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Introduction to COMPUTER NETWORKS
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DEEMED TO BE UNIVERSITY

Network Protocols

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Learning Objectives in Reliable Networks

- Network Trends
  - Online Collaboration
  - Cloud Computing
- Reliable Network features
  - Fault tolerance
  - Scalability
  - Quality of Service(QoS)
  - Security

Network Trends

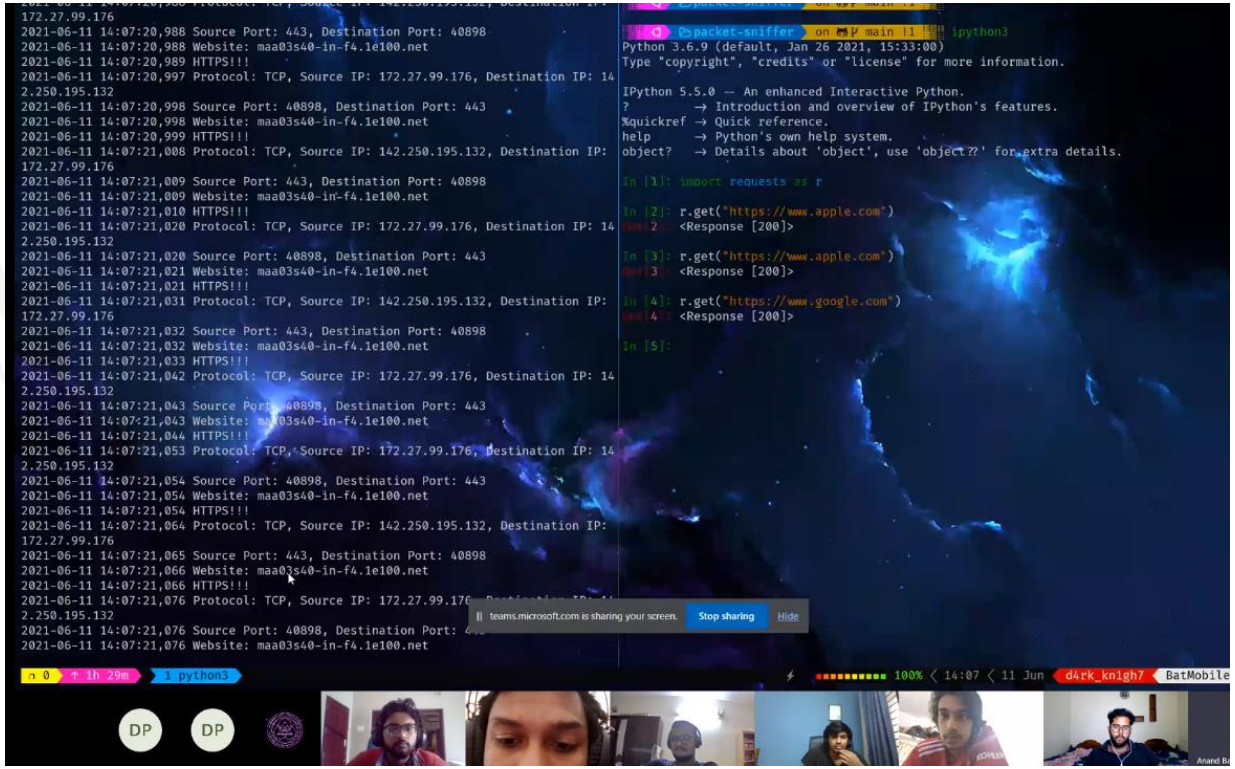
- Role of Network must adjust and continually transform to meet the user needs

- Networking trends that effect organizations and consumers:
  - Online Collaboration
  - Cloud Computing

Ref: Cisco Netacad CCNA Introduction to Networks

Online Collaboration

- Collaborate and work with others over the network on joint projects
- Collaboration tools are high priority in covid lockdowns for business and education
  - Ex: Skype, Microsoft teams, WebEx
- Multi-functional tools aiming at
  - Send instant messages
  - Post images, videos and links
  - Audio and Video call
  - Share screen



Cloud Computing

- Cloud Computing allows us to store our data on the public servers
  - Helps to access shared data from multiple devices
  - Ex: Gmail Drive, Microsoft One Drive
- Cloud Computing is made possible by data centers
  - Companies not having data center can also borrow these services

Ref: Cisco Netacad CCNA Introduction to Networks

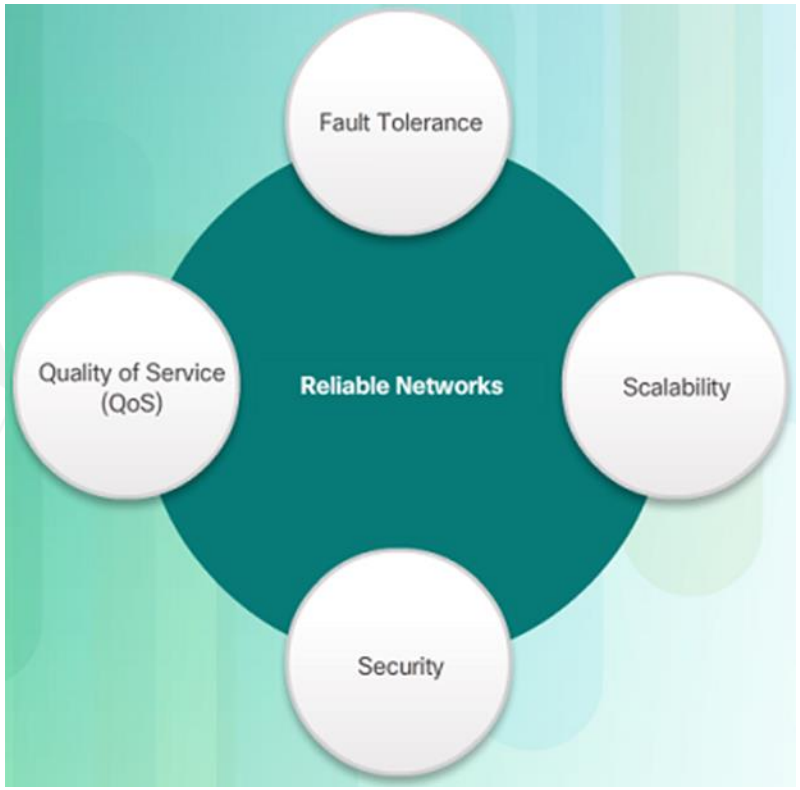
Network Architecture

- Network Architecture is the design of a computer network
- Includes hardware, software and connectivity.
- Refers to the technologies that support the infrastructure that moves the data across the network
  - Network infrastructure to all the resources of a network that makes the network
- Responsible for Standards and Frameworks that can address various network types and solve problems to improve reliability

Ref: Cisco Netacad CCNA Introduction to Networks

Reliable Networks

- User expect any designed network to be reliable in operation
- Reliability = continuity of service
- Four characteristic of any reliable network architectures are
  - ❖ Fault Tolerance
  - ❖ Scalability
  - ❖ Quality of Service (QoS)
  - ❖ Security



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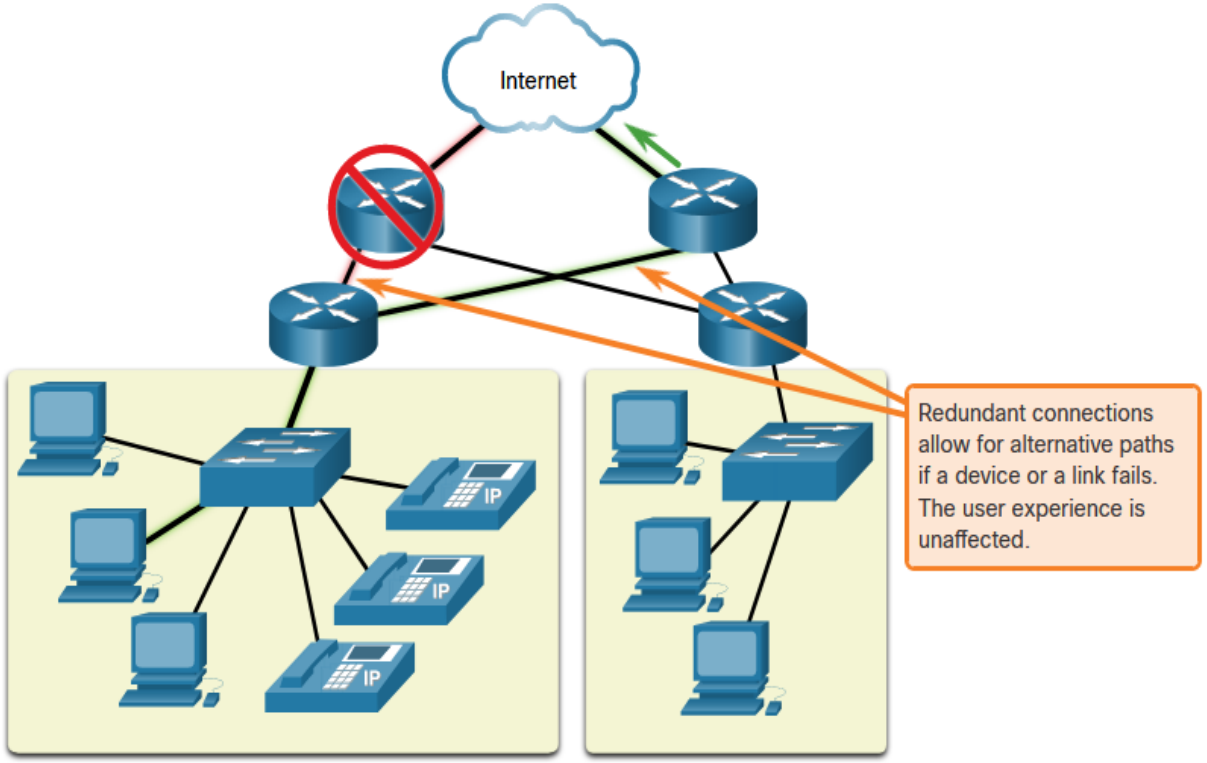
Fault tolerance

- Ability to provide continued operation in the presence of faults
- Problem: How to limit the impact of failure by limiting the number of affected devices?
- Solution: Introducing Redundancy



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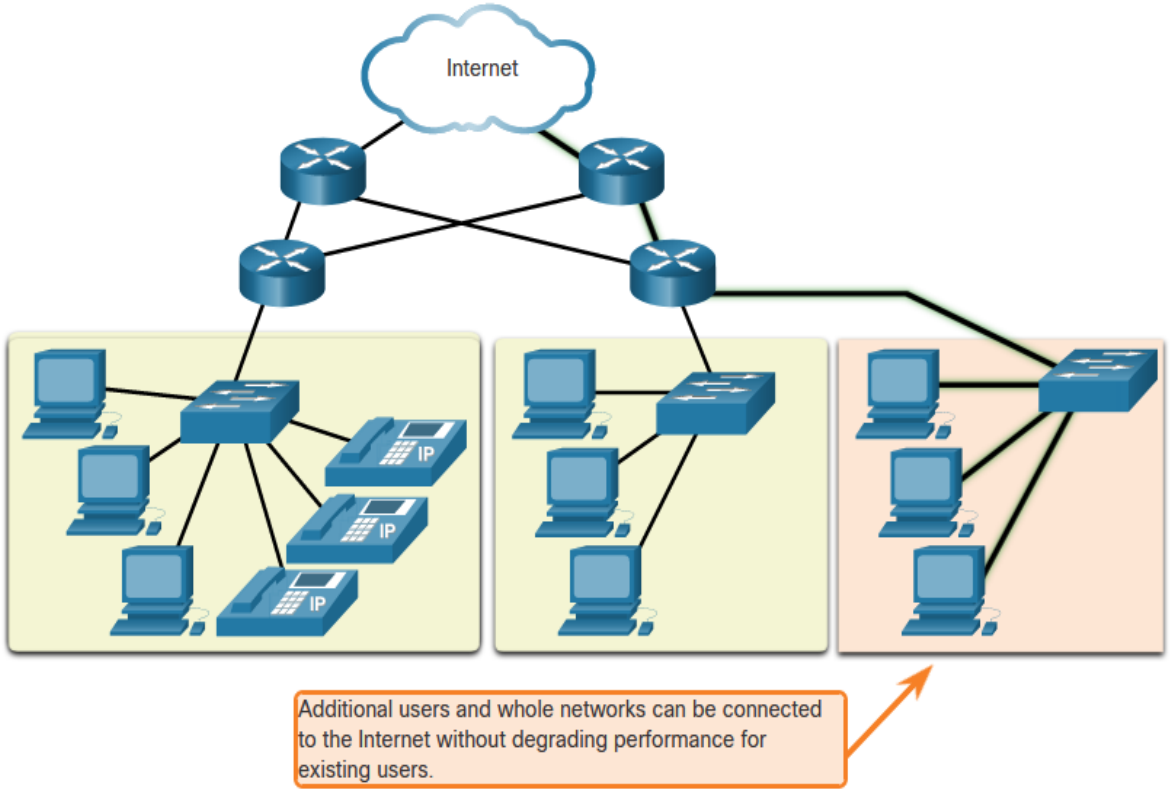
Scalability

- Problem: How to expand the network or services without affecting the existing one?
- Solution: Hardware or software expansion
- Additional users and whole networks can be connected to the internet without degrading performance for existing users.



