ITEC 414
Network Programming

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Five Layer Model and Applications

Overview

- We turn our attention to TCP/IP software model beginning with Application layer and work our way down through the Transport, Network, Data Link, and Physical layers.
- When we get to the Transport layer, we will discuss the differences between TCP and User Datagram Protocol (UDP) and explain why specific applications use one instead of the other.
- We will also briefly describe some common TCP/IP applications (HTTP, DNS, DHCP, etc...)

Basic Needs for TCP/IP Communication

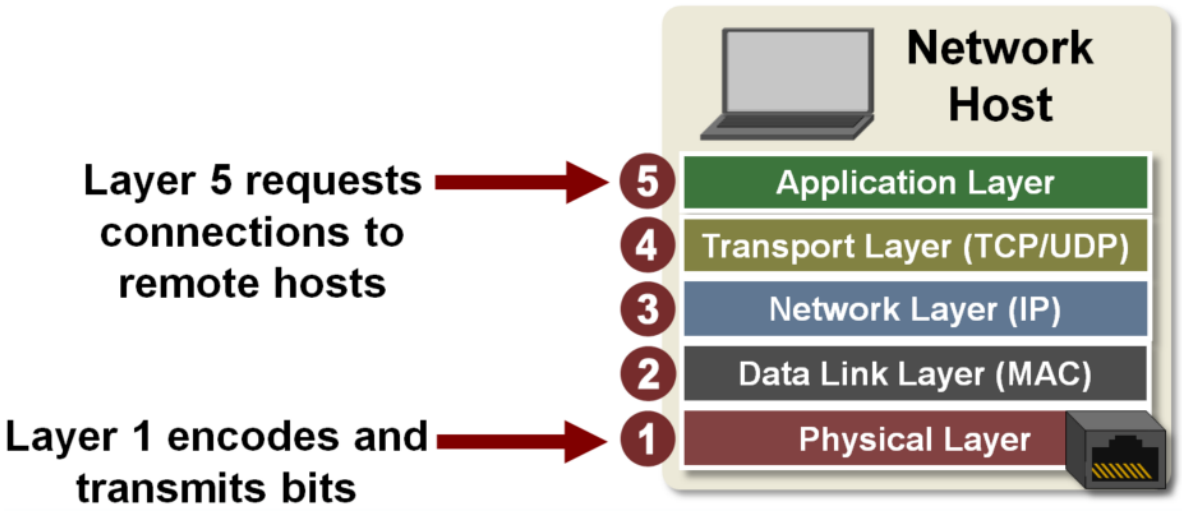
- Some of the applications we use require us to move data across a network from point A to point B.
- The **Transmission Control Protocol/Internet Protocol** (TCP/IP) network provides a framework for transmitting this data, and it requires some basic information from us to move this data.

Basic Needs for TCP/IP Communication

- We need to specify if we want the most reliable or fastest transmissions and we need to specify where we want the data delivered.
- Sometimes our data is routed based on its **IP addresses** and sometimes its routed based on its **MAC address**.
- The data we send needs both addressing capabilities.
- This information needs to be sent along with all transmitted data. We also need to physically transmit the data from one location to another.

TCP/IP Five Layer Software Model

- We need to provide this basic information needed by TCP/IP in a standard format the network can understand.
- This format is provided by its five-layer software model. Each layer provides TCP/IP with the basic information it needs to move our data across the network. These layers group functions according to the task that needs to be performed. Every function in this model is targeted to help a specific layer perform its job.



You are probably familiar with the seven-layer OSI model. TCP/IP simplifies this model to five layers. OSI stands for Open Systems Interconnect which is a standard communication systems model. The top four layers of the seven layer OSI model have been condensed into the top two TCP/IP layers.

