearson Education-Prentice Hall and D. Wetherall, 2011

Spanning Trees

- Consider the network below, containing 5 interconnected switches
  - Spanning tree algorithm selects a root bridge (which can be manually chosen)
  - Enables the least cost paths to the root, and disables redundant ones
  - Redundant ones can be later re-enabled if the topology changes



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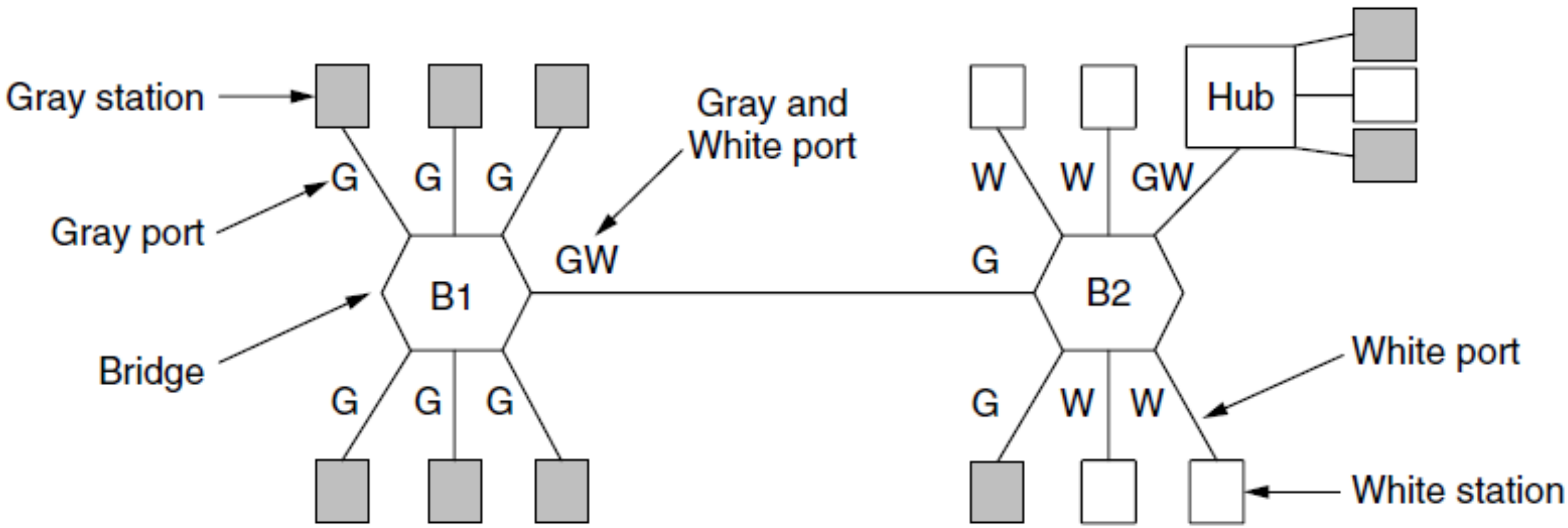
Virtual LANs

- There is often a need to have a different physical and logic topology
  - A manager might be in an office with their team
  - HR might share the same physical LAN with external webservers
  - R&D might load the network a lot more than marketing
  - Control broadcast domain

- Virtual LANs
  - Stations on the same *physical* LAN can appear on separate *logical* (virtual) LANs

Virtual LANs

- Different VLANs are commonly named (or coloured) for identification
- Membership can be assigned through a number of different possible methods
  - E.g. static port assignment, address based etc



- Hubs may 'break' the boundaries of the VLAN (as above)

