CS 497: Cybersecurity

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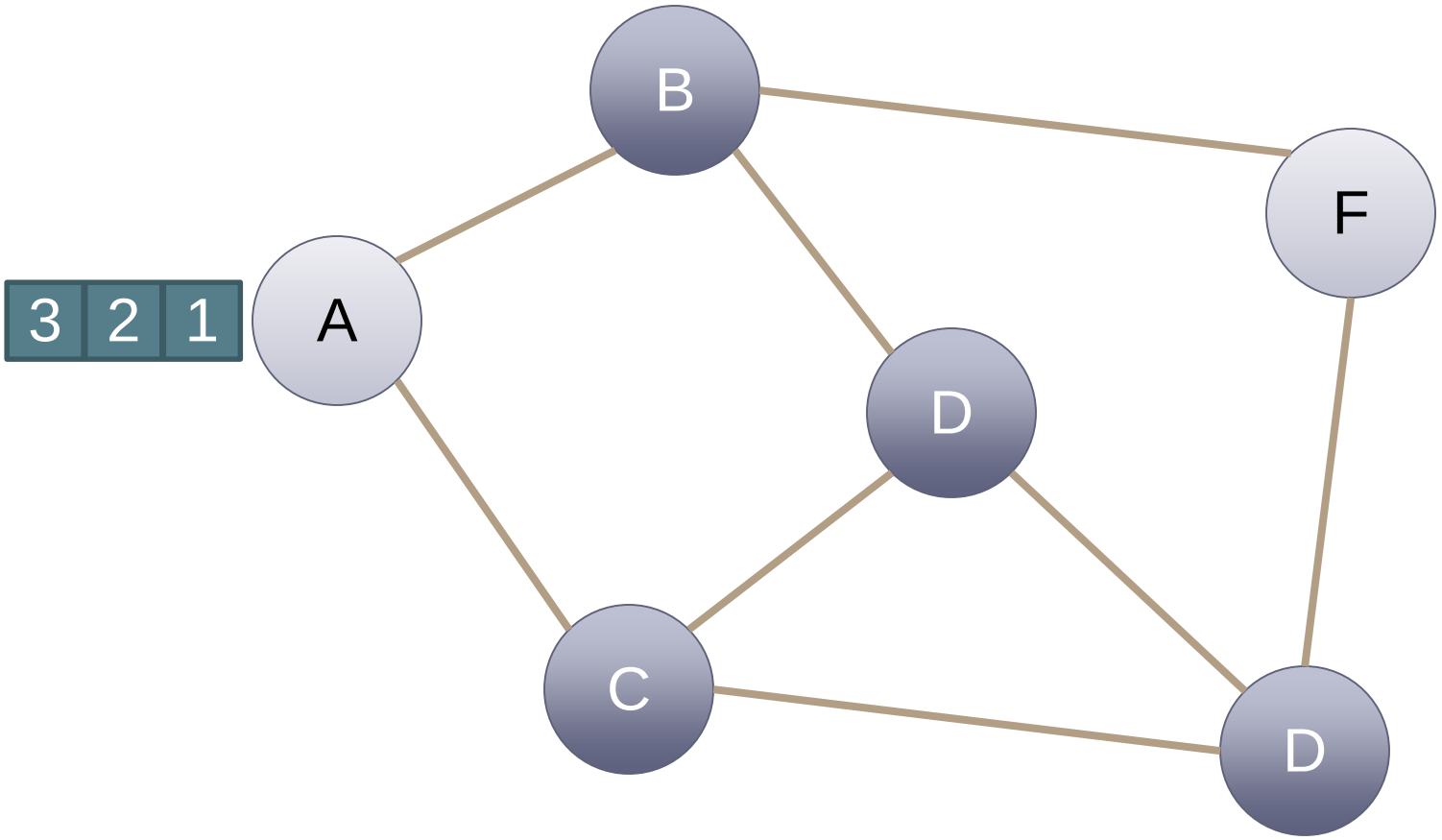
Computer Networks

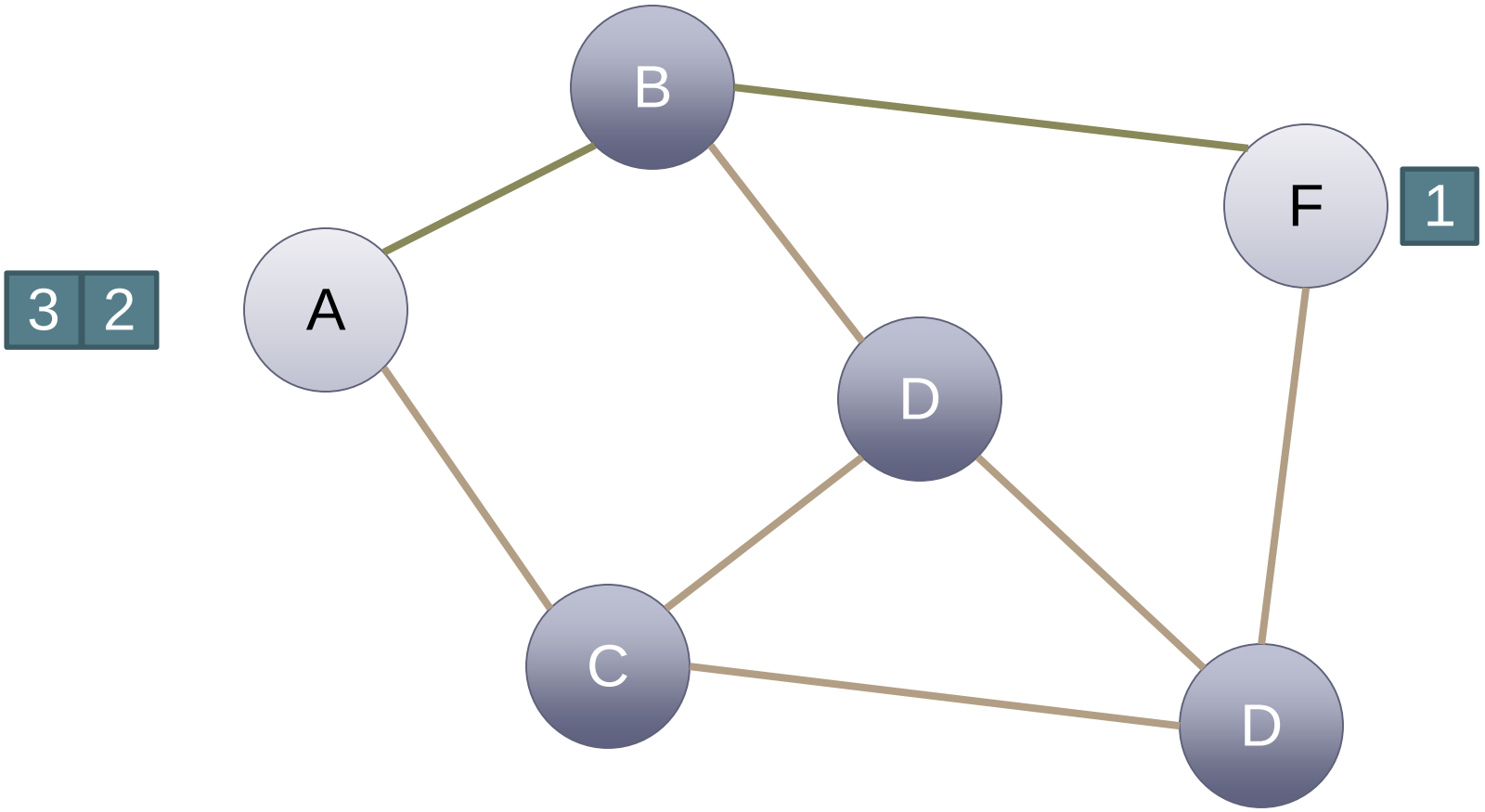
Circuit and Packet Switching

- **Circuit switching**
  - Legacy phone network
  - Single route through sequence of hardware devices established when two nodes start communication
  - Data sent along route
  - Route maintained until communication ends
- **Packet switching**
  - Internet
  - Data split into packets
  - Packets transported independently through network
  - Each packet handled on a best efforts basis
  - Packets may follow different routes

