Computer Networks

Lecture 15

Sequence of Content

- **What is a Network?**
- **Networking Applications**
  The Internet, Telephone, GPS, Television and Radio Broadcasting, Wi-Fi and Bluetooth, Cellular Radio Transmissions
- **Network Characteristics**
  Topologies, Architectures, Size and Coverage Area
- **Communication Protocols and Networking Standards**
  TCP/IP, Ethernet, WiMAX, Cellular Standards, Wireless Standards
- **Networking Hardware**
  Network Adapters, Hubs, Switches and Routers

Satellite Internet

Satellite internet applications in Pakistan are poised to revolutionize connectivity, especially in remote and underserved areas.

Key Players and Partnerships:

- **Kacific and PAKSAT:** They're partnering to bring affordable, high-speed satellite internet to Pakistan, leveraging the Paksat MM1 satellite's 11 Ka-band spot beams to cover over 20,000 sites
- **Starlink:** Expected to launch in Pakistan by the end of 2025, Starlink promises fast speeds (up to 220 Mbps) and low latency, ideal for bridging the digital divide
- **Pak Datacom and Kacific:** Their strategic alliance aims to deliver high-speed satellite internet across Pakistan, focusing on education, healthcare, enterprise, and government sectors

Satellite Internet

Applications in Pakistan

1. Education

- Remote Learning: High-speed internet enables students in rural areas to access online platforms and resources
- Bridging Disparities: Helps reduce academic gaps between urban and rural populations

2. Healthcare

- Telemedicine: Stable connections allow doctors to reach patients in remote areas, improving healthcare outcomes.

Satellite Internet

Applications in Pakistan

3. Business and Economy

- E-commerce and Digital Sales: Entrepreneurs in remote regions can expand internationally
- Mobile Backhaul: Enhances connectivity for cellular operators, bypassing infrastructure limitations

4. Government and Emergency Services

- Disaster Response: Reliable connectivity aids coordination during emergencies
- Government Initiatives: Supports Pakistan's digital inclusion vision, like the "Digital Pakistan" initiative.

Satellite Internet

Challenges

- **Regulatory Hurdles:** Pakistan Space Activities Regulatory Board (PSARB) and Pakistan Telecommunication Authority (PTA) approvals are pending
- **Cost:** Initial hardware and monthly fees might be steep for many households
- **Infrastructure:** Need for Fixed Gateway Earth Stations within Pakistan for data control and content monitoring

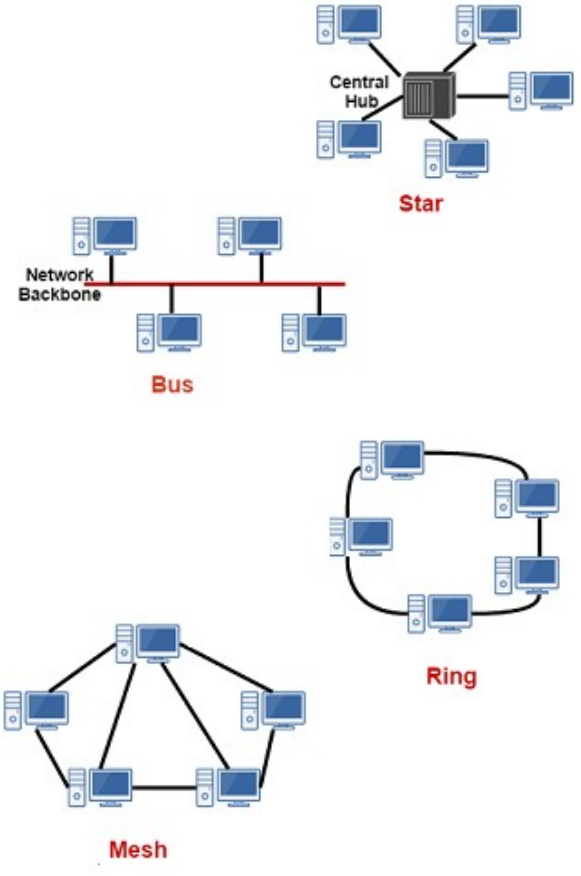
Potential Impact

- **Digital Divide:** Satellite internet can connect over 131.8 million Pakistanis currently offline
- **Economic Growth:** Expected to boost revenue streams and digitalization efforts

Network Topologies:

Arrangement or layout of different elements (links, nodes, etc.) in a computer network