TCP/IP Five Layer Software Model

- Each layer only communicates with adjacent layers.
- Software running in a higher layer does not have to know about or perform tasks delegated to lower layer functions and vice versa.
- For example, the software you write for your application only needs to know how to request a connection with a remote host using the Transport layer.
- It doesn't need to know how bits are encoded before transmission. That is the Physical layer's job.

TCP/IP Five Summary

Application Layer

The Application layer is where applications requiring network communications live. Examples of these applications include email clients and web browsers. These applications use the Transport Layer to send requests to connect to remote hosts.

TCP/IP Five Summary

Transport Layer

The Transport layer establishes the connection between applications running on different hosts. It uses TCP for reliable connections and UDP for fast connections. It keeps track of the processes running in the applications above it by assigning port numbers to them and uses the Network layer to access the TCP/IP network.

Network Layer

The Network layer is responsible for creating the packets that move across the network. It uses IP addresses to identify the packet's source and destination.

Data Link Layer

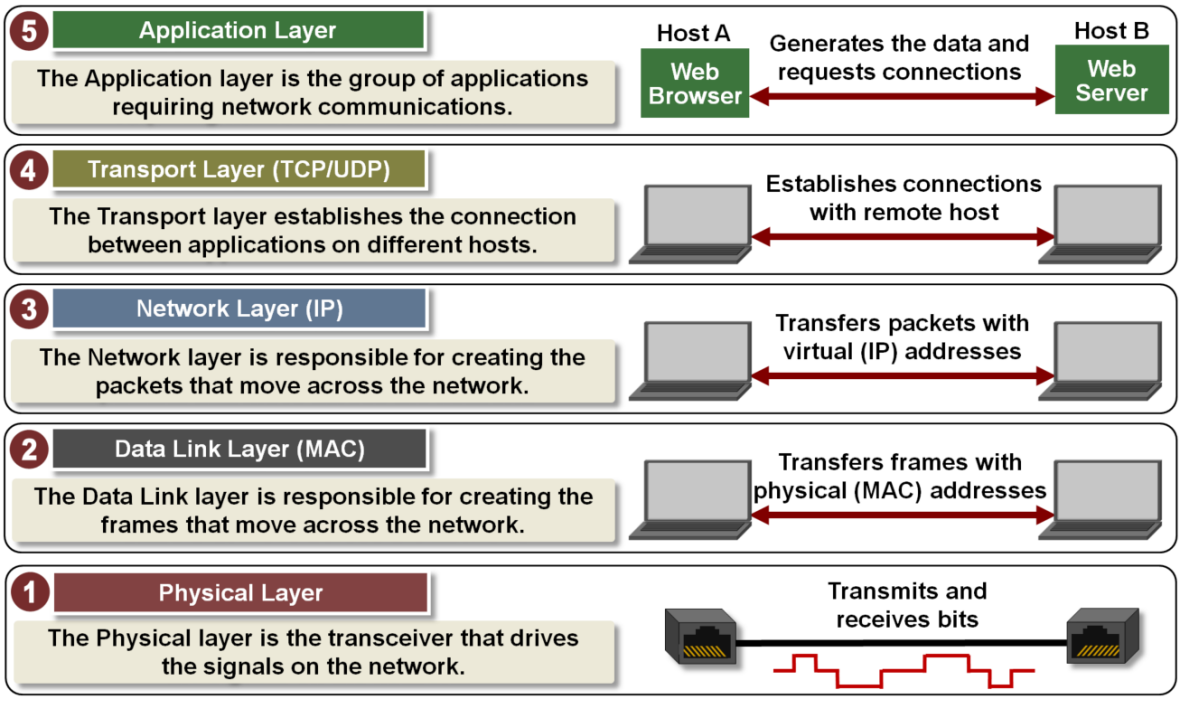
The Data Link layer is responsible for creating the frames that move across the network. These frames encapsulate the packets and use MAC addresses to identify the source and destination.

TCP/IP Five Summary

Physical Layer

The Physical layer encodes and decodes the bits found in a frame and includes the transceiver that drives and receives the signals on the network.