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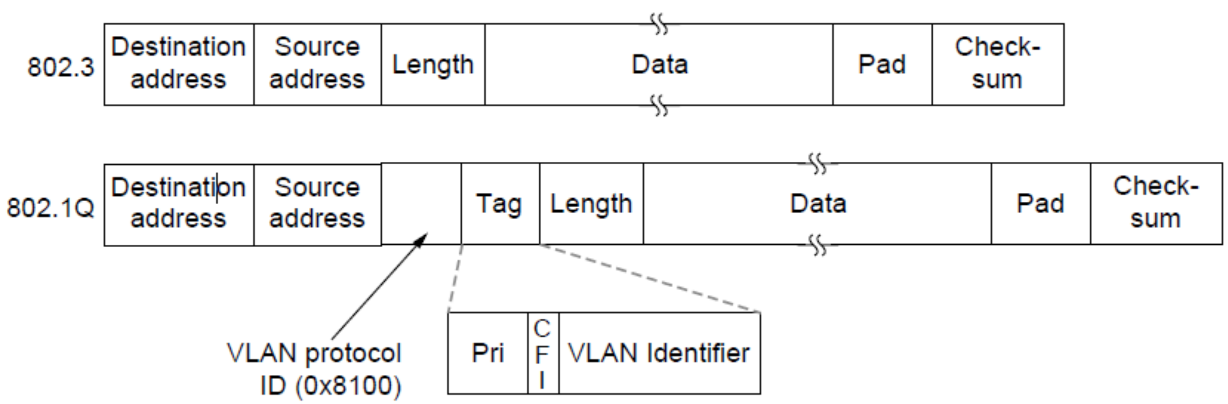
VLANs: IEEE 802.1Q

- How to identify ‘colour’? Need to redefine Ethernet standard (ARGH!)
- IEEE 802.1Q does this (but is backwards compatible with old hardware)
  - First time frames meet a VLAN-compatible NIC/switch, it’s tagged (and vice-versa)



- 802.1Q frames add a 2-byte tag (containing the *VLAN identifier*)
  - Also adds *priority* (real-time vs non-real-time traffic) – Not VLANs!
  - Not end-to-end, just affects the priority given in the switch
- The ‘old’ Length/Type value is 0x8100 to indicate the VLAN protocol

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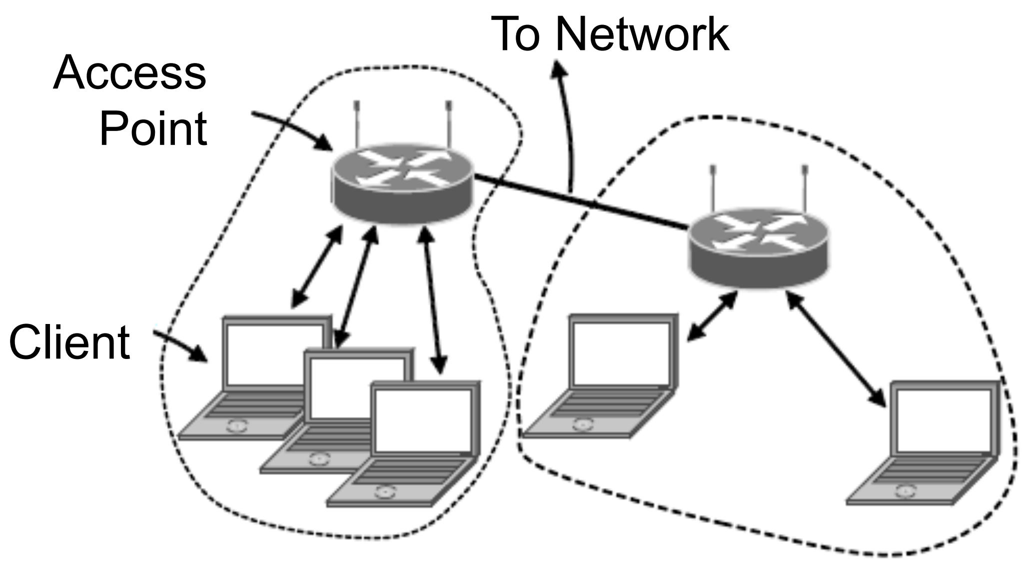
Wireless LANs

802.11/WiFi

802.11 Architecture

- Wireless clients associate to a wired Access Point (AP)
- Two modes:
  - Infrastructure Mode (a star topology)
  - Ad-Hoc (a peer-to-peer topology)