- **Star Network:** All devices are connected to a central device, typically a switch or hub
- **Bus Network:** All devices are connected to a single central cable, called the bus or backbone
- **Ring Network:** Devices in a ring topology are connected in a circular fashion
- **Mesh Network:** Every device is connected to every other device in the network



Network Characteristics

Comparative Analysis:

Network Topology	Advantages	Disadvantages
Star Network	▪ Easy to install/manage centrally ▪ Failure of one node doesn't disrupt others (if switch/hub robust) ▪ Scalable (add devices to central point)	▪ Central point is single point of failure (if hub/switch fails) ▪ High cabling cost if central point far from nodes
Bus Network	▪ Simple, cost-effective cabling ▪ Suitable for small networks	▪ Single cable issue affects whole network ▪ Troubleshooting hard; terminators needed at ends ▪ Limited distance/speed
Ring Network	▪ Deterministic data flow (token passing) ▪ Can be efficient in controlled environments	▪ One node failure can disrupt whole ring (unless dual ring) ▪ Adding/removing nodes tricky
Mesh Network	▪ High redundancy; robust against failures ▪ Great for critical systems needing high reliability	▪ Complex, costly cabling & management ▪ High resource usage for full mesh

Key Considerations:

- **Scalability:** Star often favoured for growth ease
- **Fault Tolerance:** Mesh excels; star depends on central node robustness
- **Cost:** Bus simple/cheap; mesh often costly
- **Performance:** Depends on implementation & traffic patterns

Network Characteristics

IoT Network Topologies:

1. **Star Topology in IoT:** Common with central hubs/gateways collecting data from devices
   - **Examples:** Smart home hubs (e.g., Google Home, Amazon Echo) connecting sensors/devices
   - **Advantages:** Easy management; central data processing
   - **Considerations:** Gateway can be bottleneck/single point of failure
2. **Mesh Topology in IoT:** Popular for extending coverage, robustness
   - **Examples:** Wireless sensor networks; IoT devices routing data peer-to-peer
   - **Advantages:** Self-healing; extended range via multi-hop
   - **Challenges:** Complexity; power constraints on nodes
3. **Other Topologies:** Hybrid approaches seen; bus/ring less common in modern IoT

Key IoT Networking Aspects:

- **Low Power Wide Area Networks (LPWAN):** Technologies like LoRaWAN, NB-IoT for long-range, low-power IoT
- **Short-range Protocols:** Bluetooth, Zigbee, Z-Wave for local IoT connectivity
- **Gateway Role:** Often translate protocols; connect constrained IoT devices to cloud/IP networks

IoT Applications & Topology Relevance:

1. **Smart Homes:** Star-like with hubs controlling devices (e.g., lighting, thermostats)
2. **Industrial IoT (IIoT):** Meshes for robust industrial sensing/control networks
3. **Wearables/Health Monitoring:** Often connect via star (e.g., smartphone hub for wearables)
4. **Smart Cities:** Mesh networks for sensors spread across urban areas
5. **Agricultural IoT:** Sensors in mesh/star for monitoring soil, environment

Challenges in IoT Networking:

- **Scalability:** Handling millions of devices
- **Security:** Device vulnerabilities; secure communication critical
- **Power Efficiency:** Many IoT devices battery-constrained
- **Interoperability:** Diverse protocols; need for standards

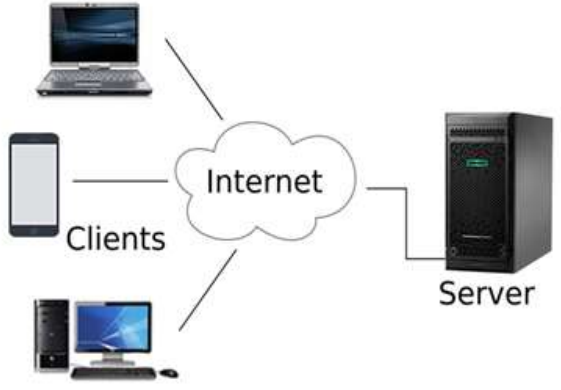
Examples of IoT Deployments:

- **Smart Meters:** Utilities use IoT for remote monitoring
- **Connected Vehicles:** IoT for vehicle-to-everything (V2X) communications
- **Environmental Monitoring:** Sensors for air/water quality

Network Architectures:

The design, structure, and framework that dictate how devices and components in a network communicate and interact

- **Client-Server:** The server provides resources, data, and services, while clients request these resources from the server
- **Peer-to-Peer (P2P):** Each device can share resources with other devices directly

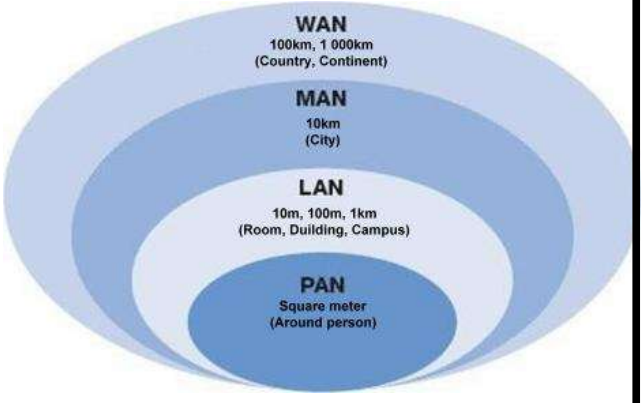


Network Characteristics

Network Size and Coverage Area:

Network size typically refers to the scale of the network in terms of the number of users, devices, or nodes, while coverage area relates to the physical area that the network can effectively serve.

- **Personal Area Networks (PANs):** Connect few devices in a range of about 10 meters (30 feet)
- **Local Area Networks (LANs):** Connect hundreds of devices, usually within a single building, ranging from a few meters up to several kilometers
- **Metropolitan Area Network (MANs):** Connect thousands of devices
- **Wide Area Networks (WANs):** All processing and data management occur in a central mainframe or server
- **Global Area Network (GANs):** Billions of devices connected, spanning the entire Earth



Network Characteristics

Local area network (LAN):

- A LAN is a small network of that covers a small area like a building.
- Coverage area 10 m to 1000 m (1 km)
- A LAN has a number of computers and other devices connected to a hub or switch which in turn connects to the internet via a router.
- LANs are used in schools, hospitals, companies etc.

Advantages of LANs	Disadvantages of LANs
▪ Enables sharing of hardware and software resources	▪ Security risk; easy spread of viruses
▪ Allow communication between users of the LAN	▪ If main server breaks down, the whole network can stop functioning

Wireless local area network (WLAN):

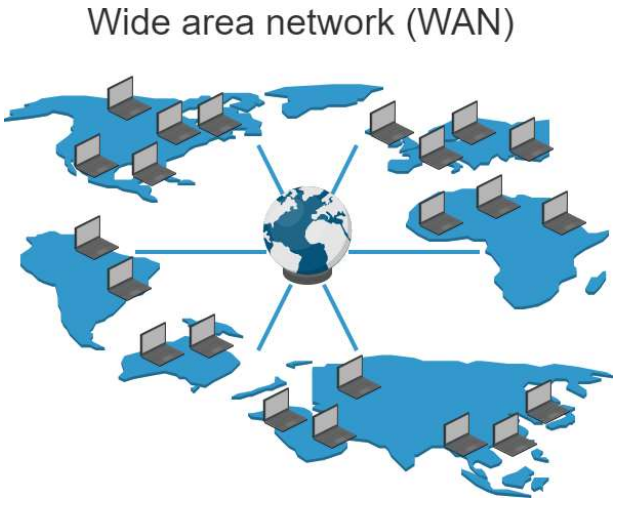
- A wireless version of LANs; make use of radio or infrared signals to connect devices together over short distances instead of cables as in LANs
- Access Points (APs) are connected to LANs for wireless communication
- APs also allow the LANs and WLANs to receive and transmit data between devices.

Comparison between Wired and Wireless Local Area Network (WLAN):

Wireless Networking	Wired Networking
▪ Easy to expand the network compared to use of cables	▪ Use of cables in LANs ensure stable and reliable connectivity between devices
▪ Devices can be move around within the network coverage area	▪ Devices are fixed due to cabling
▪ Safer due to lack of cabling	▪ Cabling is cheaper but can cause accidents
▪ Prone to interferences from other signals and slow data transfer rates	▪ Faster connectivity and data transfer due to cablings
▪ Less security; radio waves can easily be hacked.	▪ Cabling is more secure and difficult to hack into network

Wide Area Networks (WANs):