TCP/IP Five Summary



Transmit Data Using Network Layers

- Now that we know the primary job of each layer, let's see how they work together to send and receive data across a TCP/IP network.
- This is a simplified view of how the network layers work together to generate frames. Higher layers pass information to lower layers.
- Each layer adds information called a header to the data being passed to it. This header contains information the layer needs to perform its job.
- We start at the Application layer.

Transmit Data Using Network Layers

Application Layer

The Application layer generates a message. In this case, the specific application is a web browser requesting a webpage download. This message is then sent to the Transport layer.

Transport Layer

The Transport layer adds the TCP or UDP header which includes the source and destination port addresses. Additional information like the packet sequence number used for TCP will also be added to the header. The data generated by the transport layer is referred to as a Segment if TCP is used, and is referred to as a Datagram if UDP is used. This segment is then sent to the Network layer.

Transmit Data Using Network Layers

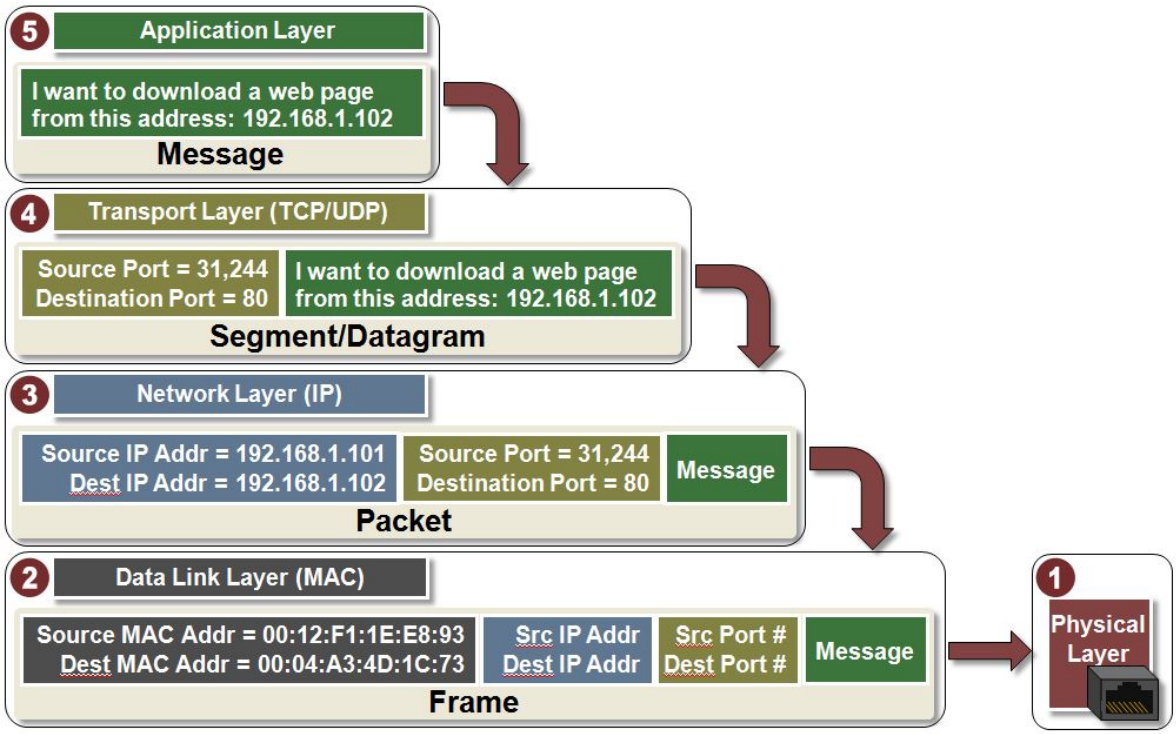
Network Layer

The Network layer adds a header including the source and destination IP address to generate a packet. This packet is then sent to the Data Link layer.