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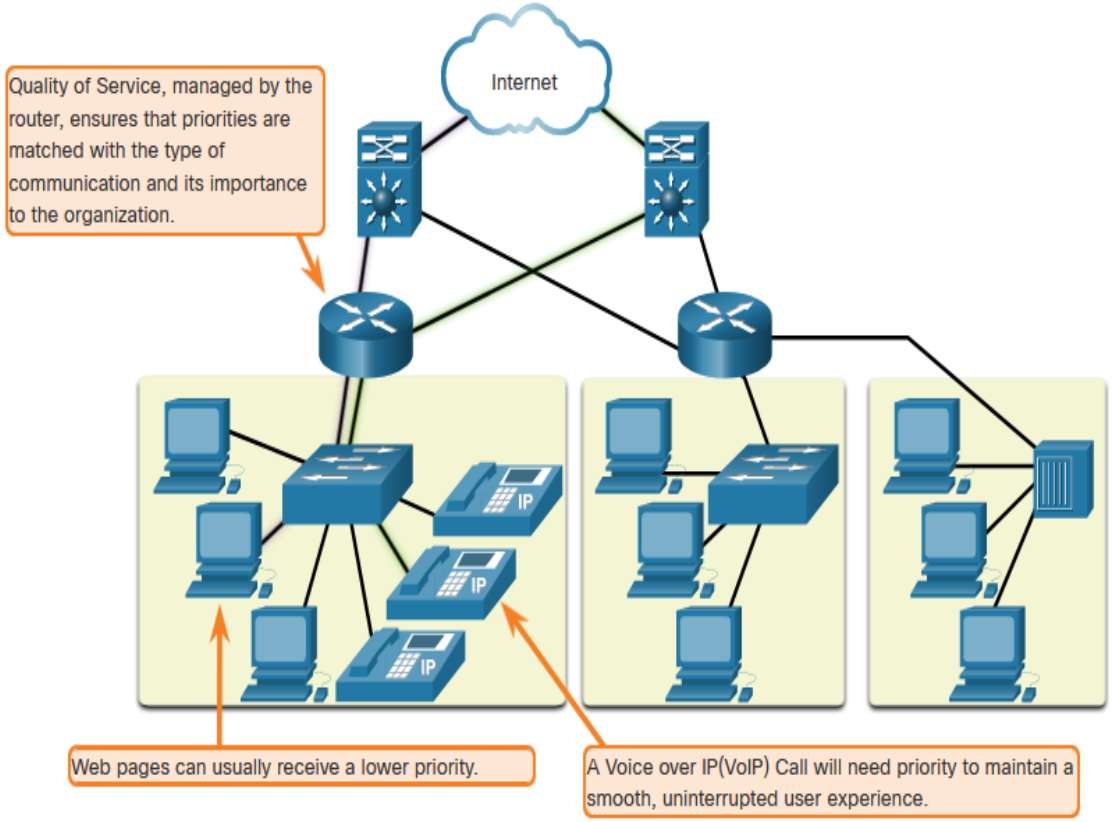
Quality of Service(QoS)

- Problem: Watching live video with constant breaks do not meet the user needs
- Solution: QoS is the primary mechanism used to ensure reliable delivery for all users
- With QoS policy, routers give priority to voice traffic packets compared to data traffic packets



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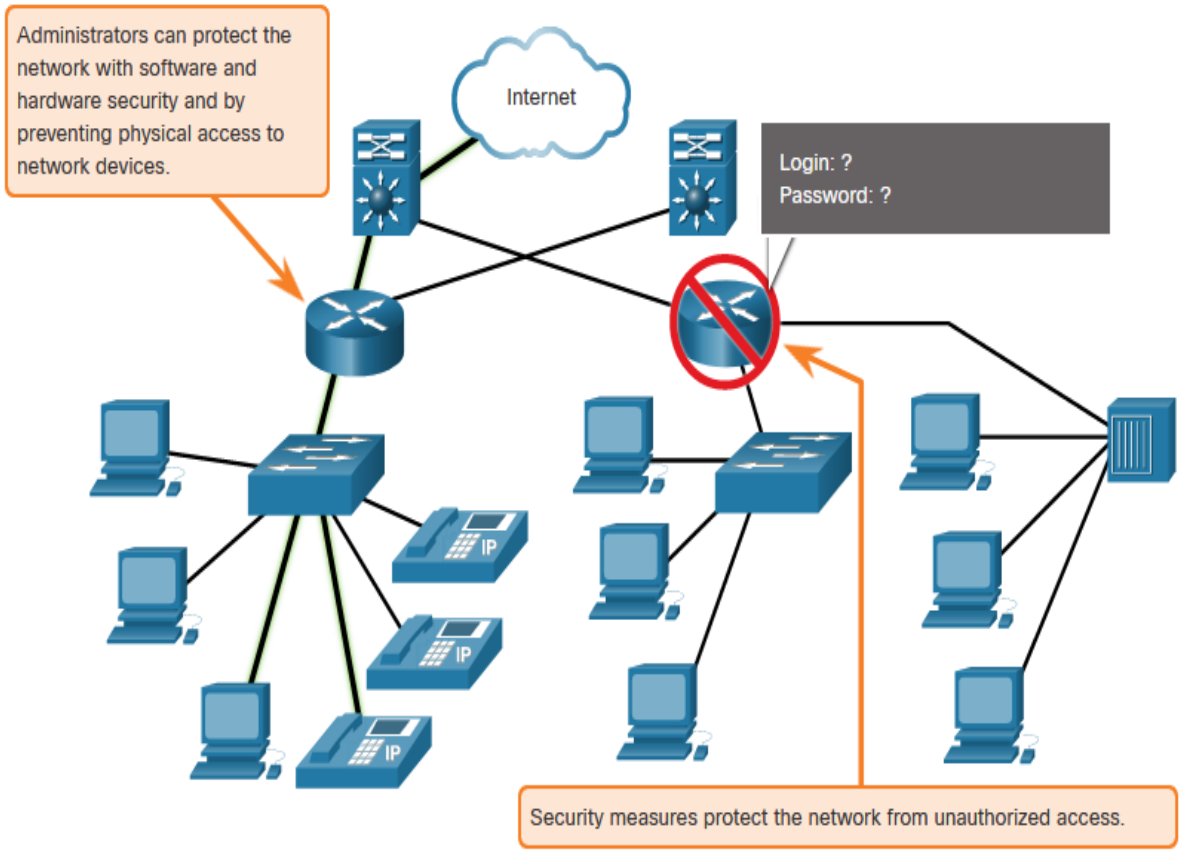
Network Security

- Two main types of network security to be addressed
  - Network Infrastructure Security
    - Physical security of network devices
    - Preventing unauthorized access to the devices
  - Information Security
    - Protection of the information or data transmitted over the network



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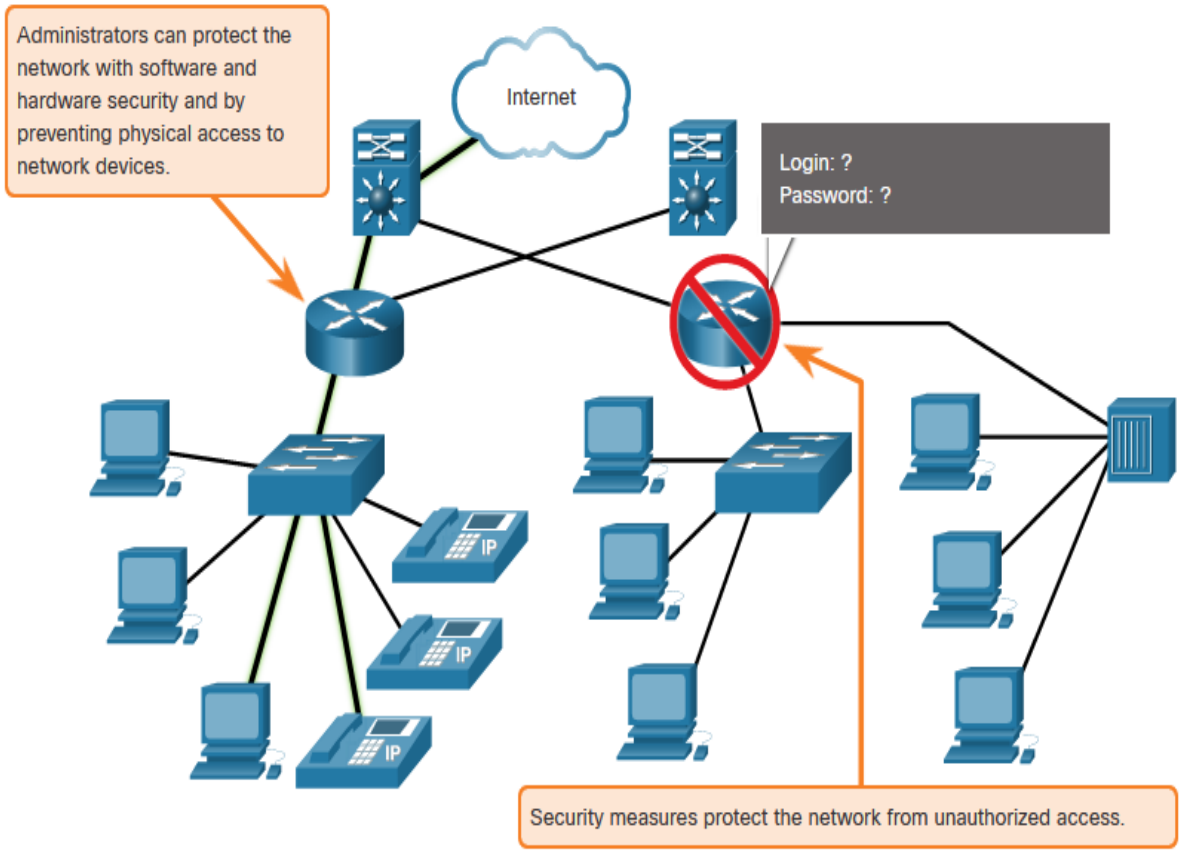
3 Goals of Network Security

- Confidentiality – only intended users can access the data
- Integrity – assurance that the data has not altered with during transmission
- Availability – assurance of timely and reliable access to data for authorized users



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Summary

- Network Trends
  - Online Collaboration
  - Cloud Computing

- Network Architecture
- Reliable Network Characteristics
  - Fault tolerance
  - Scalability
  - Quality of Service (QoS)
  - Network Security
- Next lecture discussion
  - Protocols

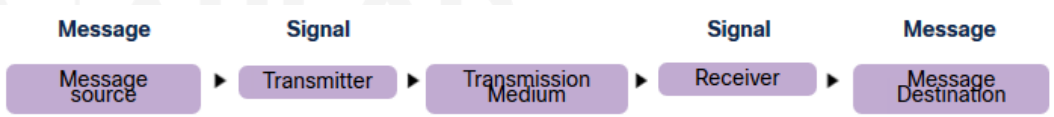
Network Protocols basics

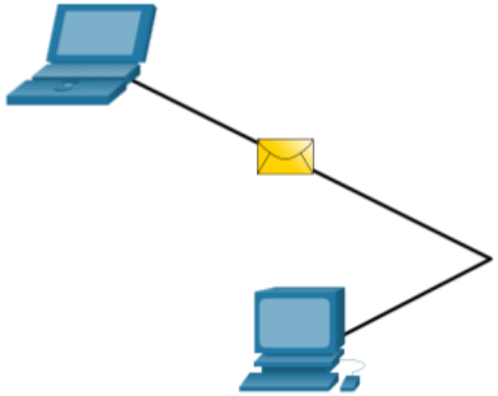
Key points to discuss in Protocols

- Rules for Communication
- Network Protocols
- Protocol Suite
- Communication Process
  - Sender side
  - Receiver side

Rules for Communication

- Set of rules needed for any communication to be effective
- Sender/Transmitter transmits signal from message source
- Receiver receives signal and becomes the message destination





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Rules for Communication

Human Protocols

Namah Shivaya! Welcome to Networks course

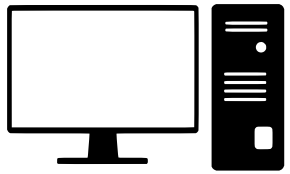
Namaskar

Did you understand internet?