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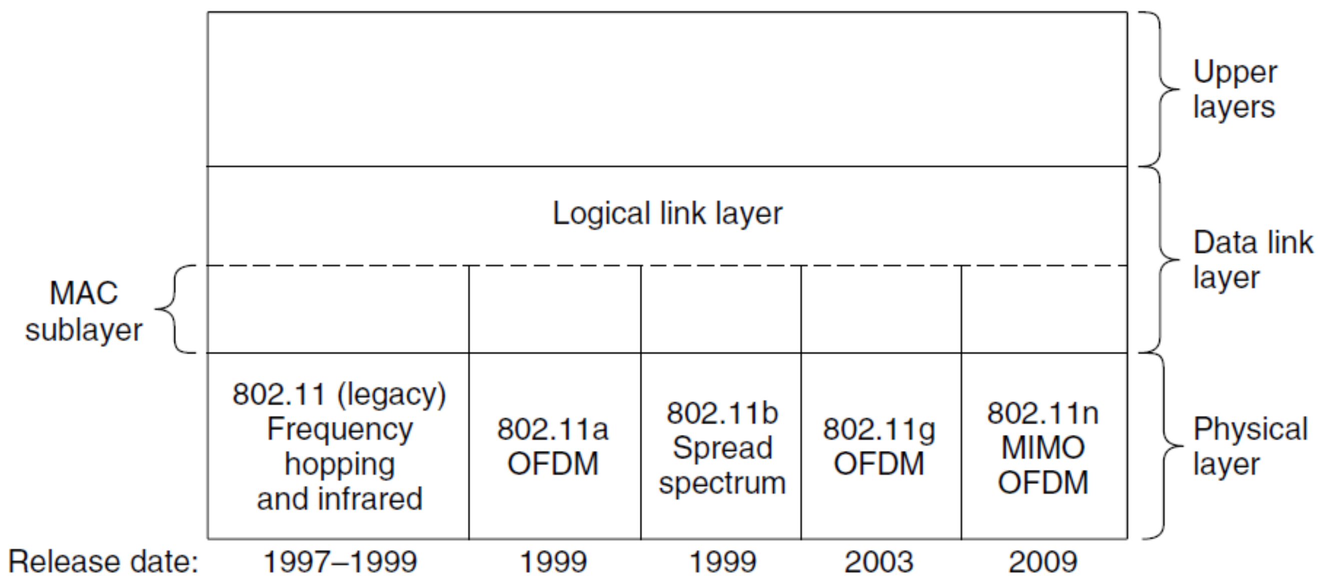
802.11 Network Architecture

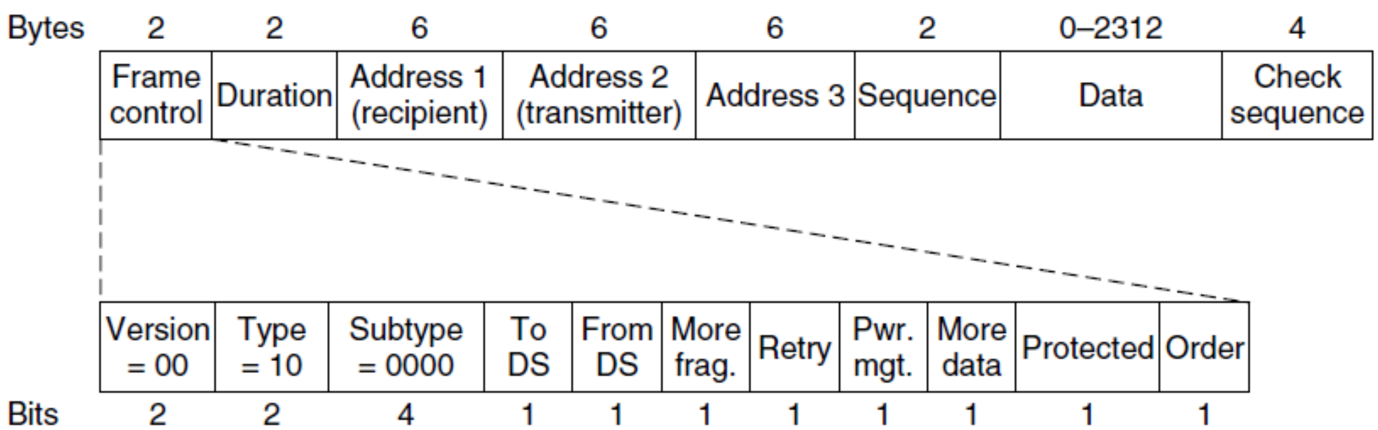
- As with all 802 protocols, they specify the PHY and DLL layers
  - In 802.11, a common MAC operates across multiple PHYs