Transmit Data Using Network Layers

Data Link Layer The Data Link layer adds a header containing the MAC address information to create a frame. The frame is then sent it to the Physical layer to transmit the bits.

Transmit Data Using Network Layers



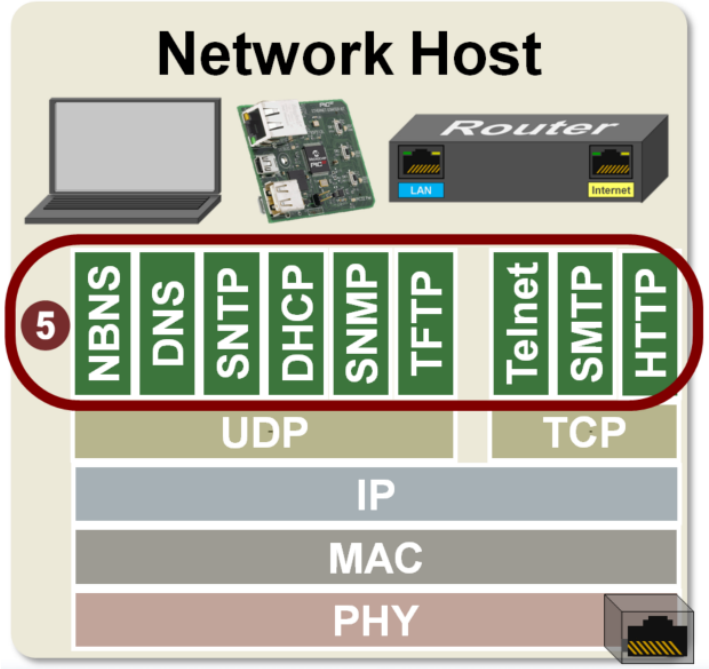
TCP/IP Terminology Reference

Layer #	Layer Name	Protocol	Protocol Data Unit	Addressing
5	Application	HTTP, SMTP, etc…	Messages	n/a
4	Transport	TCP/UDP	Segments/ Datagrams	Port #s
3	Network or Internet	IP	Packets	IP Address
2	Data Link	Ethernet, Wi-Fi	Frames	MAC Address
1	Physical	10 Base T, 802.11	Bits	n/a

Application Layer (Layer 5)

- The top layer or layer 5 is called the Application layer.
- This is where most Transmission Control Protocol/Internet Protocol (TCP/IP) applications live.
- The software you generate for your end application will typically interact with some of these applications.
- The most commonly used TCP/IP application is HTTP (Hypertext Transport Protocol) which is used for surfing the internet.

Application Layer (Layer 5)



Common Applications

Application	Description
DHCP	Dynamic Host Configuration Protocol assigns IP addresses
DNS	Domain Name System translates website names to IP addresses
HTTP	Hypertext Transfer Protocol used to transfer web pages
NBNS	NetBIOS Name Service translates local host names to IP addresses
SMTP	Simple Mail Transfer Protocol sends email messages
SNMP	Simple Network Management Protocol manages network devices
SNTP	Simple Network Time Protocol provides time of day
Telnet	Bi-directional text communication via a terminal application
TFTP	Trivial File Transfer Protocol used to transfer small amounts of data