Yes. Network of Networks

Time

Network Protocols



TCP Connection Request

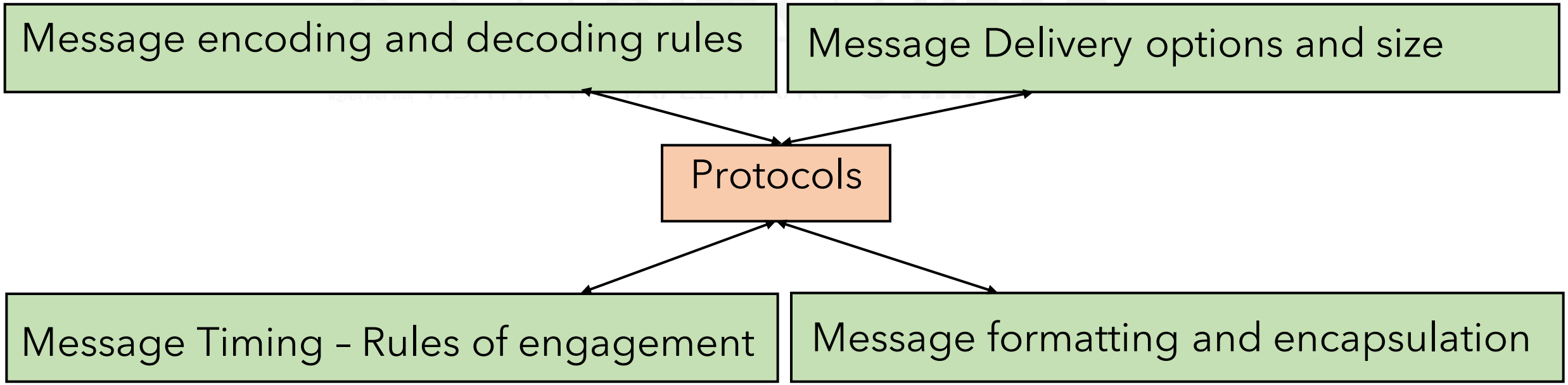
TCP Connection Response

HTTP Web page URL Request
Ex: http://amrita.edu

HTTP Web page 200 Ok

Network Protocol Requirements

- Protocols = set of rules
- Protocols should meet these requirements to send the message

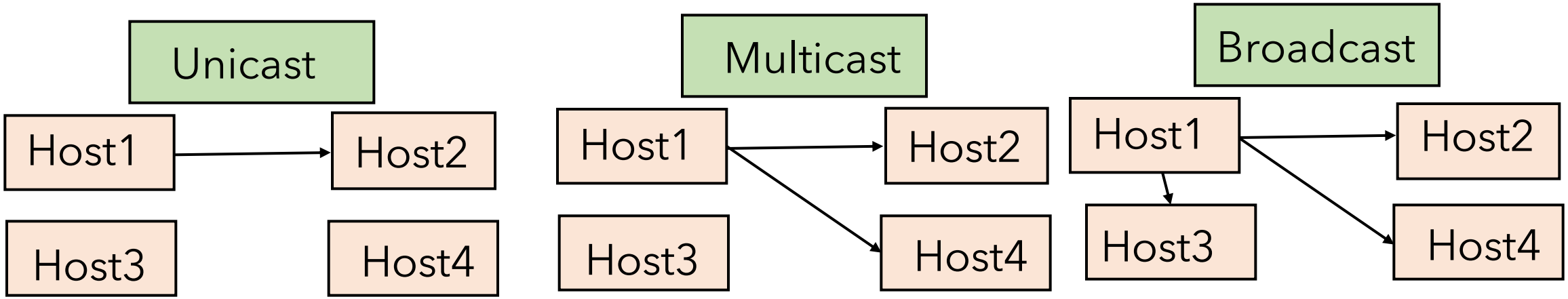


Message Encoding

- Encoding is the process of converting information into another acceptable form for transmission.
  - Sender encodes the message source to signal to get transmitted in the Communication medium.
- Decoding reverses this process to interpret the information.
  - Receiver decodes the signal to the message

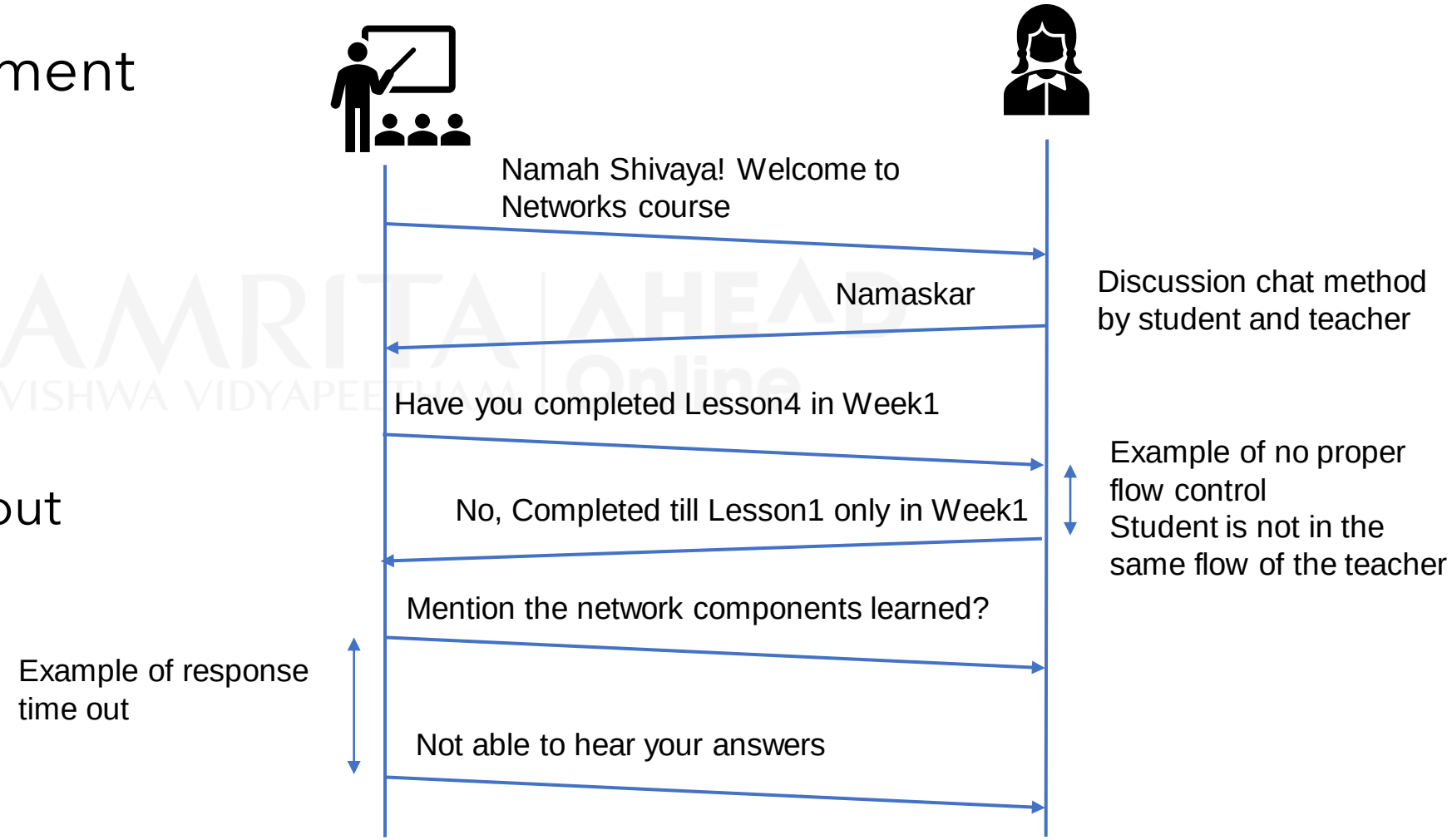
Message Delivery Options & Size

- Different delivery options in the same network
  - Unicast : One Sender ->One Receiver
  - Multicast : One Sender -> Group of Receivers
  - Broadcast: One Sender -> All Receivers
- Message size restricted depending on Media/link capacity



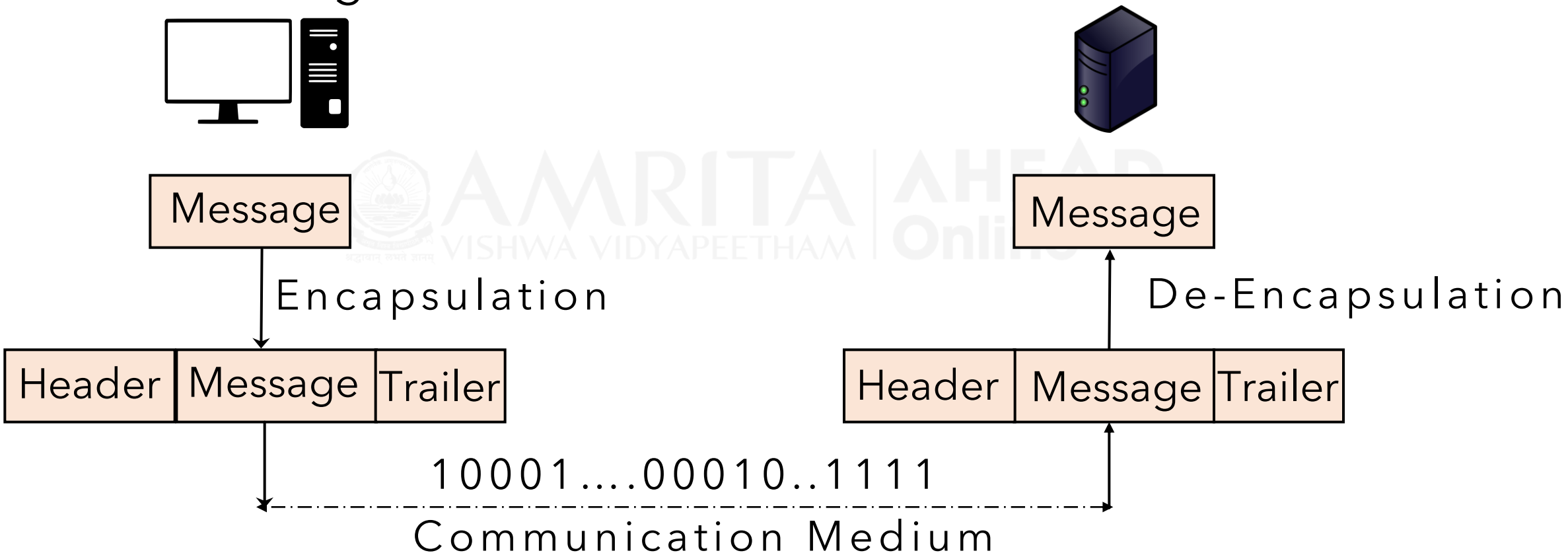
Message Timing

- Rules of Engagement
  - Access Method
  - Flow control
  - Response time out



Message Formatting & Encapsulation

- Body of the letter is encapsulated with the envelope cover having destination address



Network Protocol Types

- Protocols can be implemented on devices in software, hardware or both

Protocol Types	Description	Example
Network Communications	Enable two or more devices to communicate over one or more network	HTTP, TCP, IP
Network Security	Secure data to provide authentication, data integrity and data encryption	TLS, SSH, SSL
Routing	Enable routers to exchange route information and thus helps to select best path for packets to move forward	OSPF, BGP
Service discovery	Used for automatic detection of devices or services	DNS, DHCP

Network Protocol Functions

- Protocols have their own Format, Function and Rules

Protocol Function	Description	Example
Addressing	Identifies sender and receiver	IP, Ethernet
Reliability	Provides guaranteed delivery	TCP
Flow control	Ensures data flows at an efficient rate	TCP
Sequencing	Uniquely labels each transmitted segment of data	TCP
Error detection	Determines if data becomes corrupted during transmission	TCP, IP, Ethernet
Application interface	Process-to-process communication between network applications	HTTP, HTTPS

Summary

- Rules of Communication
- Network Protocols

- Protocol Requirements
  - Message Encoding
  - Message delivery options and size
  - Message timing
  - Message formatting and encapsulation

- Next lecture discussion
  - Protocol suite

Protocol suite and Standards

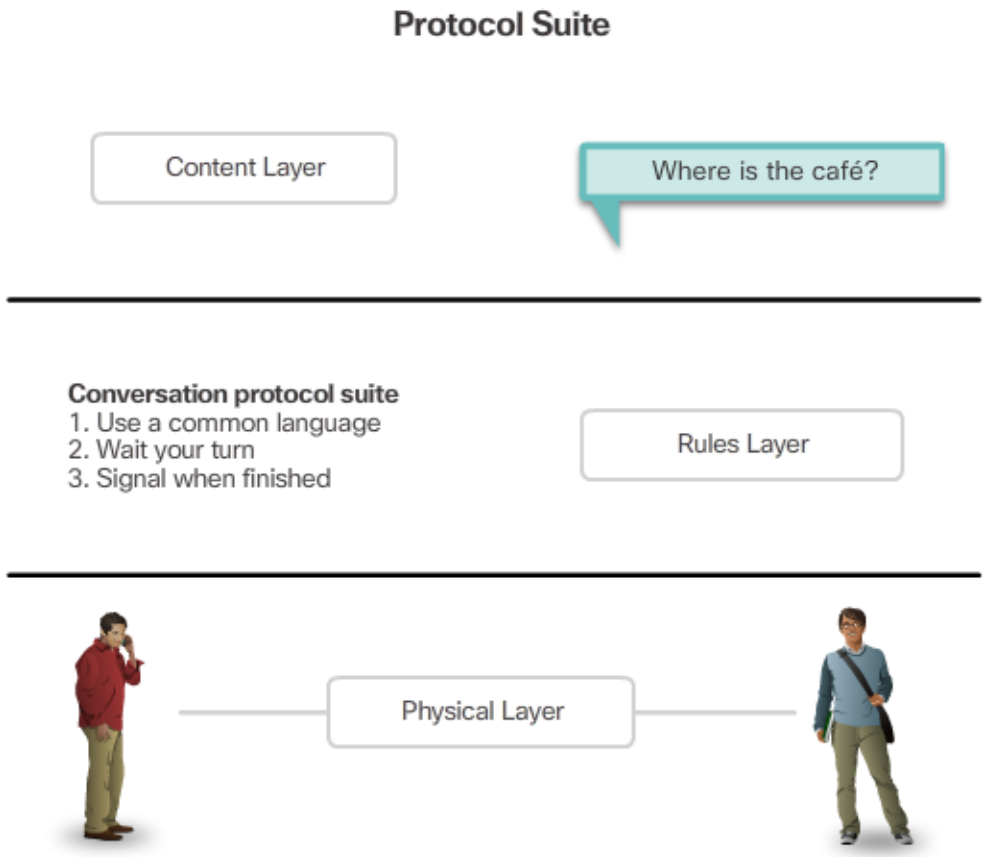
Reference: CCNA ITN Ch3.1, 3.2 Protocol rules