  - *Not going to look at the different PHYs here*

802.11 Frame Format: Frame Control

- 2 byte field



- **Version:** Protocol version, to allow future extensions to 802.11
- **Type:** Indicates a data, control or management frame
- **Subtype:** e.g. RTS/CTS message
- **ToDS/FromDS:** Frame going *to* or coming *from* the network connected to the AP (called the Distribution System)

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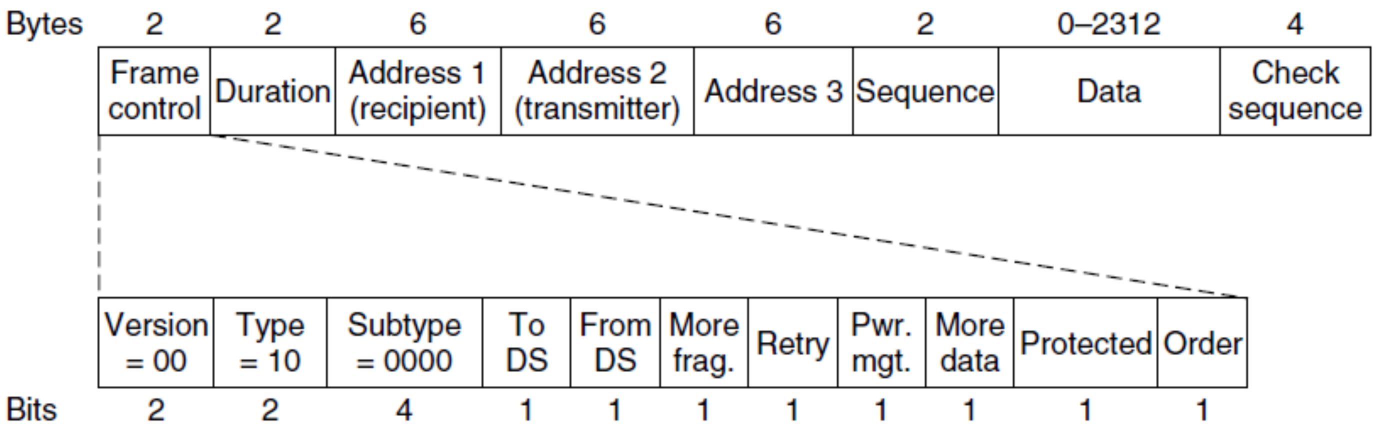
802.11 Frame Format: Frame Control