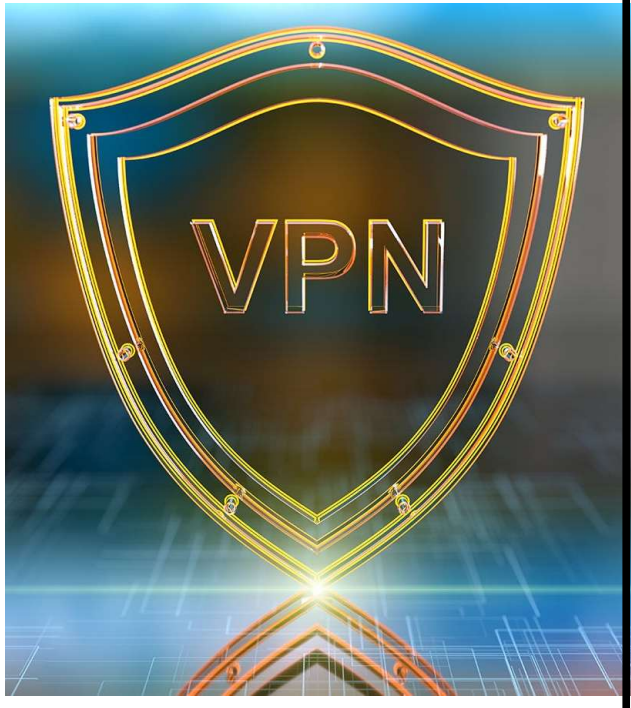
- Networks that extend over large geographical areas connecting devices over long distances wirelessly
- Coverage area 100 km to over 1000 km
- WANs are often a combination of several LANs joined together using routers.
- Use telephone networks and satellites for communication
- Examples of WANs are the internet, ATMs



Virtual Private Networks (VPNs):

A technology that creates a secure and encrypted connection over a less secure network, such as the Internet

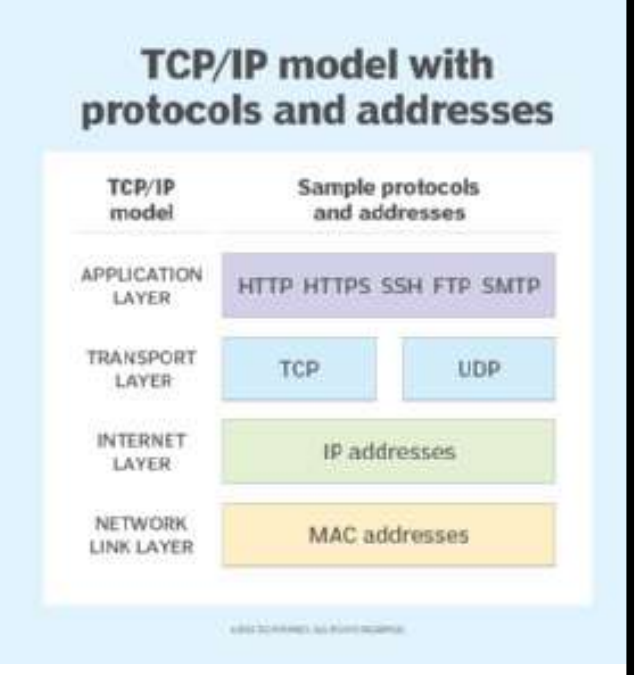
- Used for enhancing privacy, securing data, and accessing restricted content
- Allows users to send and receive data across shared or public networks as if their devices were directly connected to a private network
- Data sent from device is encrypted in a secure tunnel between the user's device and the VPN server
- IP address of the VPN server is used instead of user’s original IP address
- Only authorized users can access the network



TCP/IP (Transmission Control Protocol/Internet Protocol):

A set of communication protocols used for the internet and similar networks

- Foundation for how data is transmitted over the internet and consists of several layers, each responsible for different aspects of data transmission
- Allows different types of computers and networks to communicate, regardless of their underlying architectures
- Can accommodate a vast number of devices, making it suitable for large networks like the internet
- Ensures data integrity and delivery through acknowledgments and retransmissions
- Other Communication Protocols include HTTP/HTTPS, FTP, SMTP, IMAP, SNMP, DHCP, BGP and RIP/OSPF