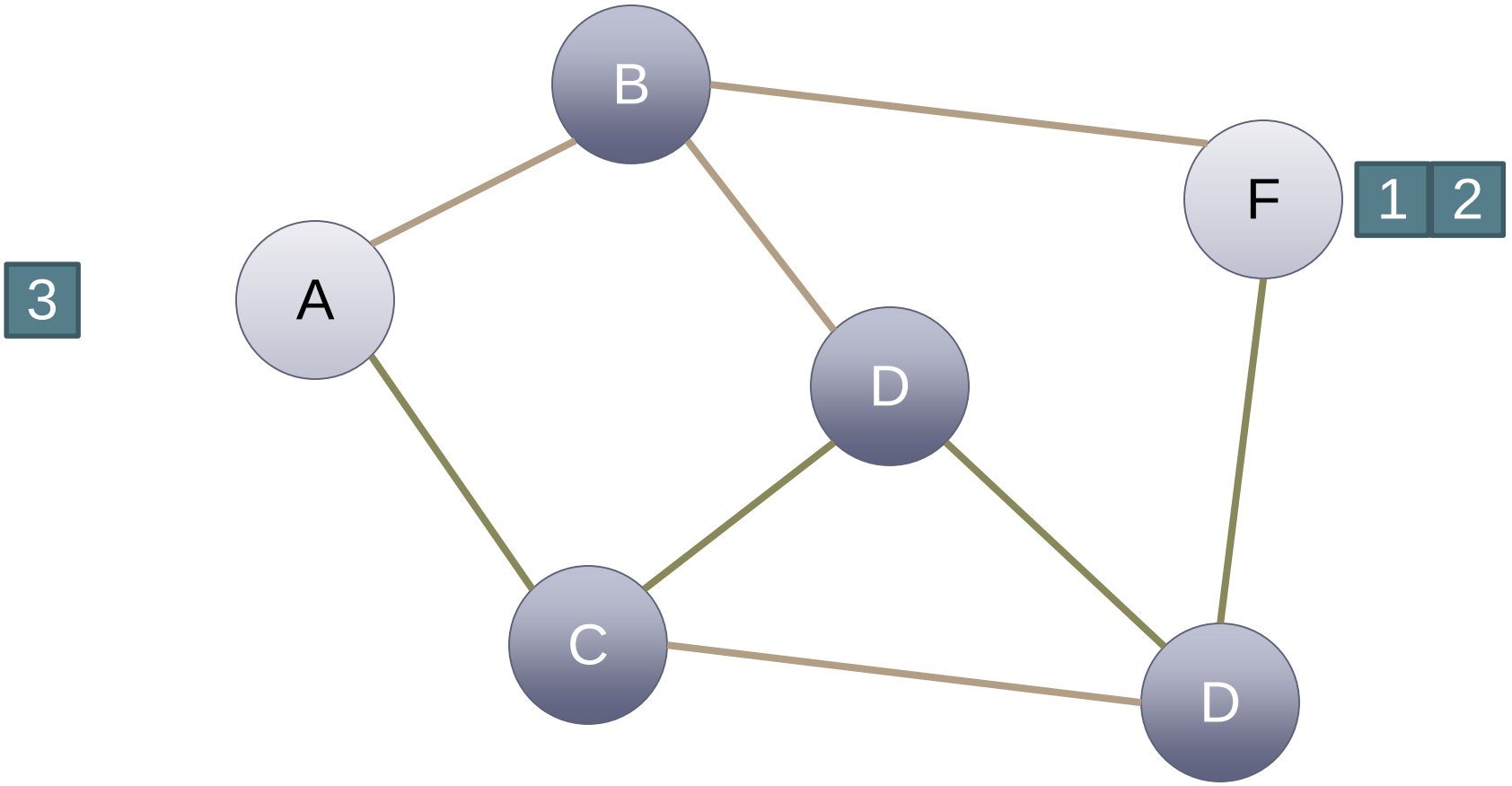
Packet Switching



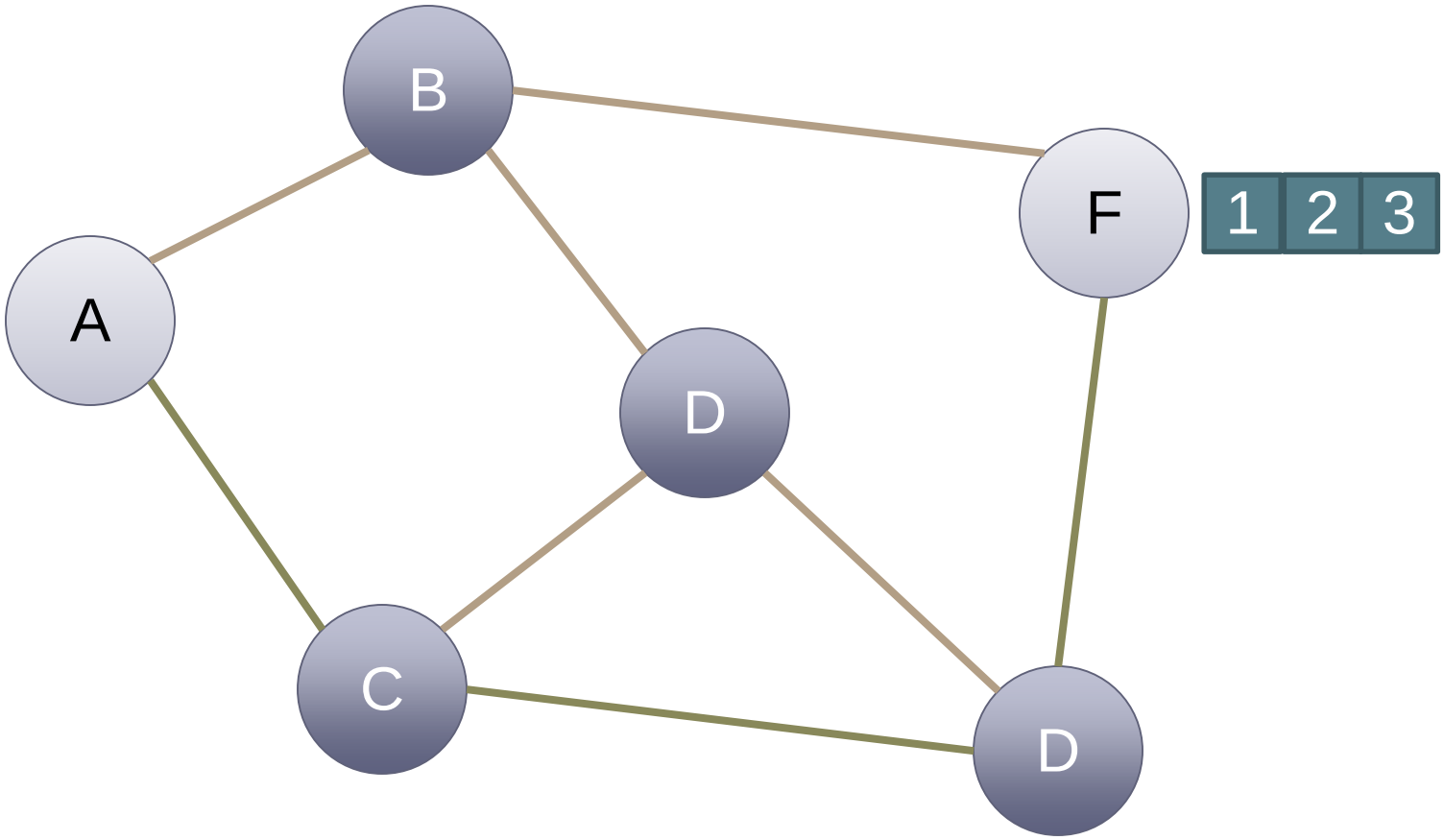
Packet Switching



Packet Switching

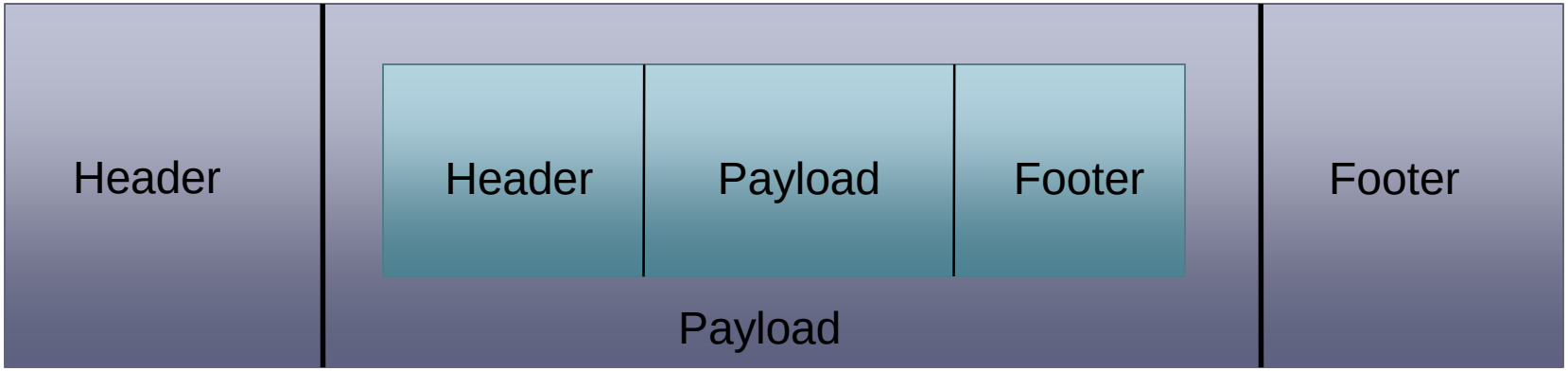


Packet Switching



Encapsulation

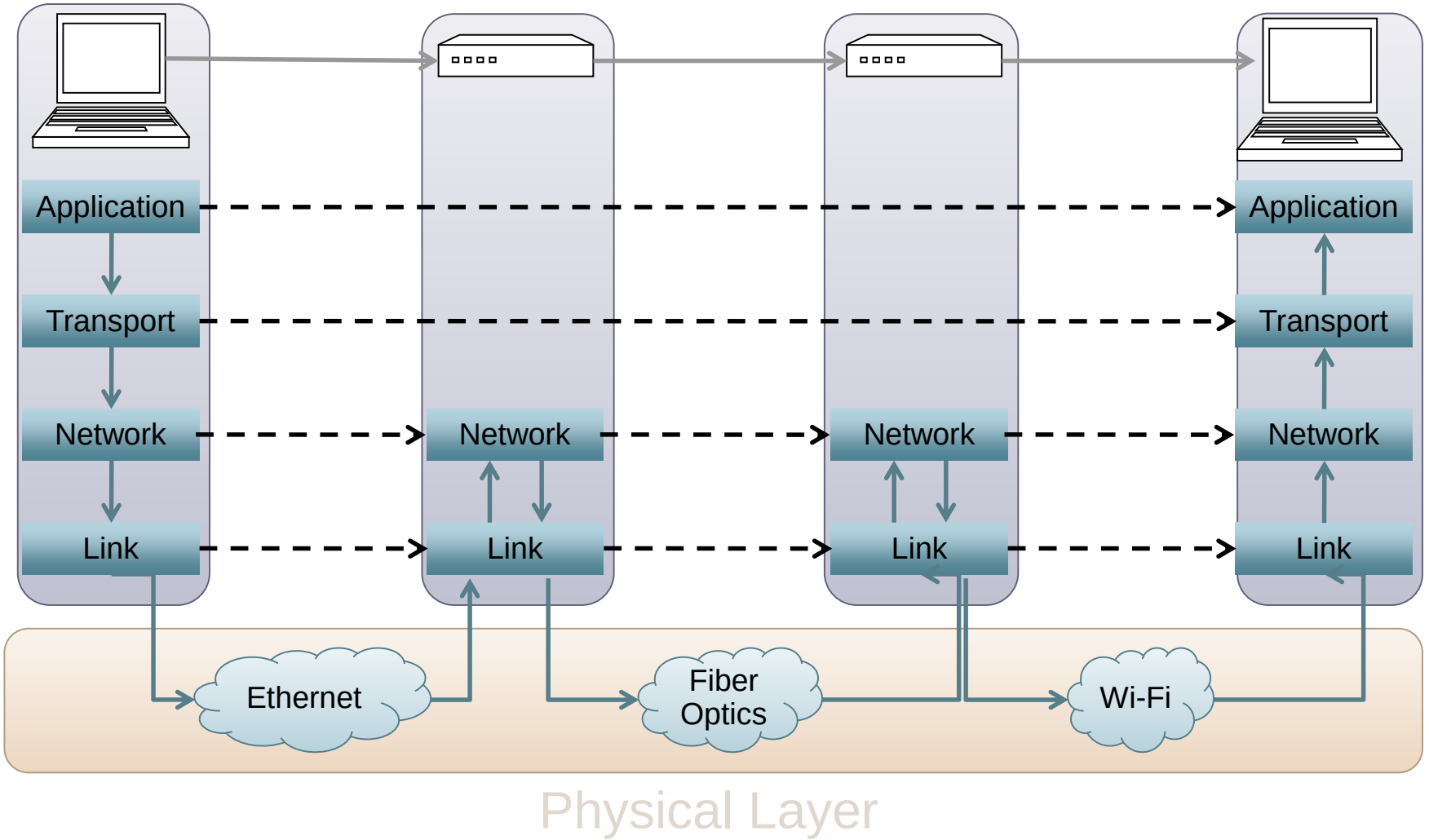
- **A packet typically consists of**
  - Control information for addressing the packet: header and footer
  - Data: payload
- **A network protocol N1 can use the services of another network protocol N2**
  - A packet p1 of N1 is encapsulated into a packet p2 of N2
  - The payload of p2 is p1
  - The control information of p2 is derived from that of p1



Network Layers

- **Network models typically use a stack of layers**
  - Higher layers use the services of lower layers via encapsulation
  - A layer can be implemented in hardware or software
  - The bottommost layer must be in hardware
- **A network device may implement several layers**
- **A communication channel between two nodes is established for each layer**
  - Actual channel at the bottom layer
  - Virtual channel at higher layers