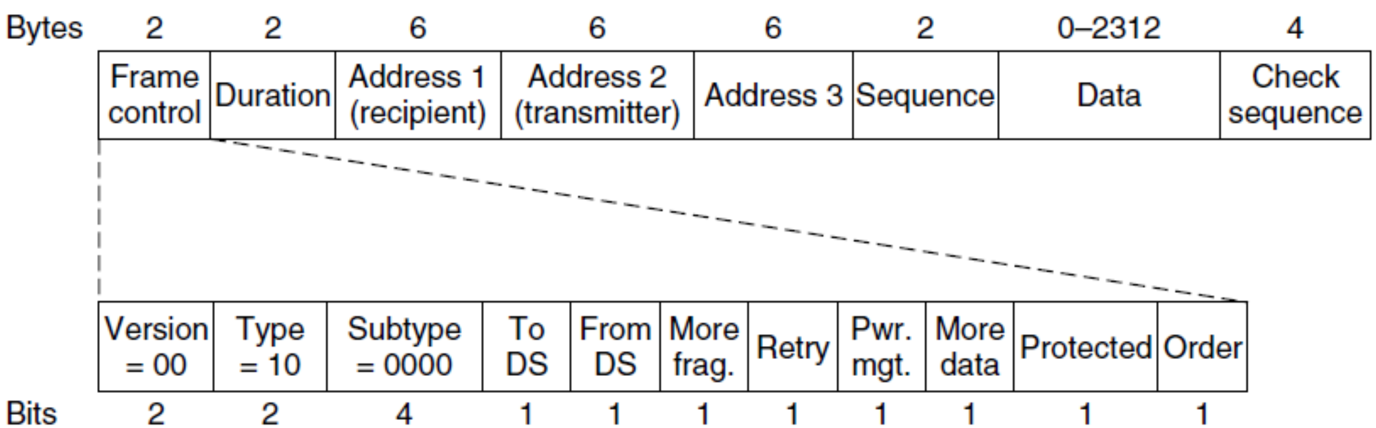
- 2 byte field



- **More Fragments:** Indicates that more fragments will follow
- **Retry:** Indicates that it's a retransmission of a previous frame
- **Power Management:** Indicates the sender is going into a low-power mode
- **More Data:** Indicates the sender has more frames to send to the receiver

802.11 Frame Format: Frame Control

- 2 byte field



- **Protected:** Indicates that the frame has been encrypted for security
- **Order:** Indicates the frames need to be passed to the higher layer in order

802.11 Frame Format: Duration

- 2 bytes

Bytes	2	2	6	6	6	2	0–2312	4
	Frame control	Duration	Address 1 (recipient)	Address 2 (transmitter)	Address 3	Sequence	Data	Check sequence

- Duration of the frame in microseconds (used for MAC protocol)

802.11 Frame Format: Addressing

- 3x 6-byte fields containing ‘MAC’ addresses

Bytes	2	2	6	6	6	2	0–2312	4
	Frame control	Duration	Address 1 (recipient)	Address 2 (transmitter)	Address 3	Sequence	Data	Check sequence

- Can be up to four addresses!
  - Destination: the MAC address of the final destination to receive the frame
  - Source: address of the source that initially created and transmitted the frame
  - Receiver: address of the next immediate station to receive the frame
  - Transmitter: the address of the station that transmitted the frame

802.11 Frame Format: Sequence

- 2-byte field

Bytes	2	2	6	6	6	2	0–2312	4
	Frame control	Duration	Address 1 (recipient)	Address 2 (transmitter)	Address 3	Sequence	Data	Check sequence

- A sequence number!
  - 12 bits sequence number (for the entire frame)
  - 4 bits fragment number (for frames that are fragmented for transmissions)

802.11 Frame Format: Data + Checksum

- Variable length field + 4-byte checksum

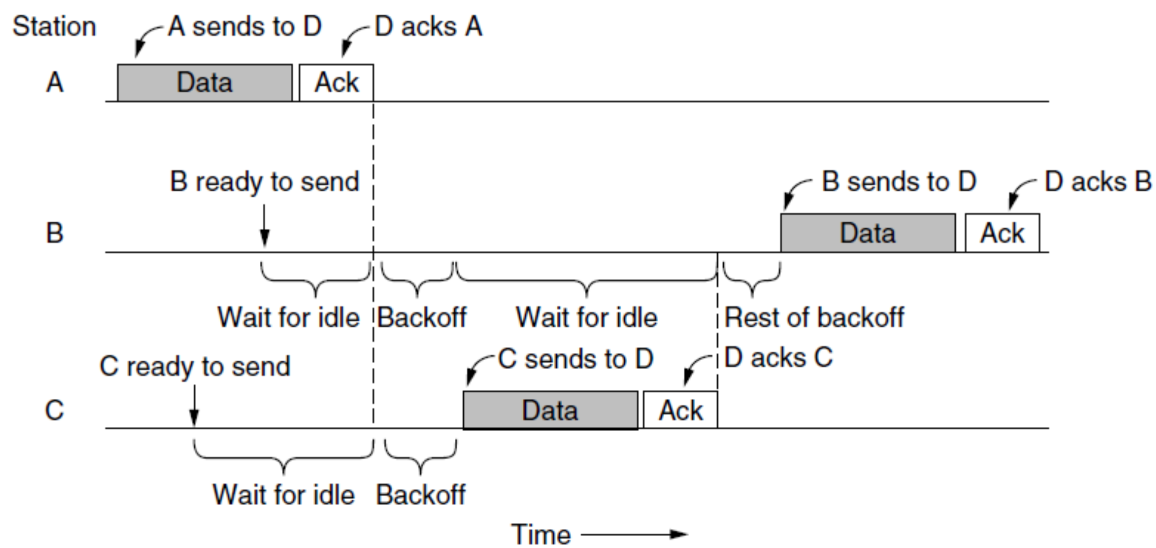
Bytes	2	2	6	6	6	2	0–2312	4
	Frame control	Duration	Address 1 (recipient)	Address 2 (transmitter)	Address 3	Sequence	Data	Check sequence