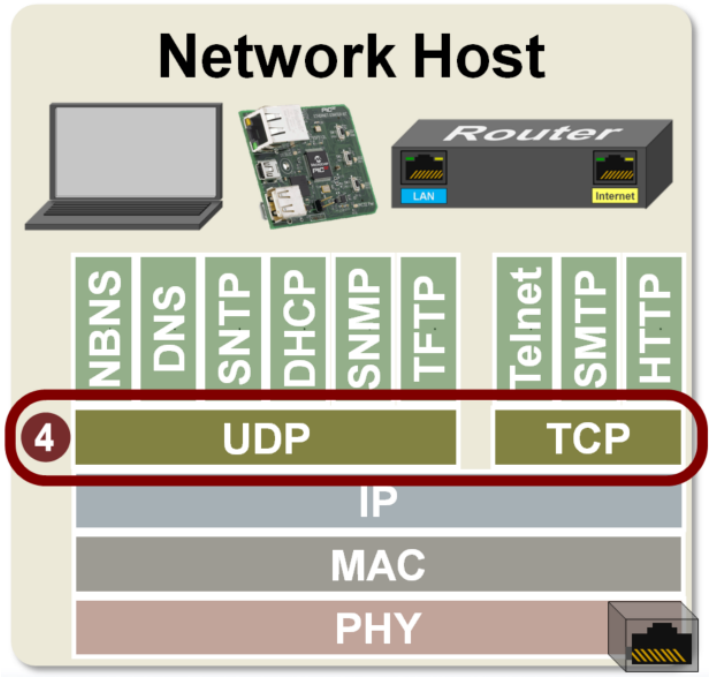
Transport Layer (Layer 4)

- Layer 4 is the Transport layer.
- The transport layer creates virtual Transfer Control Protocol (TCP) or User Datagram Protocol (UDP) connections between network hosts.
- This layer sends and receives data to and from the applications running on its host.

Transport Layer (Layer 4)

- The Transport layer assigns port numbers to the processes running in applications on the host and adds a TCP or UDP header to the messages received from the applications detailing the source and destination port numbers.
- Note that some of the applications, specifically Telnet, SMTP, and HTTP require TCP as the transport protocol while the others use UDP.

Transport Layer (Layer 4)



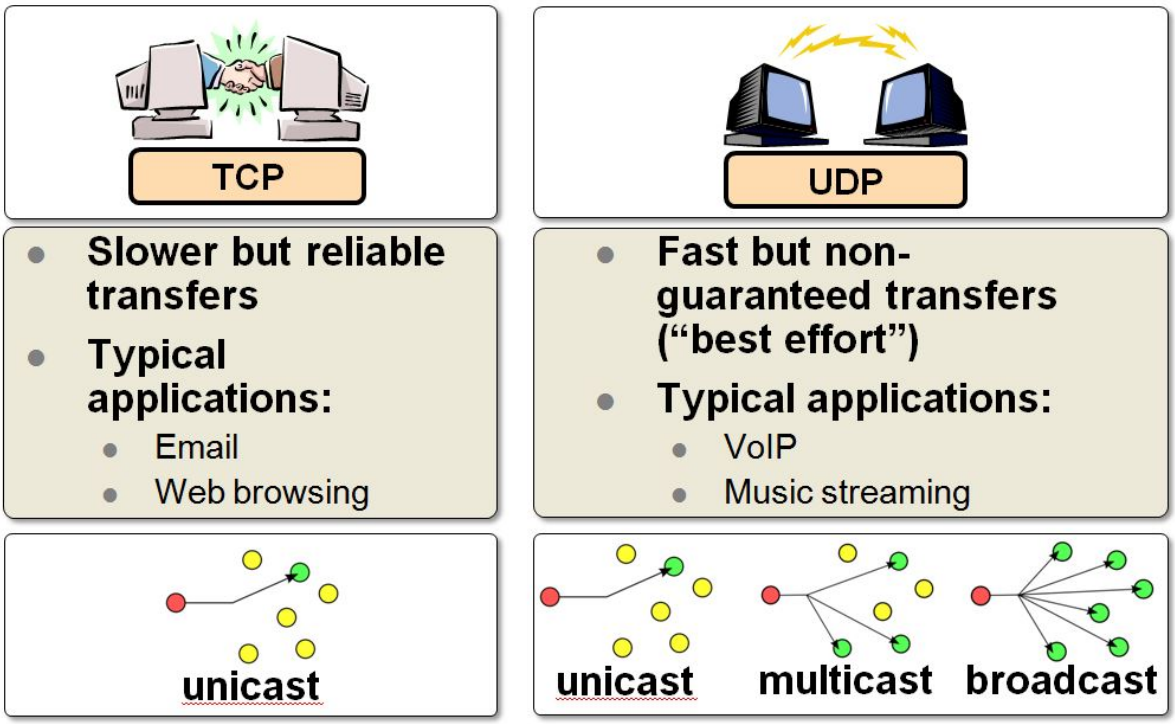
Transport Layer (Layer 4)