Key points in Protocol Suite & Internet Standards

- What is protocol suite?
- Analyze Evolution of Protocol suites
  - Open
  - Proprietary
- Analyze Internet Standards and Organizations
  - IP Addressing
  - Communication protocols

Protocol Suite

- Protocol suite?
  - Group of inter-related protocols necessary to perform a communication function
  - set of protocols that work together to solve a problem
- Protocols are viewed in terms of layers
  - @Sender: Content Layer ->Rules Layer -> Physical Layer
  - @Receiver: Physical Layer -> Rules Layer -> Content Layer



Ref: CCNA Introduction to Networks from Cisco Netacad

Evolution of Protocol Suites

- Several competing protocol suites providing comprehensive network communication services

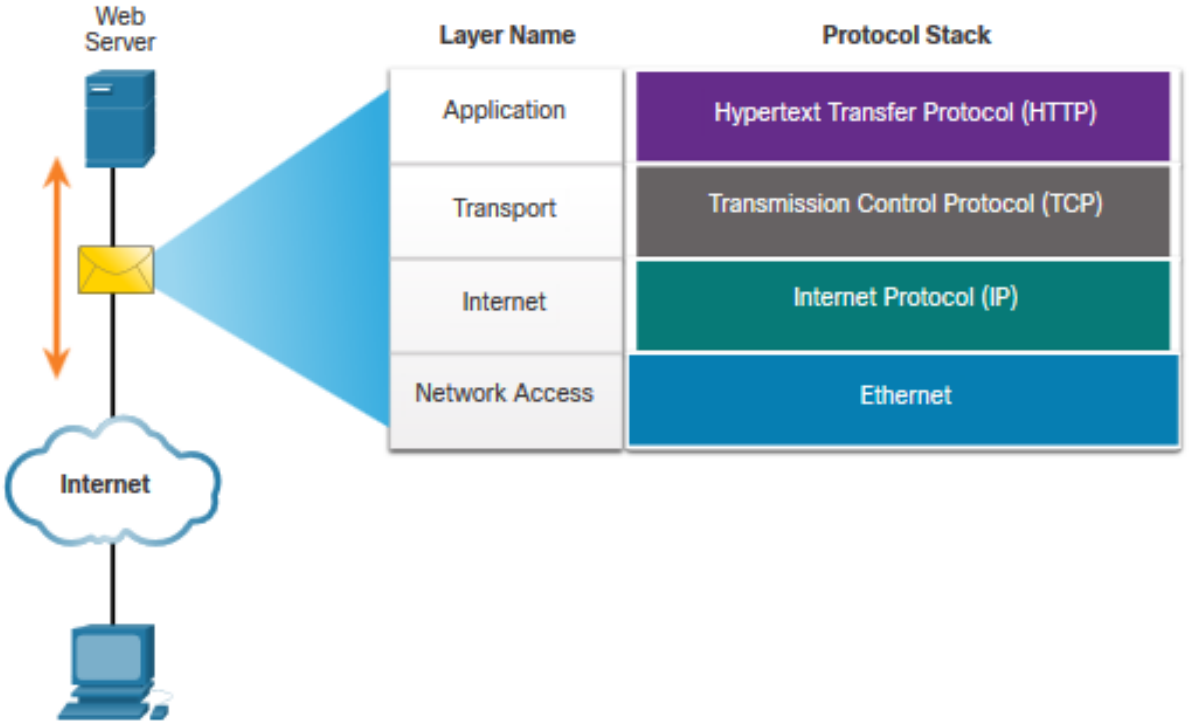
- Open Standards
  - TCP/IP
  - OSI

- Proprietary
  - AppleTalk
  - Novell Netware

TCP/IP Layer Name	TCP/IP	ISO	AppleTalk	Novell Netware
Application	HTTP DNS DHCP FTP	ACSE ROSE TRSE SESE	AFP	NDS
Transport	TCP UDP	TP0 TP1 TP2 TP3 TP4	ATP AEP NBP RTMP	SPX
Internet	IPv4 IPv6 ICMPv4 ICMPv6	CONP/CMNS CLNP/CLNS	AARP	IPX
Network Access	Ethernet ARP WLAN			

TCP/IP Protocol example

- Interaction of protocols in communication between a web server and web client uses TCP/IP protocol suite.
- TCP/IP protocol suite is used in the internet and an open standard maintained by Internet Engineering Task Force (IETF)
  - Standards based protocol suite endorsed by networking industry and approved by standards organizations



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Open Standards

- Open standards encourage:
  - Interoperability
  - Competition
  - Innovation
- Standards organizations are
  - Vendor neutral
  - Non profit organizations
  - Established to develop and promote the concept of open standards

Ref: CCNA Introduction to Networks from Cisco Netacad

Network protocols -> Layered Models

- Network protocols is Set of rules defined in the software process for
  - How are messages formatted or structured?
  - How and when error and system messages are passed between devices?
  - Setup and termination of data transfer session

- Networks are complex with many components. Organizing network structure better is possible by Layered models

Ref: J. Kurose and K. Ross 2012, Computer Network,6th ed.

Summary

- Protocol Suite and concept of layers
- Different Protocol suites evolution
  - Open – TCP/IP, OSI
  - Proprietary – Apple, Novel

- Internet Standards
  - IETF, IANA etc
- Next lecture discussion
  - Layered Models

Layered Models

Reference: CCNA ITN Ch3.5 Layered models

Key points to discuss in Layered Models

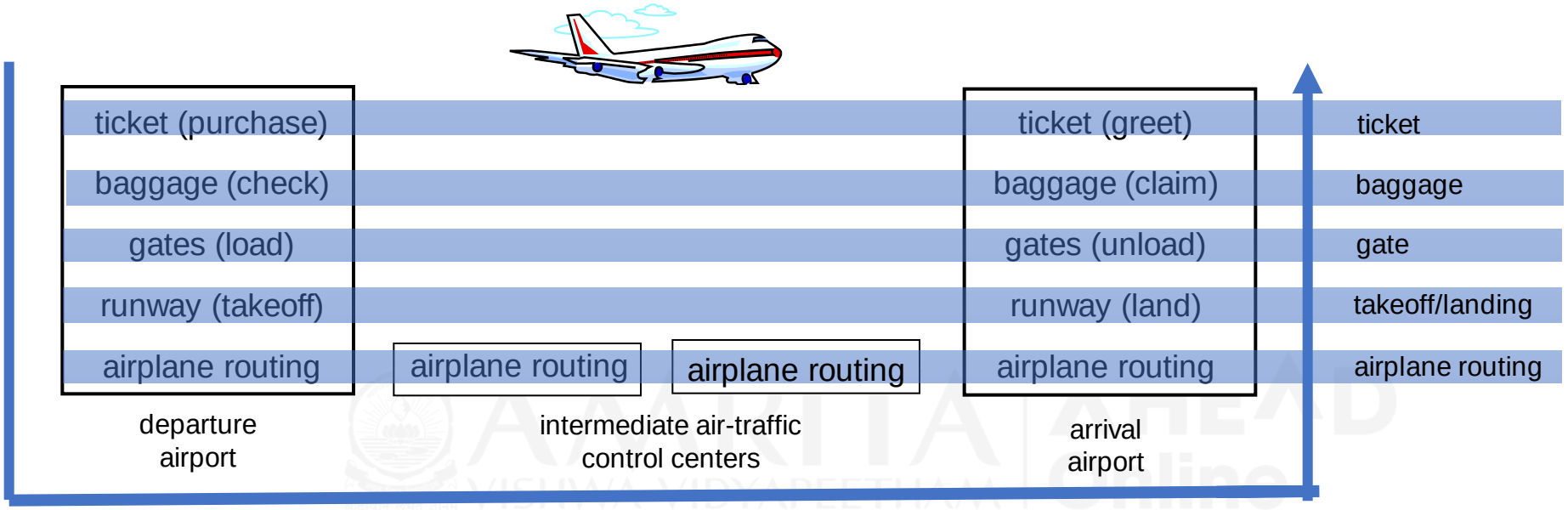
- Why Layering?
- What is layered approach?
- Benefits of Layered models
- Protocol model
  - TCP/IP Implemented Model
  - OSI Reference Model
- Protocol stack in sending and receiving a message

Protocol "Layers"

- Networks are complex with many hardware and software components
  - End Devices – Laptop, Mobile etc.
  - Intermediary Devices – Switch, routers etc.
  - Media – Wired: Copper, Fiber etc. Wireless: Radio, microwave
  - Applications - provides human interface
  - Protocols – set of rules for network communication
  - Services – follow protocols to prepare data for the network
- Protocol "layers" helps in organizing the structure of the complex systems like network.

Ref: CCNA Introduction to Networks from Cisco Netacad

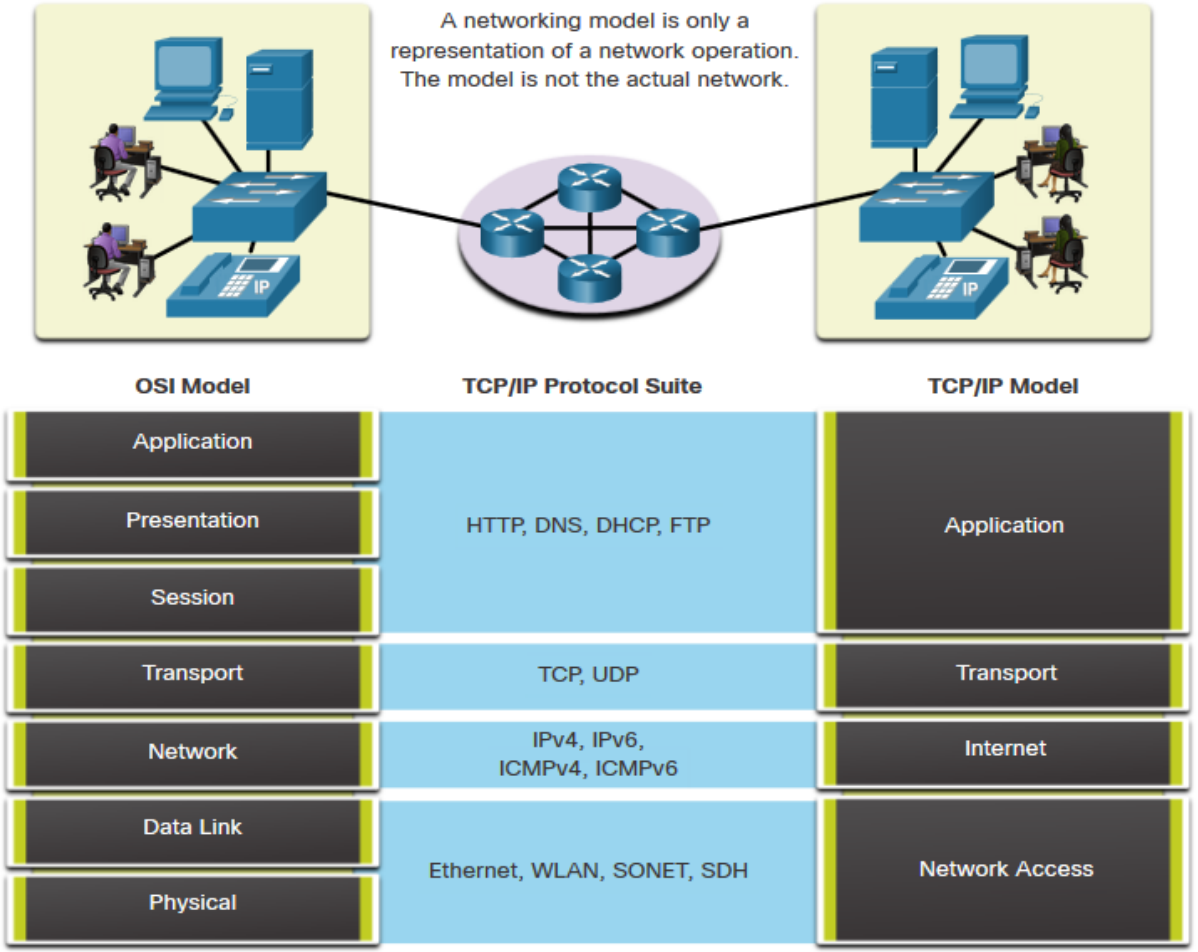
Layered approach analogy



- Analogy – Organization of air travel – series of steps
- Layers: each layer implements a service
  - Via its own internal-layer actions (Ex: at the gate layer, loading & unloading)
  - Relying on services provided by layer below (Ex: in the gate layer, using the takeoff/landing service)

Ref: J. Kurose and K. Ross 2012, Computer Network,6th ed.

Why Layered Model ?