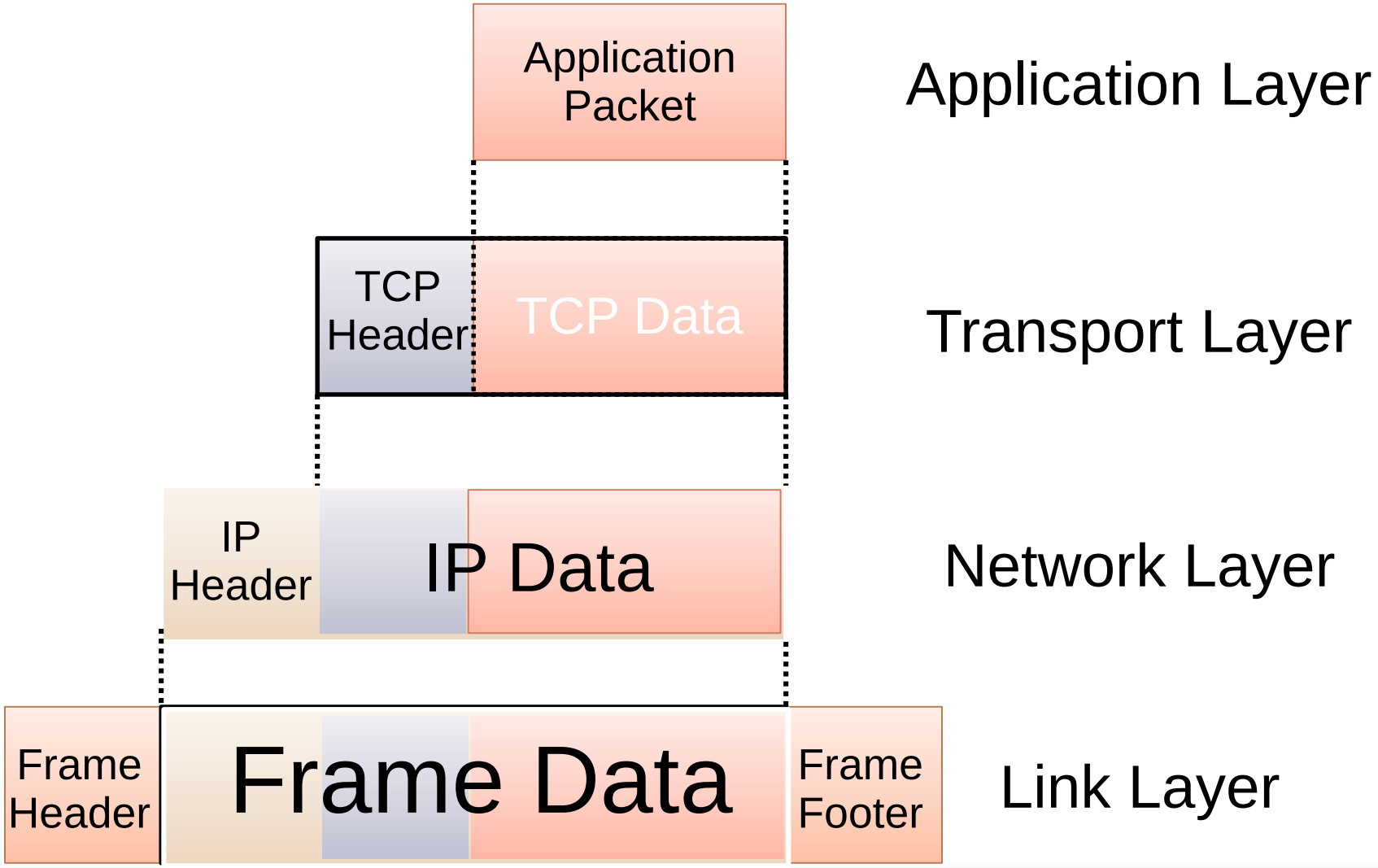
Internet Layers



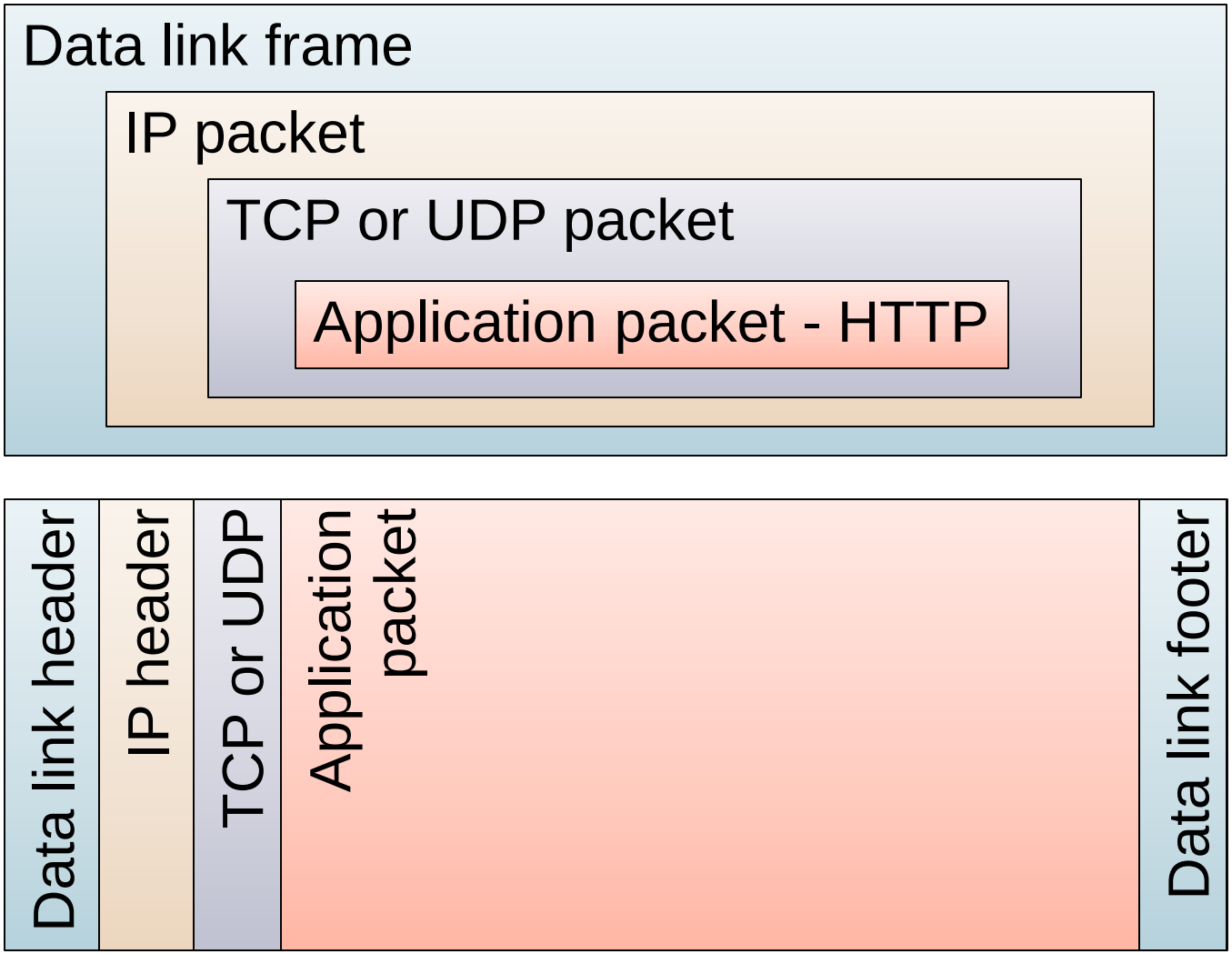
Intermediate Layers

- **Link layer**
  - Local area network: Ethernet, WiFi, optical fiber
  - 48-bit media access control (MAC) addresses
  - Packets called frames
- **Network layer**
  - Internet-wide communication
  - Best efforts
  - 32-bit internet protocol (IP) addresses in IPv4
  - 128-bit IP addresses in IPv6
- **Transport layer**
  - 16-bit addresses (ports) for classes of applications
  - Connection-oriented transmission layer protocol (TCP)
  - Connectionless user datagram protocol (UDP)