- Some applications require reliable ordered delivery of packets. The TCP protocol provides this capability.
- It uses error detection, retransmissions and acknowledgements. This protocol cares about your data.

Transport Layer (Layer 4)

- Other applications don't care if every packet is received. These applications can take advantage UDP's lower overhead to enable faster transmissions.
- Typical TCP applications include email and web browsing and typical UDP applications include VoIP and music streaming.
- TCP is strictly used for point to point or unicast transmissions while UDP can also be used for multicast and broadcast transmissions.

Transport Layer (Layer 4)



TCP and UDP Headers

- The header added to messages by the Transport layer includes more than just the source and destination port numbers.
- The following are all the information included in TCP and UDP headers.
- Note how the TCP protocol requires more information and overhead to guarantee data delivery.

TCP and UDP Headers

TCP Segment Header Format

Bit #	0 – 7	8 – 15	16 – 23	24 – 31
0	Source Port		Destination Port	
32	Sequence Number			
64	Acknowledgment Number			
96	Data Offset	Res	Flags	Window Size
128	Header and Data Checksum		Urgent Pointer	
160...	Options			

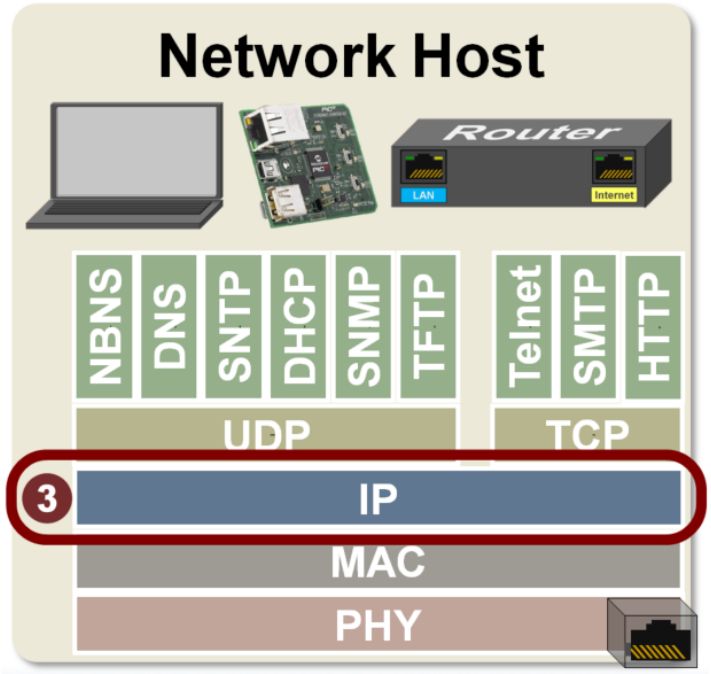
UDP Datagram Header Format

Bit #	0 – 7	8 – 15	16 – 23	24 – 31
0	Source Port		Destination Port	
32	Length		Header and Data Checksum	

Network Layer (Layer 3)