Ref: CCNA Introduction to Networks from Cisco Netacad

- Used to easily explain/ understand complex concepts such as how network operates (or how airline system works)
- TCP/IP and OSI models describe network operation
- Modularization eases maintenance, updating of system
  - Ex: change in services of one layer doesn't affect other layers

Benefits of using a layering model

- Assist in protocol design because protocols that operate at a specific layer have defined information that they act upon and a defined interface to the layers above and below
- Foster competition because products from different vendors can work together
- Prevent technology or capability changes in one layer from affecting other layers above and below
- Provide a common language to describe networking functions and capabilities

Ref: CCNA Introduction to Networks from Cisco Netacad

Protocol stack

- Network designers organize protocols in layers
  - Each protocol belongs to one of the layers
- Each layer provides its services by
  - Performing actions specific to the layer
  - Use the services of the layer directly below it. Ex: HTTP uses the TCP service
- Layer N protocol distributed among the end system, switches and other network components
  - Each component performs layer N services. Ex: Router = Layer 3
- When taken together, the protocols of various layers are called protocol stack

Ref: CCNA Introduction to Networks from Cisco Netacad

Internet Protocol stack = TCP/IP model

5. Application	Support network applications like web, email	HTTP, SMTP
4. Transport	Process-to-process data transfer	TCP, UDP
3. Network	Routing packets to destination	IP, OSPF etc.
2. Data Link	Data transfer between neighbouring devices	HDLC, PPP
1. Physical	Bits as signals on the wire	Ethernet

Ref: CCNA Introduction to Networks from Cisco Netacad

OSI Reference Model

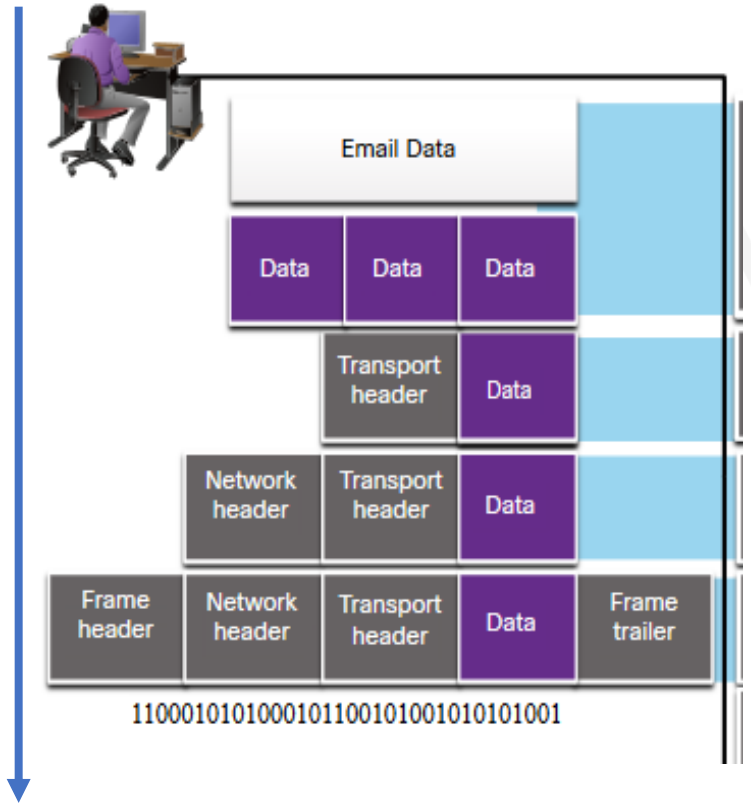
7. Application	Support network applications like web, email
6. Presentation	Provides for common representation of the data
5. Session	Managed data exchange sessions
4. Transport	Process-to-process data transfer
3. Network	Determine the best path through the network
2. Data Link	Data transfer between neighbouring devices
1. Physical	Bits as signals on the communication medium

Ref: CCNA Introduction to Networks from Cisco Netacad

Internet Protocol stack = TCP/IP model

5. Application	Data
4. Transport	Segment
3. Network	Packet
2. Data Link	Frame
1. Physical	bits

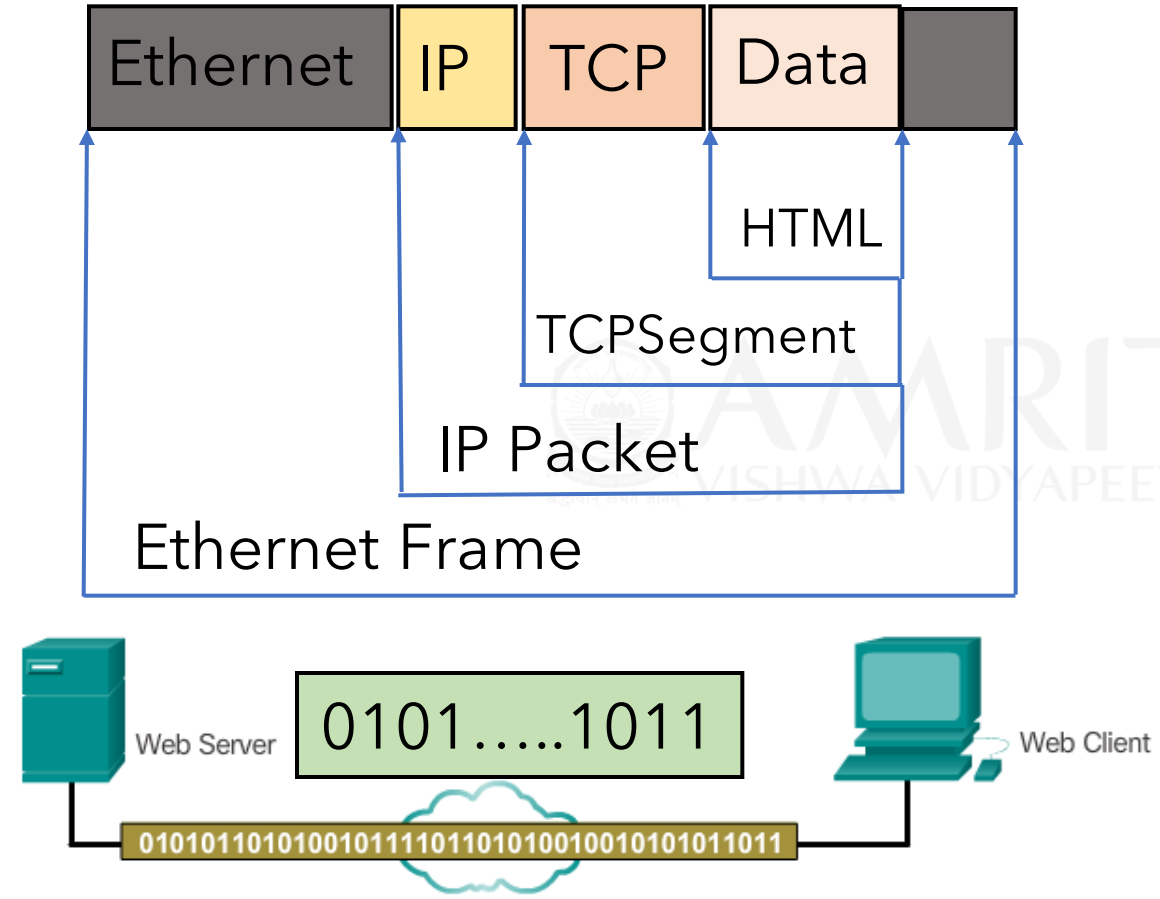
Pushing down the stack



- Encapsulation = process where protocols add their information to the data.
- At each layer, a protocol data unit has a different name to reflect its new functions.

Ref: CCNA Introduction to Networks from Cisco Netacad

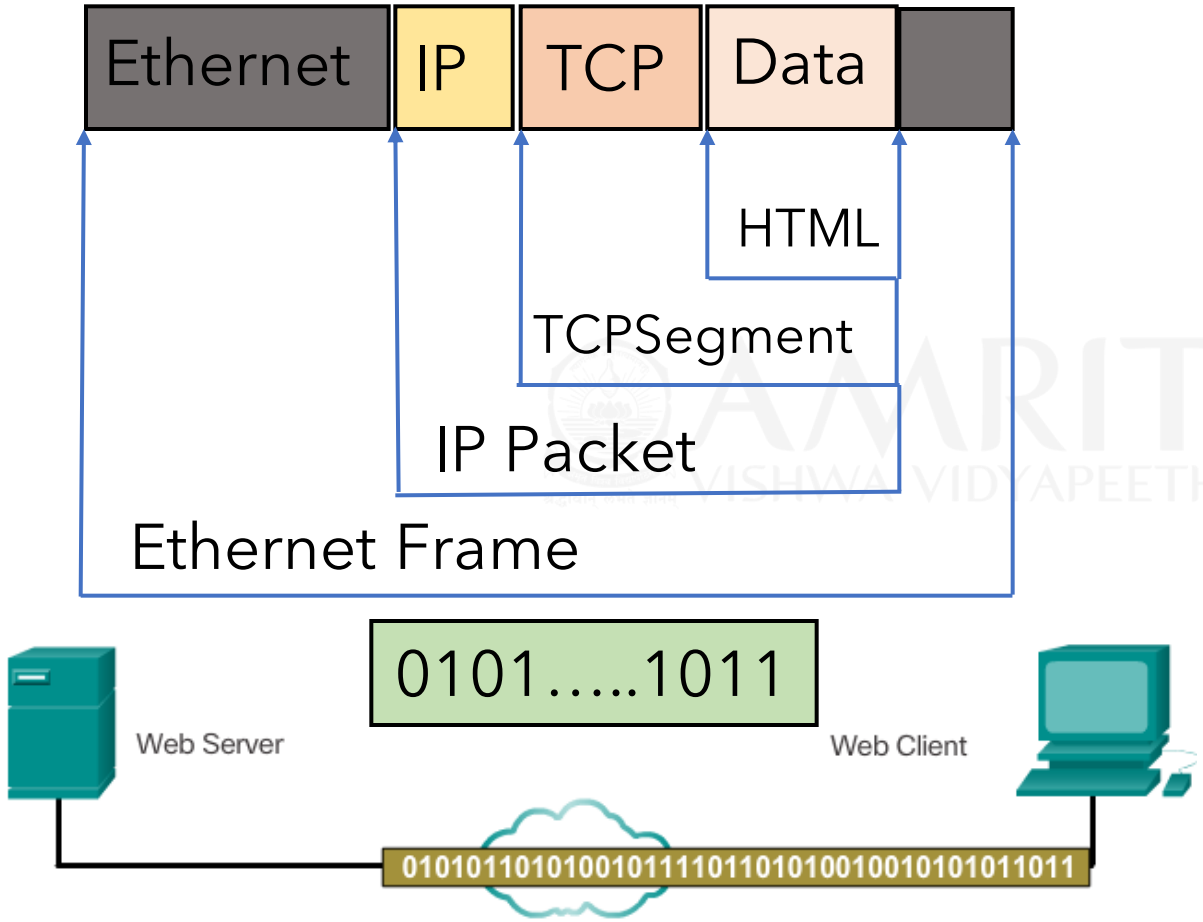
Sending message - Internet protocol stack



Ref: CCNA Introduction to Networks from Cisco Netacad

- Data are pushed down in protocol stack in sending a message in TCP/IP Communication process
- Encapsulation is adding control or header information along with the User data
- Encapsulation takes place in the sender side
- Ex: Web server sending web page (HTML)

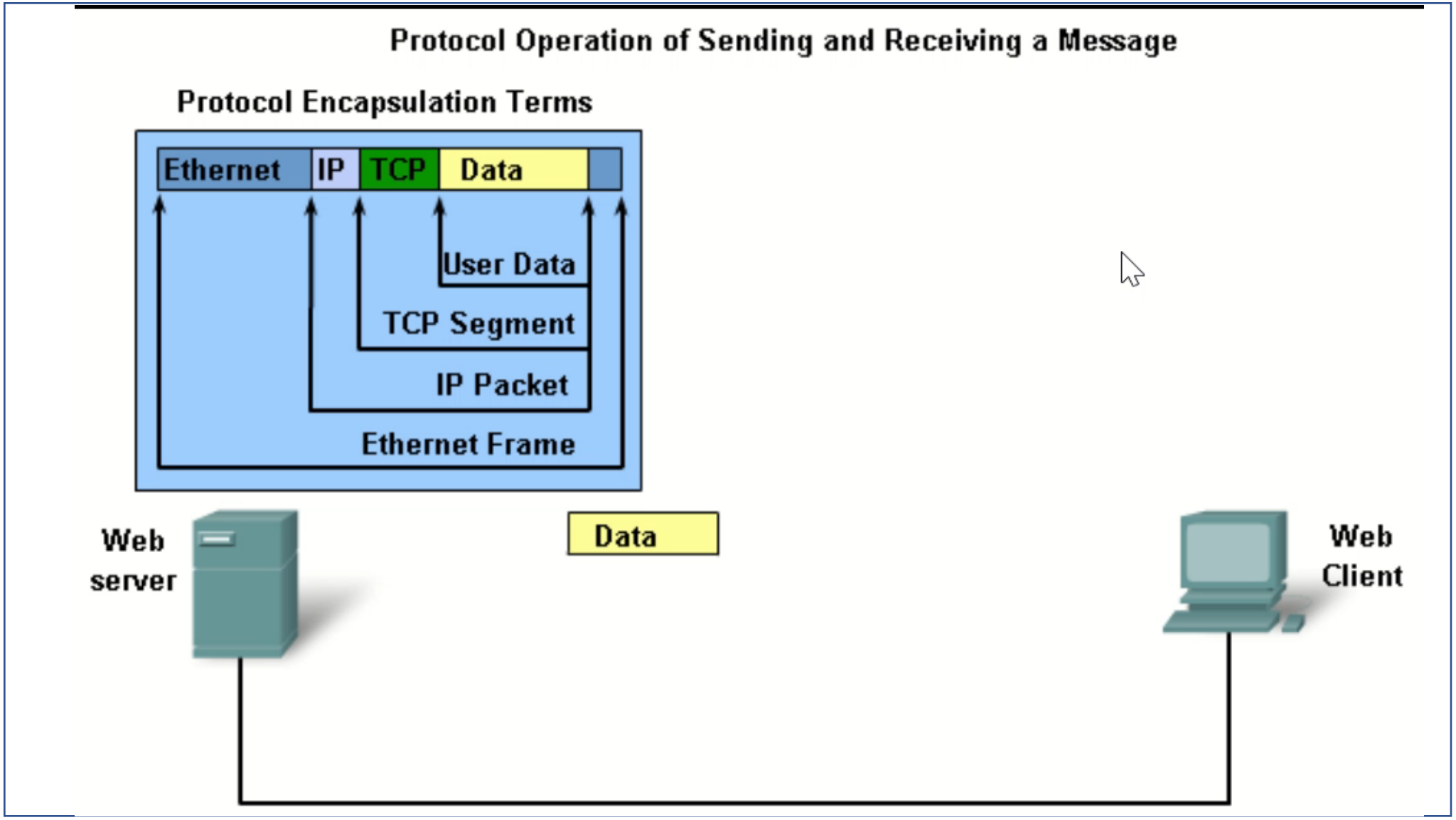
Protocols in Receiving a message



Ref: CCNA Introduction to Networks from Cisco Netacad

- Data is popped out from protocol stack in Receiving a Message in TCP/IP Communication process
- De-Encapsulation is removing control or header information from the User data
  - De-Encapsulation takes place in the receiver side
- Ex: Web Client receiving web page from web server