Internet Packet Encapsulation

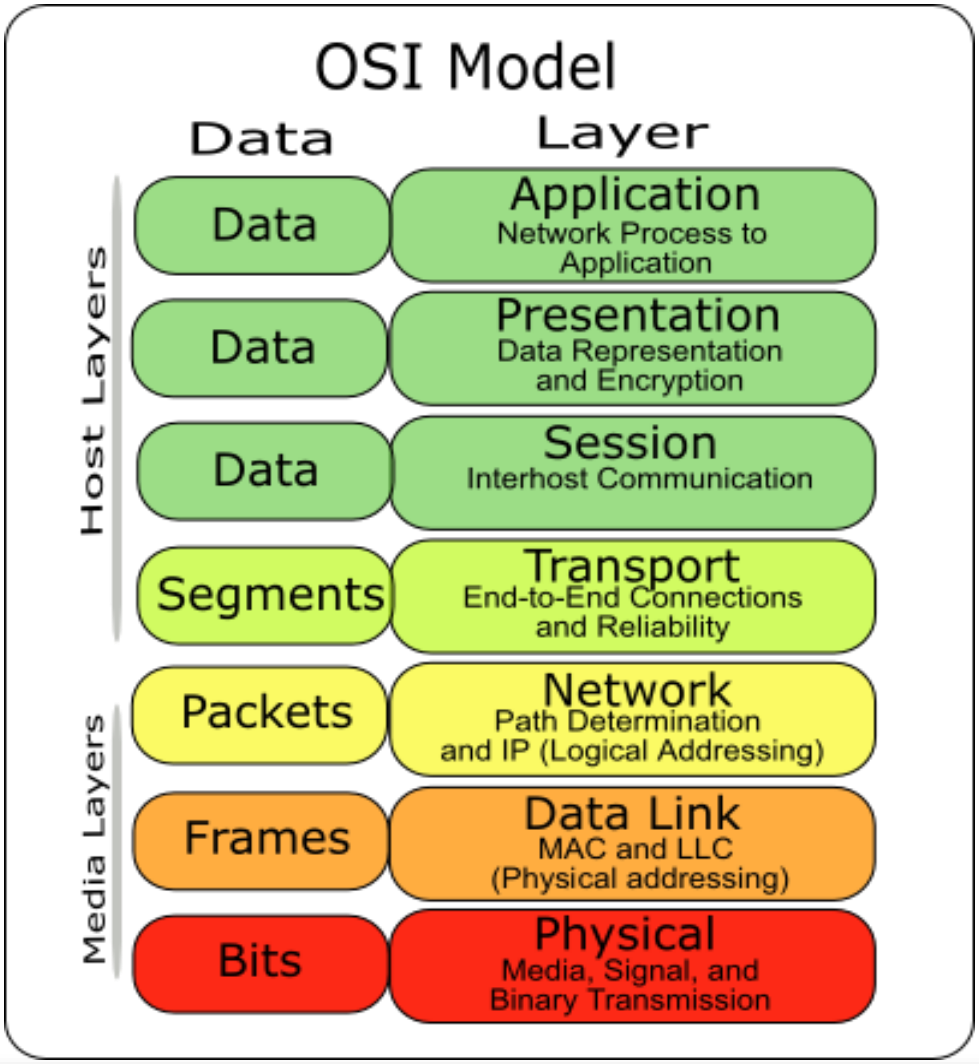


Internet Packet Encapsulation



The OSI Model

- **The OSI (Open System Interconnect) Reference Model is a network model consisting of seven layers**
- **Created in 1983, OSI is promoted by the International Standard Organization (ISO)**



Network Interfaces

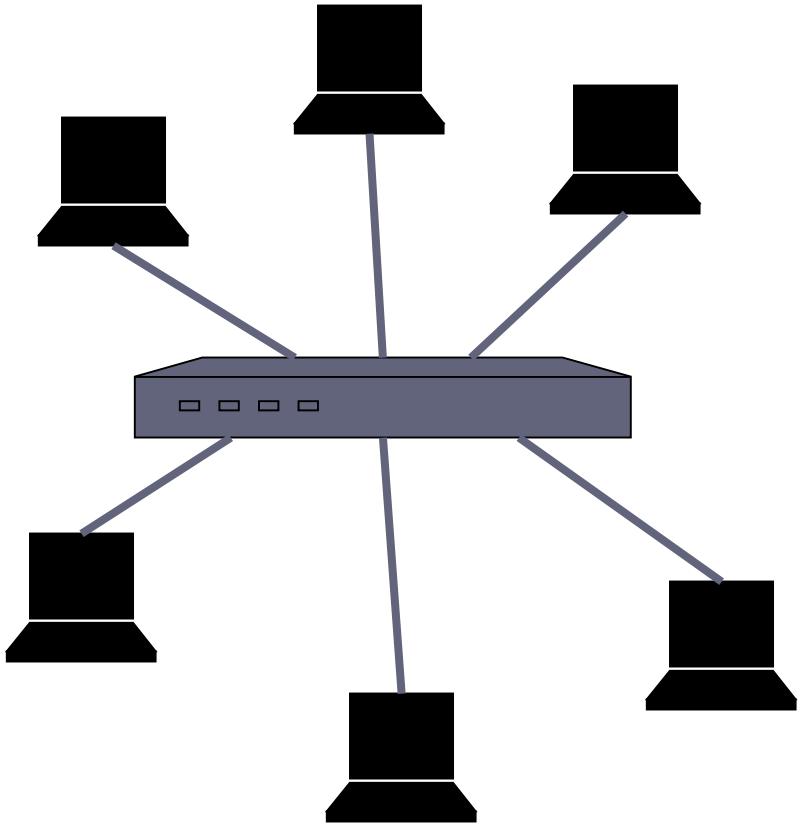
- **Network interface: device connecting a computer to a network**
  - Ethernet card
  - WiFi adapter
- **A computer may have multiple network interfaces**
- **Packets transmitted between network interfaces**
- **Most local area networks, (including Ethernet and WiFi) broadcast frames**
- **In regular mode, each network interface gets the frames intended for it**
- **Traffic sniffing can be accomplished by configuring the network interface to read all frames (promiscuous mode)**

MAC Addresses

- **Most network interfaces come with a predefined MAC address**
- **A MAC address is a 48-bit number usually represented in hex**
  - E.g., 00-1A-92-D4-BF-86
- **The first three octets of any MAC address are IEEE-assigned Organizationally Unique Identifiers**
  - E.g., Cisco 00-1A-A1, D-Link 00-1B-11, ASUSTek 00-1A-92
- **The next three can be assigned by organizations as they please, with uniqueness being the only constraint**
- **Organizations can utilize MAC addresses to identify computers on their network**
- **MAC address can be reconfigured by network interface driver software**