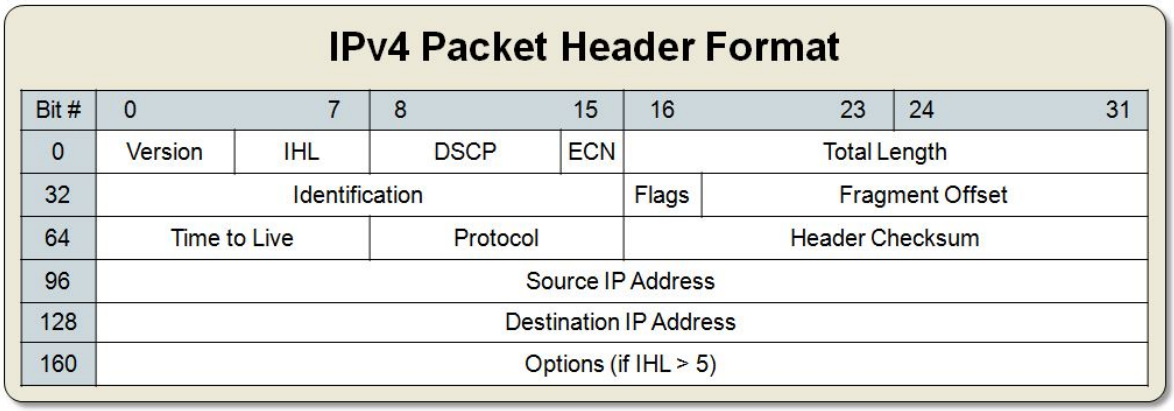
- Layer 3 is the Network or Internet layer.
- When transmitting data, this layer adds a header containing the source and destination IP addresses to the to the data received from the Transport layer.
- The packet it creates will then be forwarded to the MAC or Data Link layer.
- When receiving data, this layer is used to determine if the packet received by the host contains the host's IP address.
- If it does, the data is forwarded up to the Transport layer.

Network Layer (Layer 3)



Routers are referred to as "layer 3" devices because they route packets based on their IP addresses.

Network Layer (Layer 3)

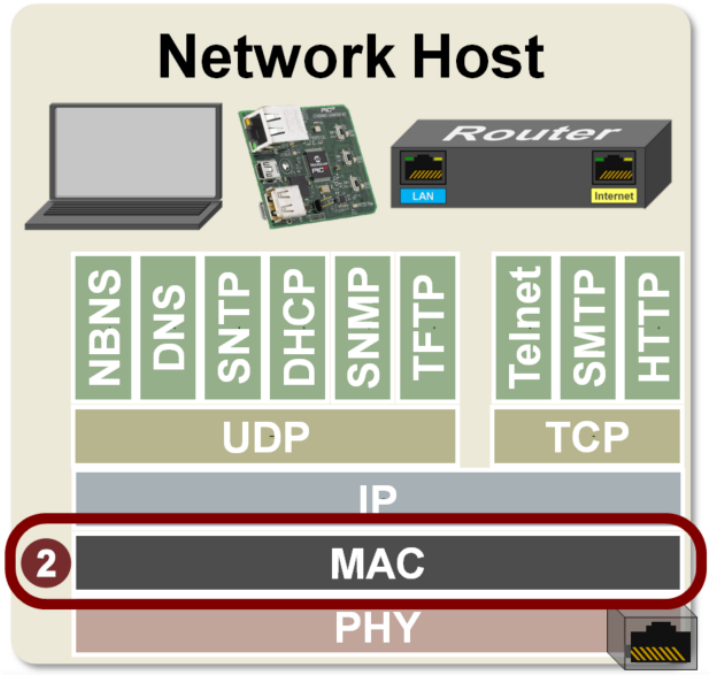


The Network layer header includes more than just the source and destination IP addresses.

Data Link Layer (Layer 2)

- Layer 2 is the Data Link layer.
- This layer uses a **Media Access Controller** (MAC) to generate the frames that will be transmitted.
- As the name suggests, the MAC controls the physical transmission media.
- The wireless transmission media used for Wi-Fi® or 802.11 has different requirements from the wired transmission media used for Ethernet or 802.3, and therefore needs a different MAC and PHY.
- Note the upper layer software is not aware of or affected by the physical interface.