Protocol Operation



Summary

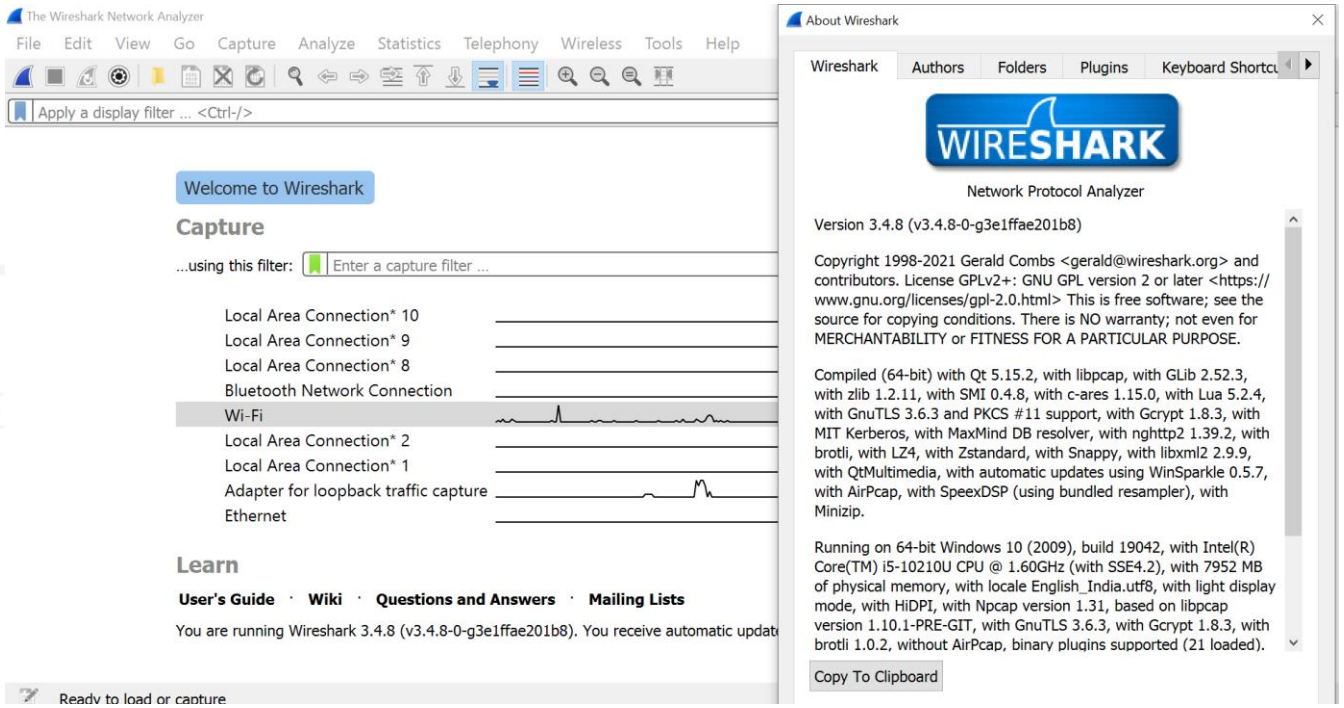
- Need for Layered approach
- Protocol models
  - TCP/IP
  - OSI
- TCP/IP Communication process
  - Encapsulation @ sender
  - De-encapsulation @ Receiver
- Next lecture discussion
  - Practical session - Wireshark

Objectives – Protocol Analyzer Tool

- Understanding Protocol analyzer tool
- Explore the logical and physical address in laptop for internet access
- Install & launch Wireshark in the laptop having internet access
- Explore the basic Wireshark features

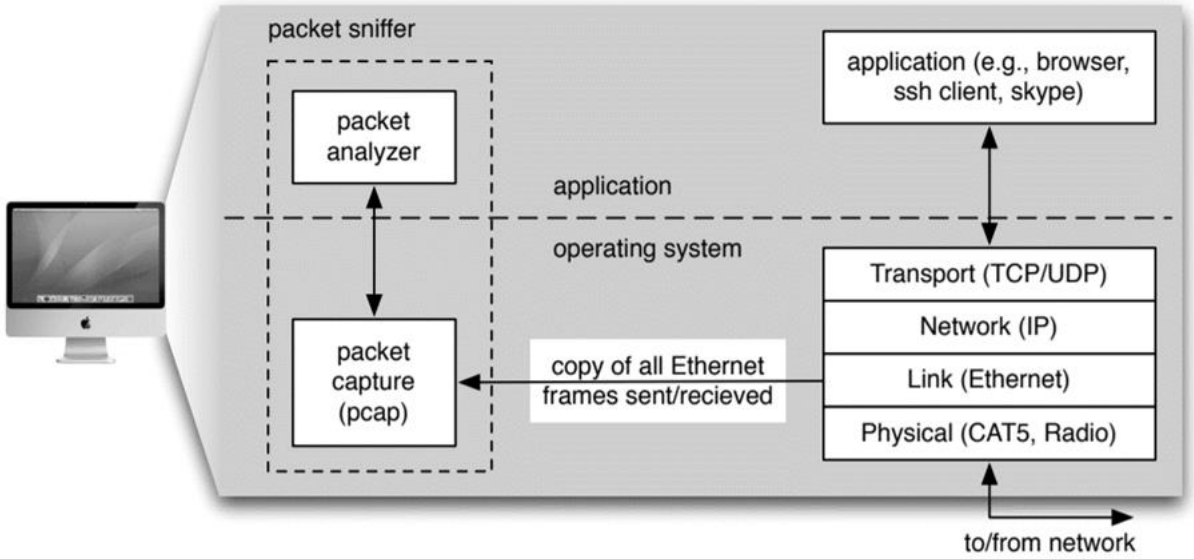
Protocol analyzer tool?

- Wireshark tool used for network troubleshooting, protocol analysis, decode and analyze protocol data unit in each layers
- Open-source packet sniffer software used by network engineers
- It can capture incoming frames and outgoing frames from an interface. Ex: Wi-Fi



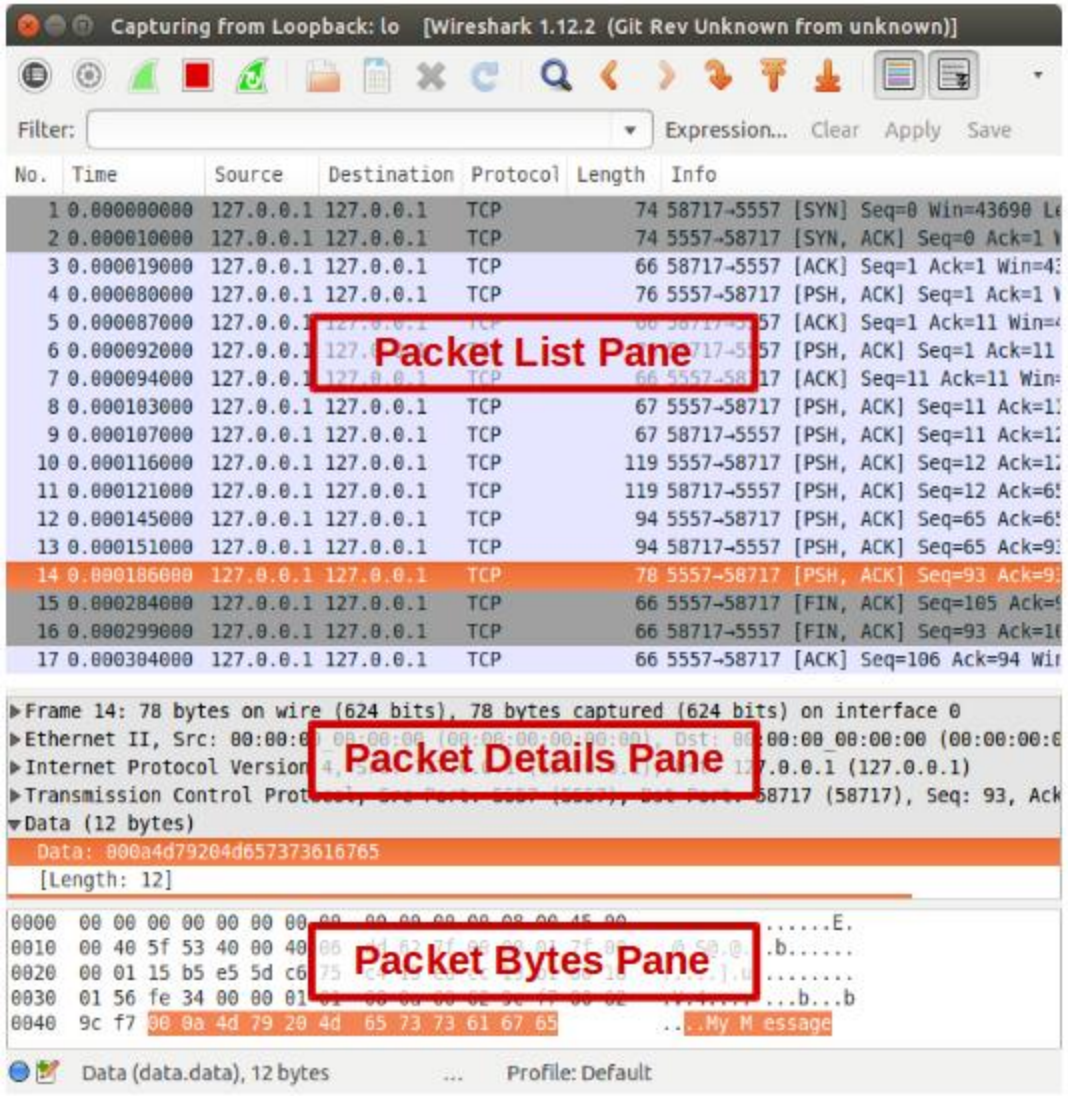
Packet Sniffer tool?

- Packet Sniffers tool are used to observe the messages on the network
- Packet sniffer captures ("sniffs") messages being sent/received from/by our laptop
- Packet capture library receives copy of frame sent from or received by your laptop
- Packet analyzer displays the content of all fields within a protocol message



Ref: J. Kurose and K. Ross 2012, Computer Network,6th ed.