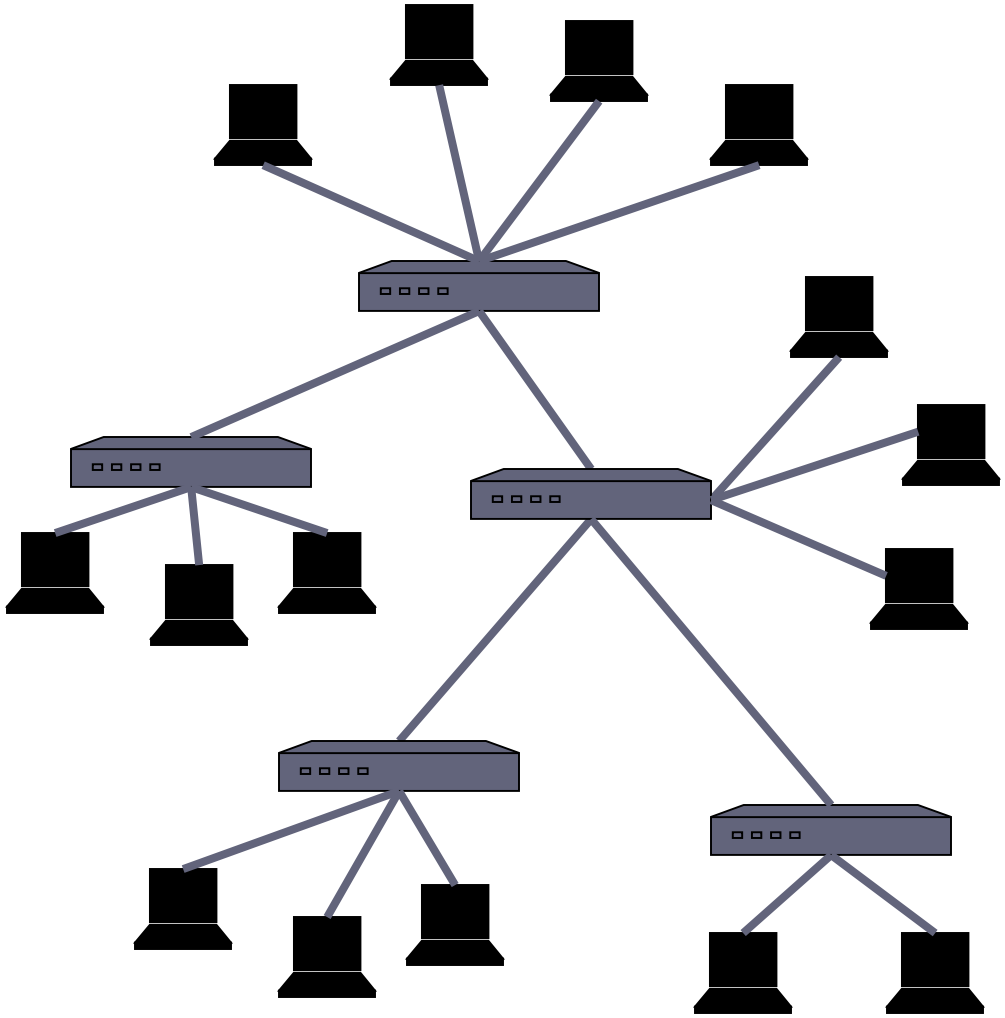
Switch

- **A switch is a common network device**
  - Operates at the link layer
  - Has multiple ports, each connected to a computer
- **Operation of a switch**
  - Learn the MAC address of each computer connected to it
  - Forward frames only to the destination computer



Combining Switches

- **Switches can be arranged into a tree**
- **Each port learns the MAC addresses of the machines in the segment (subtree) connected to it**
- **Fragments to unknown MAC addresses are broadcast**
- **Frames to MAC addresses in the same segment as the sender are ignored**



MAC Address Filtering

- **A switch can be configured to provide service only to machines with specific MAC addresses**
- **Allowed MAC addresses need to be registered with a network administrator**
- **A MAC spoofing attack impersonates another machine**
  - Find out MAC address of target machine
  - Reconfigure MAC address of rogue machine
  - Turn off or unplug target machine
- **Countermeasures**
  - Block port of switch when machine is turned off or unplugged
  - Disable duplicate MAC addresses

Viewing and Changing MAC Addresses

- Viewing the MAC addresses of the interfaces of a machine
  - Linux: ifconfig
  - Windows: ipconfig /all
- Changing a MAC address in Linux
  - Stop the networking service: /etc/init.d/networking stop
  - Change the MAC address: ifconfig eth0 hw ether <MAC-address>
  - Start the networking service: /etc/init.d/networking start
- **Changing a MAC address in** Windows
  - Open the Network Connections applet
  - Access the properties for the network interface
  - Click "Configure …"
  - In the advanced tab, change the network address to the desired value
- Changing a MAC address requires administrator privileges

ARP

- The address resolution protocol (ARP) connects the network layer to the data layer by converting IP addresses to MAC addresses
- ARP works by broadcasting requests and caching responses for future use
- The protocol begins with a computer broadcasting a message of the form

  who has <IP address1> tell <IP address2>
- When the machine with <IP address1> or an ARP server receives this message, its broadcasts the response

  <IP address1> is <MAC address>
- The requestor's IP address <IP address2> is contained in the link header
- The Linux and Windows command arp - a displays the ARP table

Internet Address	Physical Address	Type
128.148.31.1	00-00-0c-07-ac-00	dynamic
128.148.31.15	00-0c-76-b2-d7-1d	dynamic
128.148.31.71	00-0c-76-b2-d0-d2	dynamic
128.148.31.75	00-0c-76-b2-d7-1d	dynamic
128.148.31.102	00-22-0c-a3-e4-00	dynamic
128.148.31.137	00-1d-92-b6-f1-a9	dynamic

ARP Spoofing

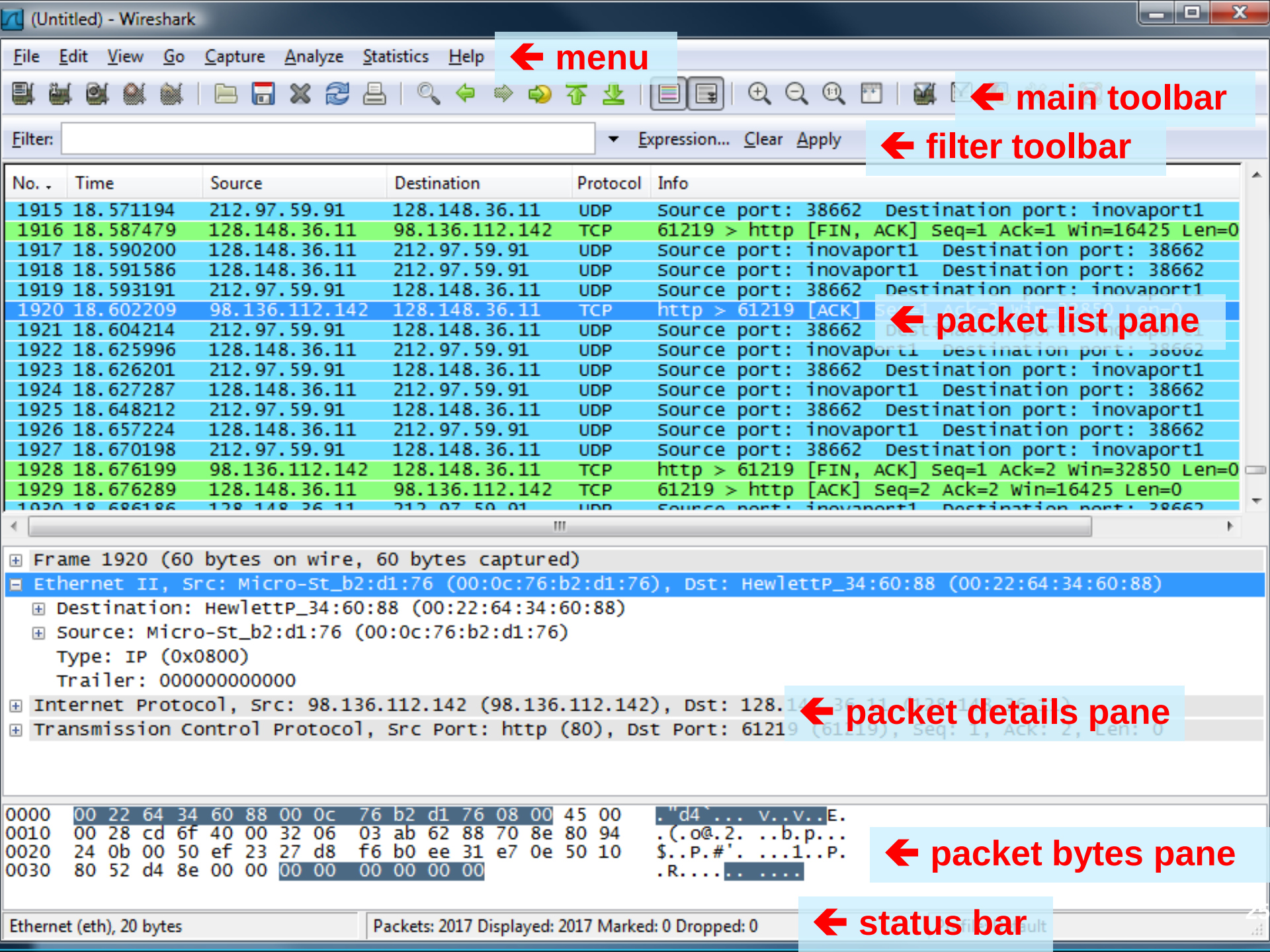
- **The ARP table is updated whenever an ARP response is received**
- **Requests are not tracked**
- **ARP announcements are not authenticated**
- **Machines trust each other**
- **A rogue machine can spoof other machines**