- Data
  - Variable length field

- Checksum
  - Standard 4-byte CRC-32

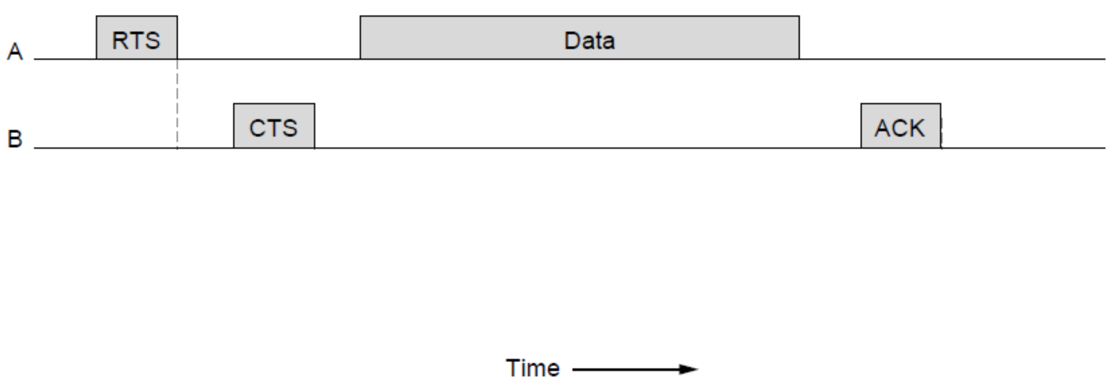
802.11 MAC

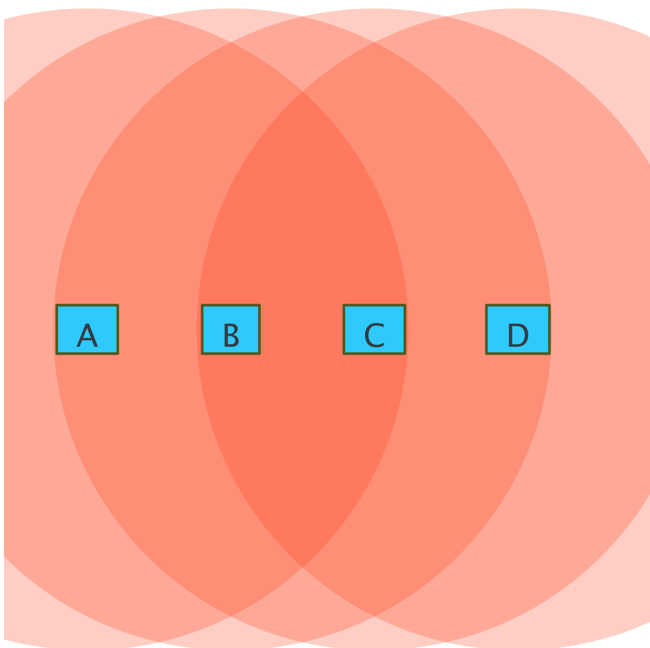
- CSMA/CA instead of CSMA/CD (of Ethernet)
  - Radio transceivers typically cannot transmit and receive at the same time
  - Plus a collision might be too weak to detect at the transmitter, but critical at the receiver
- CSMA/CA
  - Random backoff between 0-15 'slots' before trying to transmit
  - If channel becomes busy, the countdown is paused
  - Acknowledgements and Retransmissions handle wireless errors (as collisions cannot be detected)