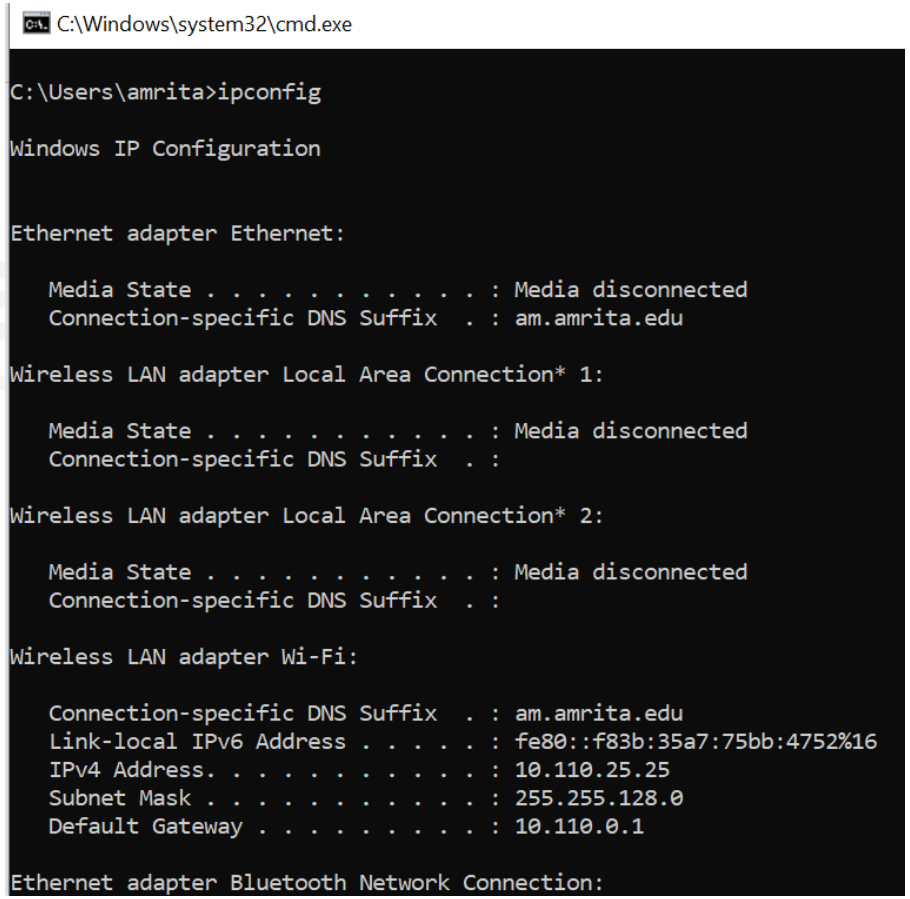
View Protocol Data Units in Wireshark



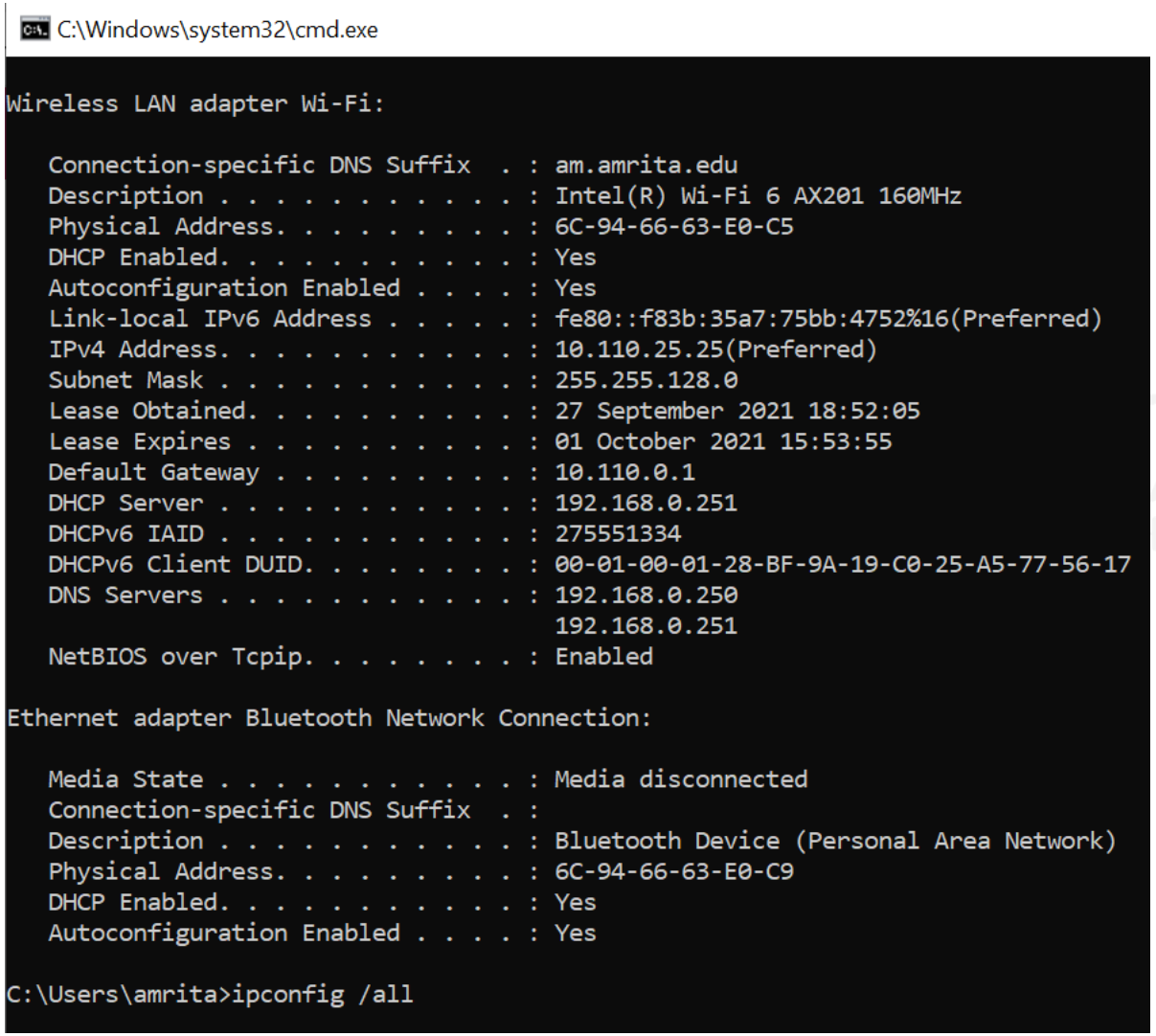
- Wireshark is programmed to recognize the structure of different network protocols.
- This enables to display the encapsulation and individual fields of a Protocol Data Unit (PDU) to help in interpretation.
- Useful tool for those working with networks and can be used for data analysis and troubleshooting.

Examine Logical IPv4 Address

- Analyze the end-device connectivity to the network in our laptop/PC is required to troubleshoot issues in the internet access
- How to gather TCP/IP configuration of an end device?
  - Use the start menu and go the command prompt
    - Type ipconfig and press the Enter key.
    - Note: ifconfig is the command in Ubuntu machine
    - It is short for IP Configuration.
- **ipconfig** command provides IP address, subnet mask and default gateway.
- The IP address and the default gateway should be in the same network or subnet, otherwise this host would not be able to communicate outside the network



Physical MAC Address



- **ipconfig /all** command is used to know the physical address
- Medium Access Control(MAC) address or Physical address refers the same
- Wireless NIC card MAC address is involved in communication if internet access it through Wi-Fi.
- Ethernet NIC card MAC address is involved in communication for accessing internet via wired LAN.

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Calibri Light 16 Font Paragraph Styles

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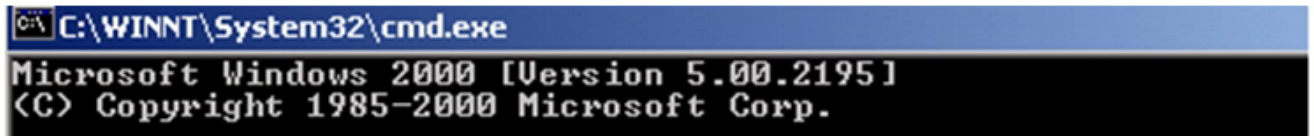
Analyzing the End Device connectivity to the Network

Part1: Gather basic TCP/IP configuration information

Use the Start menu to open the Command Prompt, an MS-DOS-like window. Press **Start**

Programs > **Accessories** > **Command Prompt** or **Start** > **Programs** > **Command Prompt**.

The following figure shows the Command screen.



Instructions to install Wireshark

- Step1: Download Wireshark
  - Based on your PC, choose 32 bit or 64 bit OS Windows installer
- Step2: Install Wireshark
  - Downloaded file is named Wireshark-win64-x.x.x.exe, where x represents version number
  - To capture live network data, same x version of **Ncap is required**.
  - Recommended to uninstall old and update it with version of Ncap x.x.x same as wireshark done by clicking next to continue.
  - USBPcap is experimental, and it would cause USB problems on your laptop. So, **do not select the checkbox to install USBPcap**.
  - Click **Next** and **Finish** to complete the installation process.

Ref: CCNA Introduction to Networks from Cisco Netacad

Launch Wireshark

- Search for Wireshark application
- Look for the list of network interfaces in the lower part of Wireshark. Choose your active interface. Double click on the active interface.
- Open your browser, e.g. Microsoft Edge and pick a URL & fetch it e.g. http://www.bettertechnology.in". Stop capturing as soon as the page is displayed
- Close unnecessary browser tabs and windows. By minimizing browser activity, we can stop computer from fetching unnecessary web content.
- Ensure that browser cache is deleted, so that web pages comes from web server

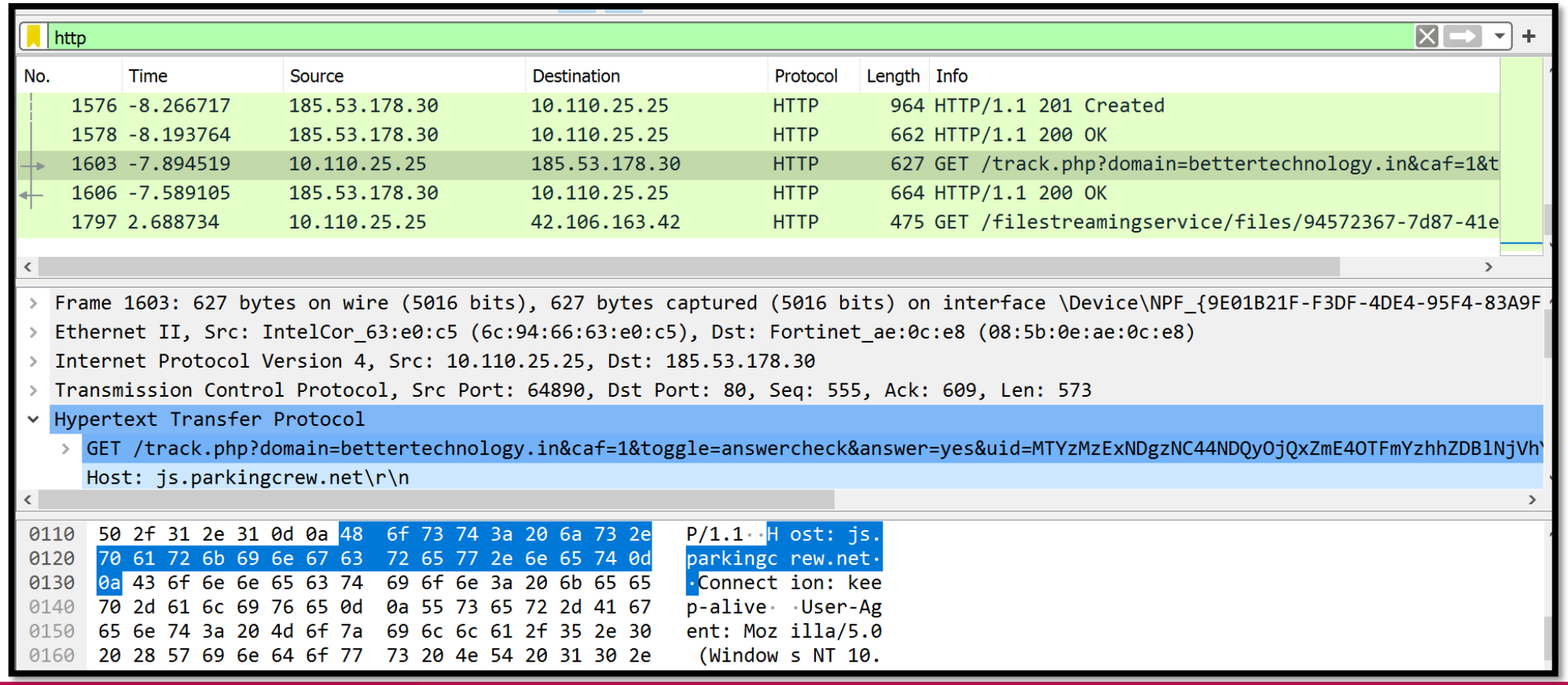
Understanding the TCP/IP protocol stack using Wireshark

1. Open Packet sniffer [Wirehark] Application and Capture the Wi-Fi/ Ethernet Interface
2. Do this activity and capture frames.
    a. Request for a web page from webserver
3. Briefly explain the Encapsulation process in at least one http request frame of the protocol analyzed. Also explain the PDU contents in each layer.