ARP Poisoning (ARP Spoofing)

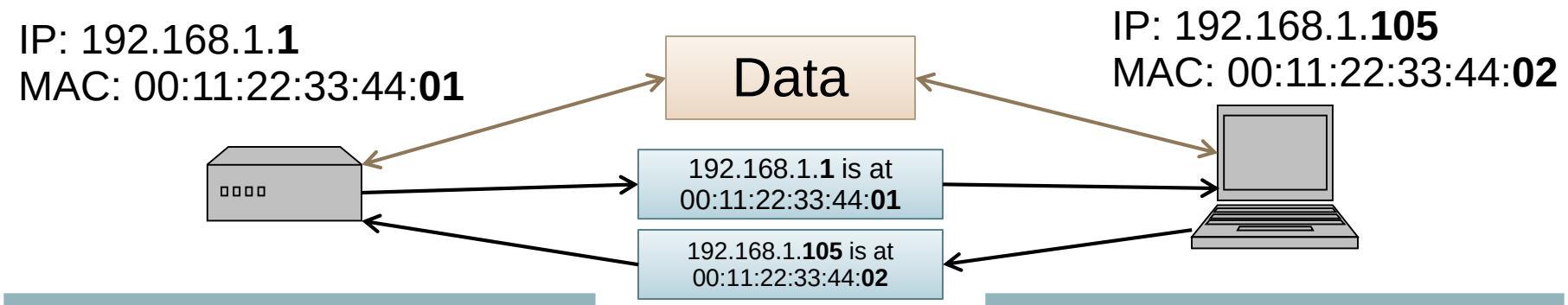
- **According to the standard, almost all ARP implementations are stateless**
- **An arp cache updates every time that it receives an arp reply… even if it did not send any arp request!**
- **It is possible to "poison" an arp cache by sending gratuitous arp replies**
- **Using static entries solves the problem but it is almost impossible to manage!**

Wireshark

- **Wireshark is a packet sniffer and protocol analyzer**
  - Captures and analyzes frames
  - Supports plugins
- **Usually required to run with administrator privileges**
- **Setting the network interface in promiscuous mode captures traffic across the entire LAN segment and not just frames addressed to the machine**
- **Freely available on www.wireshark.org**


(Untitled) - Wireshark
File Edit View Go Capture Analyze Statistics Help
menu
main toolbar
Filter:
Expression... Clear Apply
filter toolbar
No. Time Source Destination Protocol Info
1915 18.571194 212.97.59.91 128.148.36.11 UDP Source port: 38662 Destination port: inovaport1
1916 18.587479 128.148.36.11 98.136.112.142 TCP 61219 > http [FIN, ACK] Seq=1 Ack=1 Win=16425 Len=0
1917 18.590200 128.148.36.11 212.97.59.91 UDP Source port: inovaport1 Destination port: 38662
1918 18.591586 128.148.36.11 212.97.59.91 UDP Source port: inovaport1 Destination port: 38662
1919 18.593191 212.97.59.91 128.148.36.11 UDP Source port: 38662
1920 18.602209 98.136.112.142 128.148.36.11 TCP http > 61219 [ACK]
1921 18.604214 212.97.59.91 128.148.36.11 UDP Source port: 38662
1922 18.625996 128.148.36.11 212.97.59.91 UDP
1923 18.626201 212.97.59.91 128.148.36.11 UDP Source port: 38662 Destination port: inovaport1
1924 18.627287 128.148.36.11 212.97.59.91 UDP Source port: inovaport1 Destination port: 38662
1925 18.648212 212.97.59.91 128.148.36.11 UDP Source port: 38662 Destination port: inovaport1
1926 18.657224 128.148.36.11 212.97.59.91 UDP Source port: inovaport1 Destination port: 38662
1927 18.670198 212.97.59.91 128.148.36.11 UDP Source port: 38662 Destination port: inovaport1
1928 18.676199 98.136.112.142 128.148.36.11 TCP http > 61219 [FIN, ACK] Seq=1 Ack=2 Win=32850 Len=0
1929 18.676289 128.148.36.11 98.136.112.142 TCP 61219 > http [ACK] Seq=2 Ack=2 Win=16425 Len=0
packet list pane
Frame 1920 (60 bytes on wire, 60 bytes captured)
Ethernet II, Src: Micro-St_b2:d1:76 (00:0c:76:b2:d1:76), Dst: HewlettP_34:60:88 (00:22:64:34:60:88)
Destination: HewlettP_34:60:88 (00:22:64:34:60:88)
Source: Micro-St_b2:d1:76 (00:0c:76:b2:d1:76)
Type: IP (0x0800)
Trailer: 000000000000
Internet Protocol, Src: 98.136.112.142 (98.136.112.142), Dst: 128.
Transmission Control Protocol, Src Port: http (80), Dst Port: 6121
packet details pane
0000 00 22 64 34 60 88 00 0c 76 b2 d1 76 08 00 45 00 ."d4`... v..v..E.
0010 00 28 cd 6f 40 00 32 06 03 ab 62 88 70 8e 80 94 .(.o@.2. ..b.p...
0020 24 0b 00 50 ef 23 27 d8 f6 b0 ee 31 e7 0e 50 10 $..P.#'. ...1..P.
0030 80 52 d4 8e 00 00 00 00 00 00 00 00 .R...... ....
packet bytes pane
Ethernet (eth), 20 bytes
Packets: 2017 Displayed: 2017 Marked: 0 Dropped: 0
status bar