802.11 MAC

- 802.11 Duration field used to populate each station's NAV (Network Allocation Vector), which is a record of when the channel is in use
- RTS/CTS can be (optionally) used...
  - 802.11 does not use the MACA approach to overcome the exposed station problem, as everyone keeps quiet on hearing the RTS or CTS (so the ACK can also get through)
  - Not widely used, as adds overhead for minimal benefit
- ...or the NAV can be used on its own





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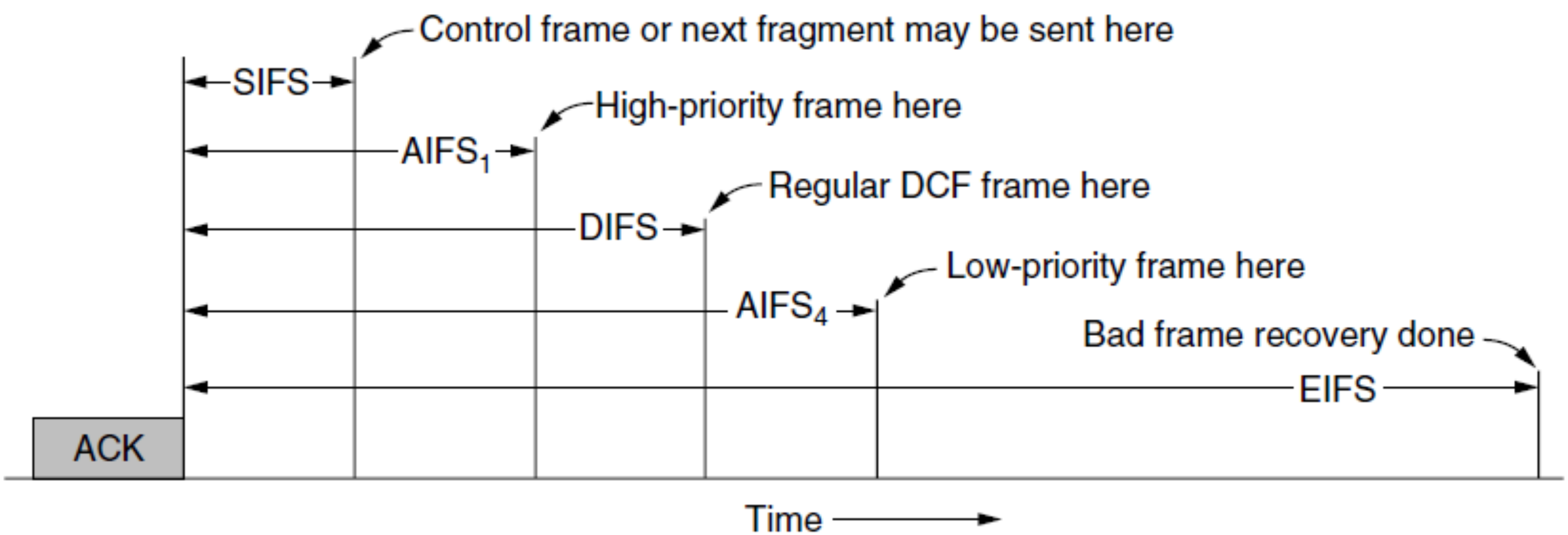
802.11 QoS Control

- Different backoff slot times add quality of service
  - Short intervals give preferred access, e.g., control, VoIP



802.11 Reliability

- 802.11 can adapt operation in response to performance (e.g. dropped frames)

- Reduce transmission rate
  - Rate adaptation allows stations to adapt the data rate
  - Lower data rates typically are more robust (correctly received with lower SNR)

- Reduce frame length
  - Can break a frame into multiple fragments (each with a checksum, and individually handled using stop-and-wait)
  - Smaller frames have a more chance of being correctly received with a constant BER

802.11 Power Management

- Power consumption is typically a concern in battery-powered devices
  - More on this in the next lecture!
- AP beacons are periodic broadcasts advertising presence and configuration
- Power-save mode
  - Station ‘goes to sleep’ between beacons
  - Wakes-up for the beacon, which indicates whether any data is buffered for it
  - If there is, the station can request it from the AP
- APSD (Automatic Power Save Delivery)
  - Frames buffered at the AP
  - Only sent to a station just after it has received frames from it
  - Works well for frequent/balanced traffic, e.g. VoIP

Questions?