Layer	Protocol	Important Contents	Purpose
Application	http	GET Request for a *given URL*	

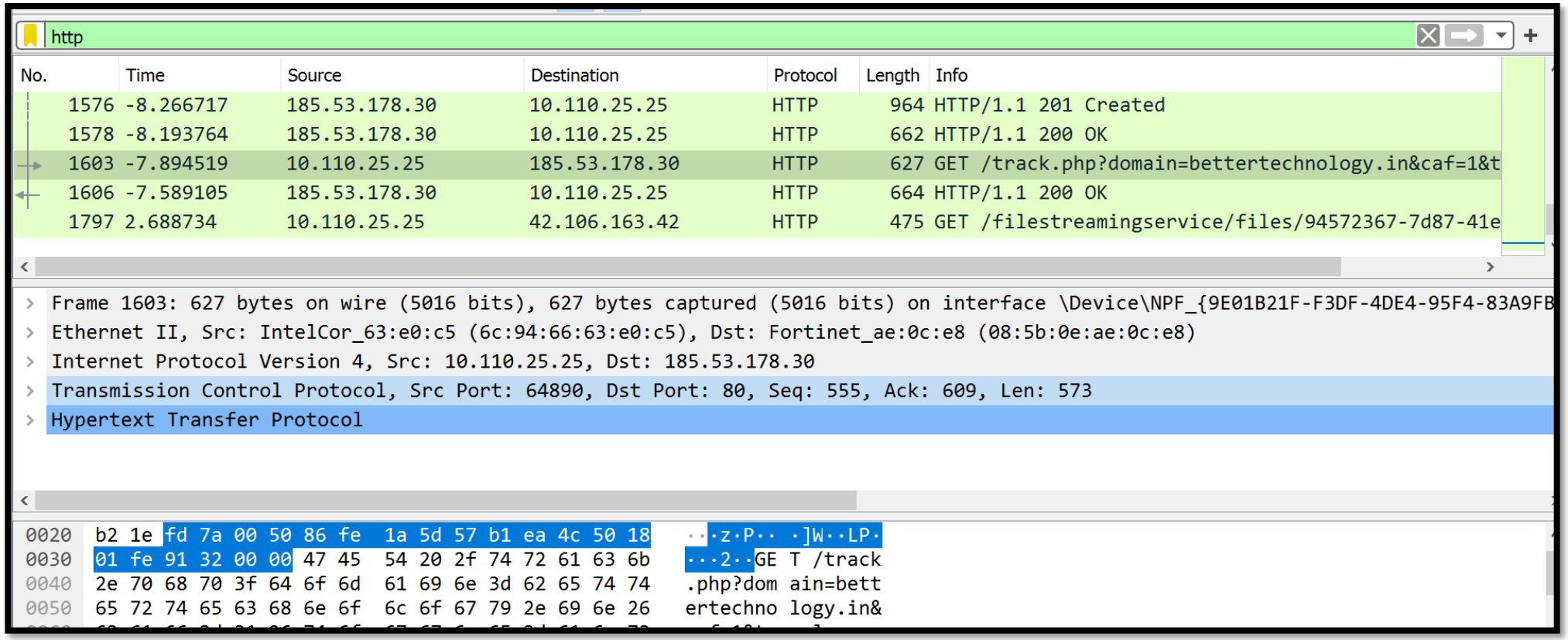
Encapsulation in requesting a web page

- Application Layer – host address (js.parkingcrew.net)
- Host server having the web page with URL bettertechnology.in



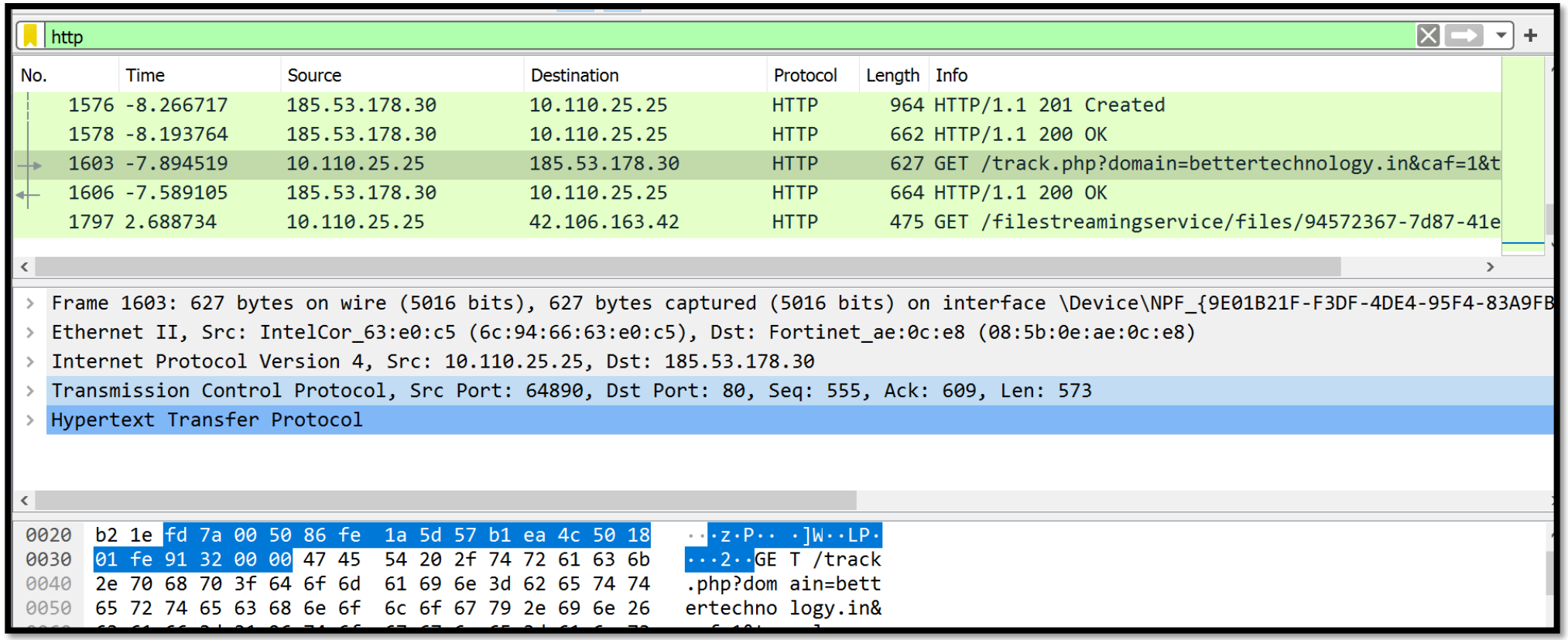
Encapsulation in requesting a web page

- Transport Layer – Port address
- Source port (my laptop as client)– 64890
- Destination port (web server) - 80



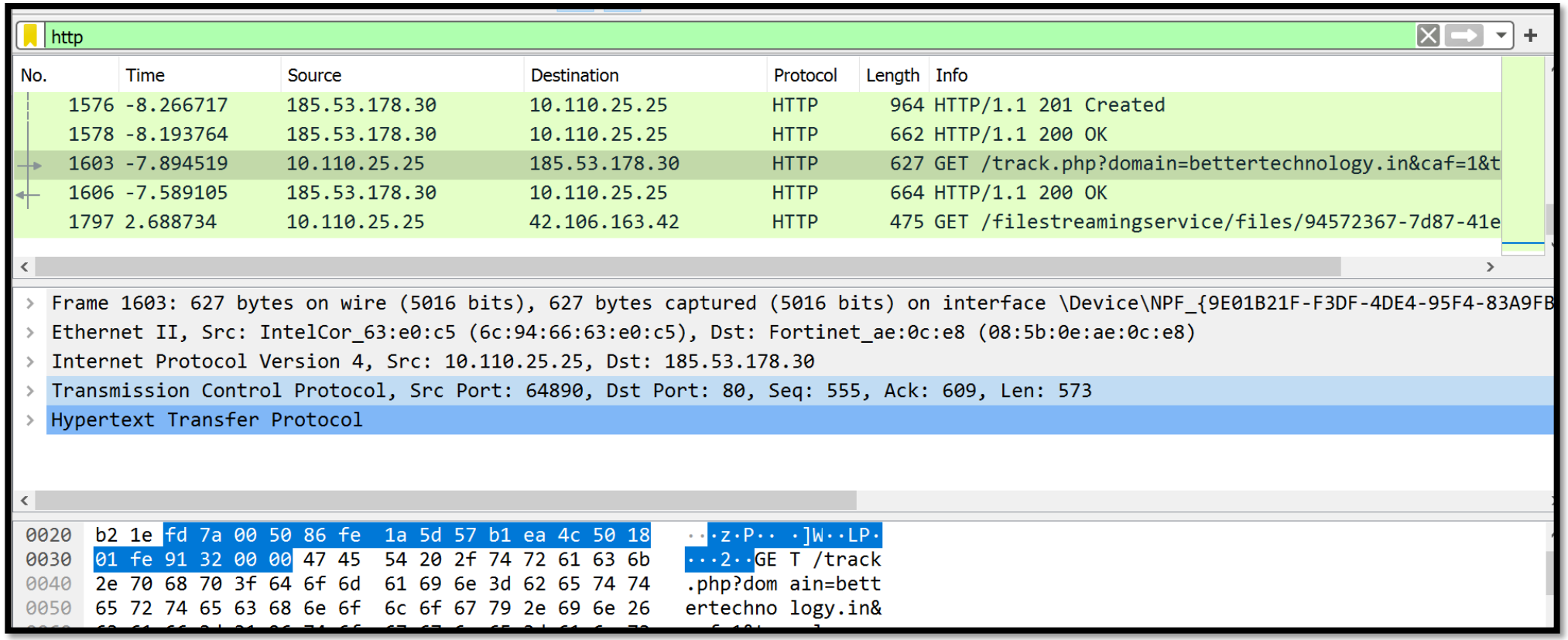
Encapsulation in requesting a web page

- Network Layer – Internet Protocol (IP) address
- Source IP: 10.110.25.25 (laptop – ipconfig)
- Destination IP: 185.53.178.30 (web server)



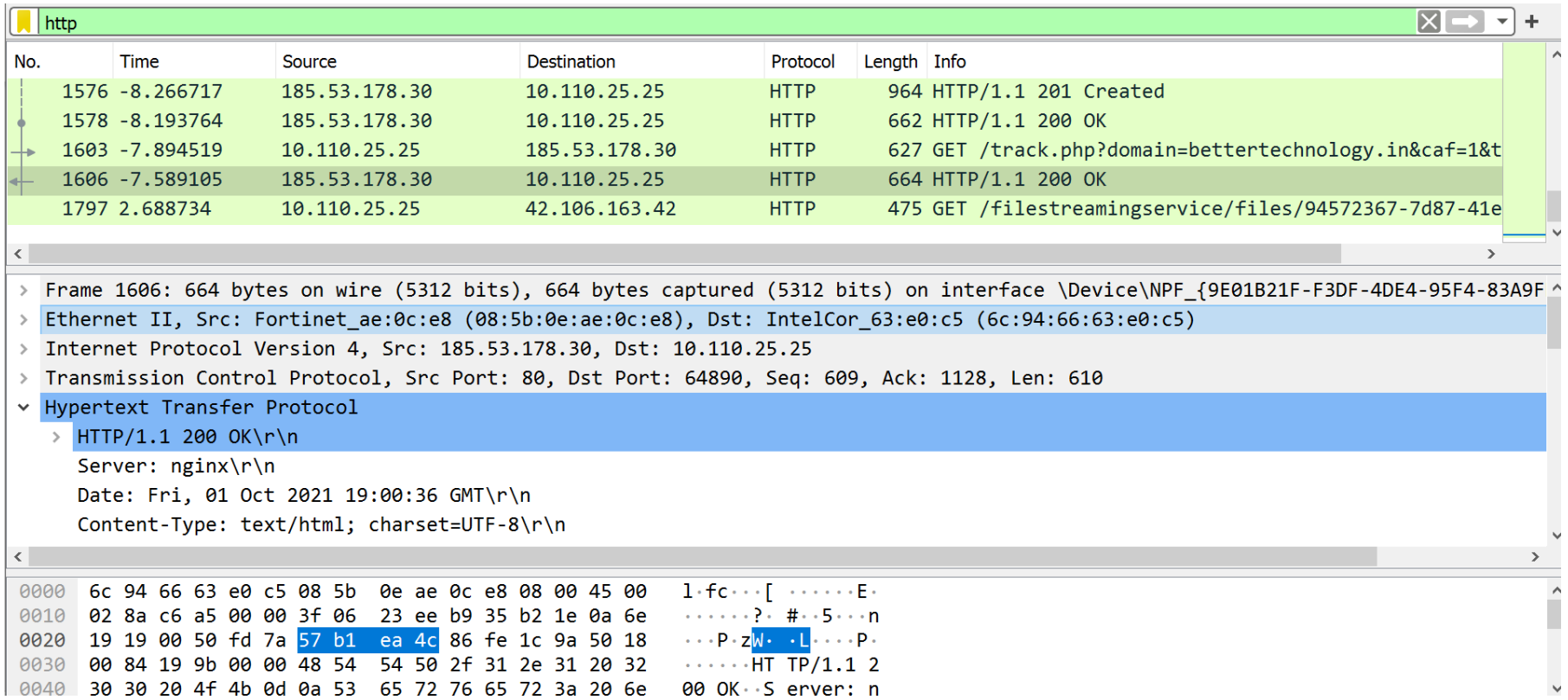
Encapsulation in requesting a web page

- Data Link Layer – Physical (MAC) address
- Source MAC: 6c:94:66:63:e0:c5 (laptop – ipconfig/all)
- Destination MAC: 08:5b:0e:ae:0c:e8 (default gateway)



De-Encapsulation in received webpage

- Application - Received webpage successfully by response code 200 ok in the laptop
- Transport – Source and destination port of request are exchanged in response
  - Src: 80
  - Dst: 64890
- Network - also Exchanged
  - Src: 185.53.178.30
  - Dest: 10.110.25.25
- Ethernet – MAC address also exchanged



Protocol Data Unit Analysis

- We will analyze now the protocol data units(**PDU**) in web page request and response packets together

Layer	Protocol	Web page request frame	Web page response frame
Application	HTTP	Host: js.parkingcrew.net	200 ok [web page confirmed]
Transport	TCP	Src port: 64890 Dest Port: 80	Src port: 80 Dest Port: 64890
Network	IP	Src IP: 10.110.25.25 Dest IP: 185.53.178.30	Src IP: 185.53.178.30 Dest IP: 10.110.25.25
Data Link & Physical	Ethernet	Src MAC: 6c:94:66:63:e0:c5 Dest MAC: 08:5b:0e:ae:0c:e8	Src MAC: 08:5b:0e:ae:0c:e8 Dest MAC: 6c:94:66:63:e0:c5

Summary

- Examined the IP address & MAC address of our laptop
- Install & launch Wireshark in the laptop having internet access
- Analyze the protocols in the packet sniffer tool for web page request and response
  - Viewed Protocol Data Units