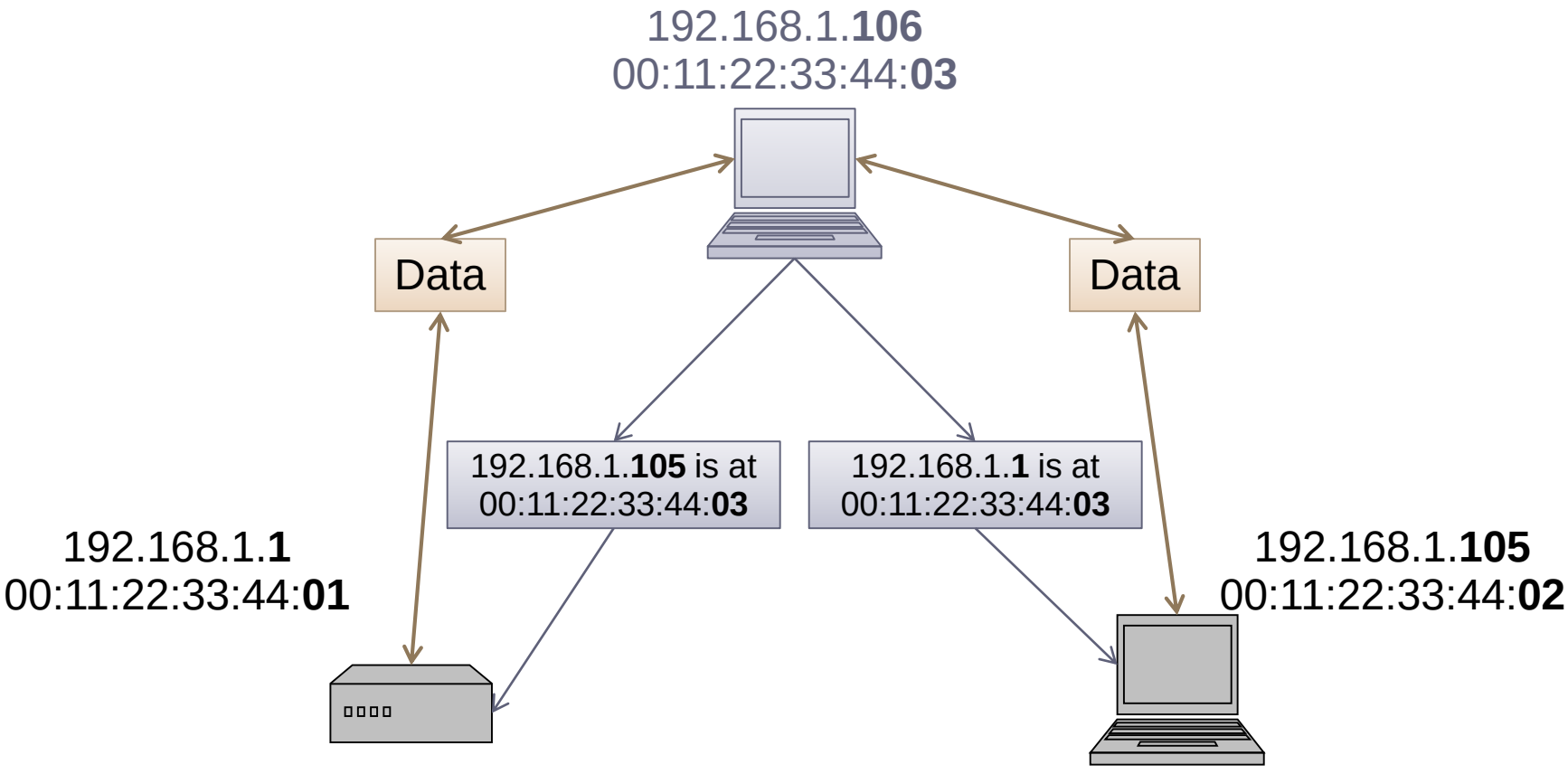
ARP Caches



ARP Cache	
192.168.1.105	**00:11:22:33:44:02**

ARP Cache	
192.168.1.1	**00:11:22:33:44:01**

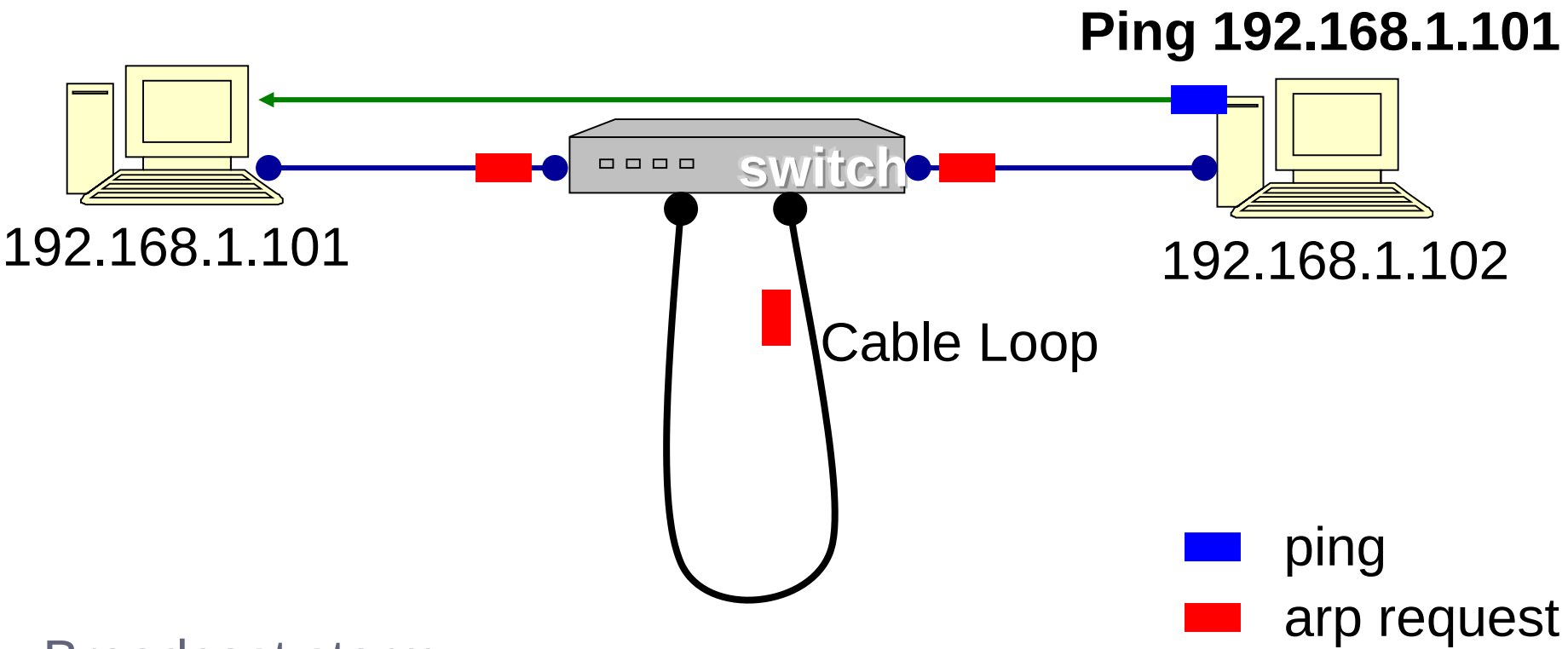
Poisoned ARP Caches



Poisoned ARP Cache	
192.168.1.105	00:11:22:33:44:03

Poisoned ARP Cache	
192.168.1.1	00:11:22:33:44:03

Network DoS using ARP



Broadcast storm

How can it be avoided?