Data Link Layer (Layer 2)



Data Link Layer (Layer 2)

- When transmitting data, this layer adds a header containing the source and destination MAC addresses to the packet received from the Network layer (layer 3).
- The frame it creates will then be forwarded to the Physical layer.
- When receiving data, this layer is used to determine if the frame received by the host contains the host's MAC address.

Data Link Layer (Layer 2)

- If it does, the data is forwarded up to the Network layer.
- Every host on the network has at least one MAC address. Laptops typically have two: one for the wired LAN and one for the wireless LAN. Home routers also typically have two MACs: one for the local network and one for the Internet.
- Note that most switches are referred to as “layer 2” devices because they route frames based on their MAC addresses.

Ethernet and WiFi Frame Format

Ethernet (802.3) Frame Format

7 bytes	1 byte	6 bytes	6 bytes	2 bytes	42 to 1500 bytes	4 bytes	12 bytes
Preamble	Start of Frame Delimiter	**Destination MAC Address**	**Source MAC Address**	Type	Data (payload)	CRC	Inter-frame gap

For TCP/IP communications, the payload for a frame is a packet

WiFi (802.11) Frame Format

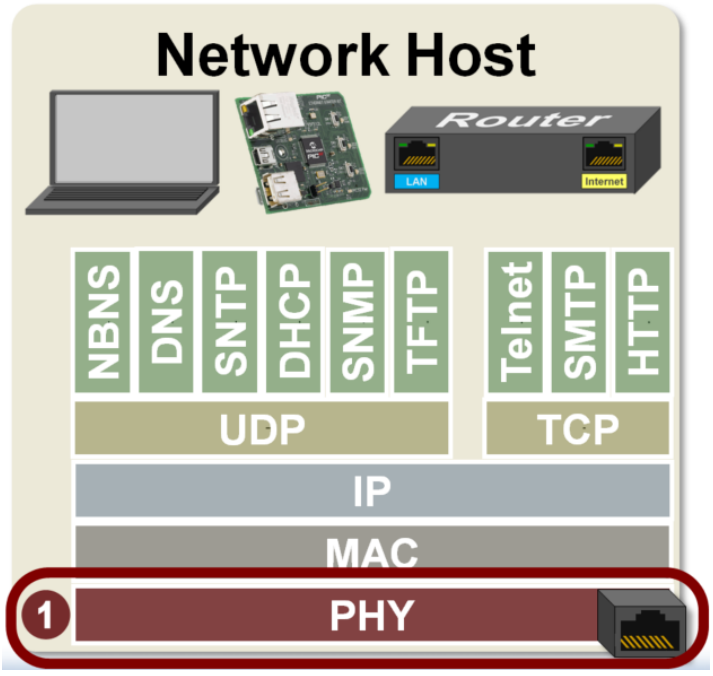
2 bytes	2 bytes	6 bytes	6 bytes	6 bytes	2 bytes	6 bytes	0 to 2312 bytes	4 bytes
Frame Control	Duration	MAC Address 1 (Destination)	MAC Address 2 (Source)	MAC Address 3 (Router)	Seq Control	MAC Address 4 (AP)	Data (payload)	CRC

The Data Link layer adds more than just the source and destination MAC addresses to the packet. Note that the MAC for Ethernet and WiFi are different and generate different frames.

Physical Layer (Layer 1)

- Layer 1 is the Physical layer. It sends and receives signals on the physical wire or antenna to transmit the bits found in frames.
- There is a PHY found at the end of every network interface (e.g. end of wire or antenna).

Physical Layer (Layer 1)



Questions

- What application transfers web pages?
- What application enables bi-directional text communication via a terminal application?
- What application translates website names to IP addresses?
- True or false? The Simple Mail Transport Protocol (SMTP) application uses the UDP transport protocol.
- When the Transport layer receives a message from a remote host, how does it know which application process to deliver it to?