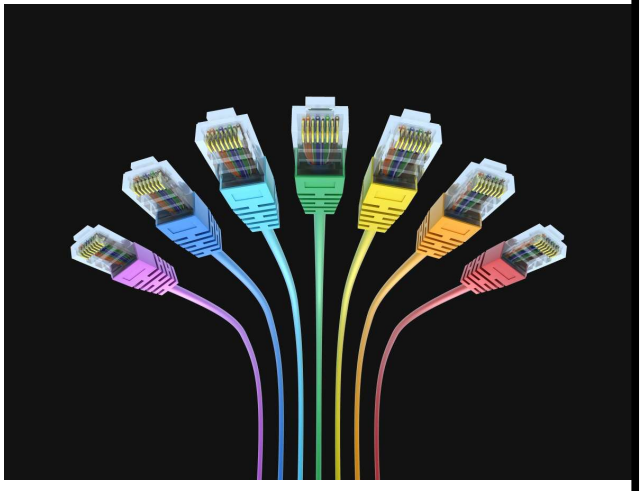
Communication Protocols and Networking Standards

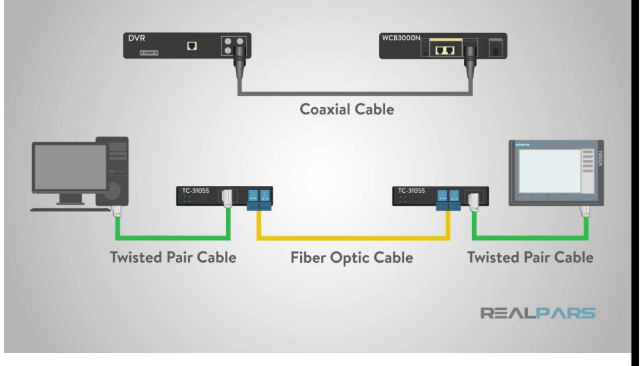
Ethernet:

A family of wired computer networking technologies commonly used in local area networks (LAN), metropolitan area networks (MAN) and wide area networks (WAN)

- Developed in the 1970s by Robert Metcalfe and his team at Xerox PARC (Palo Alto Research Center). It was initially designed to connect computers within a building and transmit data over coaxial cables.

- Ethernet operates on the principle of collision detection and avoidance. Before transmitting, devices listen to the network to see if it's busy. If two devices transmit simultaneously, a collision occurs, and both devices stop, wait a random time, and then attempt to retransmit.





Wi-Fi (802.11)

- A family of wireless networking standards using the IEEE standard 802.11
  - Current standard for wireless networks in homes and offices
  - Designed for medium-range transmission
  - Wi-Fi hardware built into most notebook computers and many consumer devices today
  - Wi-Fi hotspots are rapidly multiplying

FIGURE 7-25
Wi-Fi enabled products. Many consumer products today contain built-in Wi-Fi connectivity.

Wi-Fi (802.11)

- Speed and distance of Wi-Fi networks depends on:
  - Standard and hardware being used (continually evolving)
  - Number of solid objects between the access point and the computer or device
  - Possible interference

FIGURE 7-26
Wi-Fi standards.

WI-FI STANDARD	DESCRIPTION
802.11b	An early Wi-Fi standard; supports data transfer rates of 11 Mbps.
802.11a	Supports data transfer rates of 54 Mbps, but uses a different radio frequency (5 GHz) than 802.11g/b (2.4 GHz), making the standards incompatible.
802.11g	A current Wi-Fi standard; supports data transfer rates of 54 Mbps and uses the same 2.4 GHz frequency as 802.11b, so their products are compatible.
802.11n	The newest Wi-Fi standard; supports speeds up to about 300 Mbps and has twice the range of 802.11g. It can use either the 2.4 GHz or 5 GHz frequency.
802.11s*	Designed for Wi-Fi mesh networks.
802.11u*	Includes additional security features.
802.11z*	Designed for direct (ad hoc) networking between advices.
802.11ac and 802.11ad**	Designed to increase throughput.

* Expected by 2010
** Expected no earlier than 2012

WiMAX and Mobile WiMAX

- WiMAX (802.16): Fairly new wireless standard for longer range wireless networking connections
  - Designed to deliver broadband to homes, businesses, other fixed locations
  - Hotzones close to 2 miles (similar in concept to cell phone towers)
  - Typical speed is 1 to 6 MHz

- Mobile WiMAX: Mobile version of the standard
  - Broadband via mobile phone, portable computer, etc.

WiMAX and Mobile WiMAX

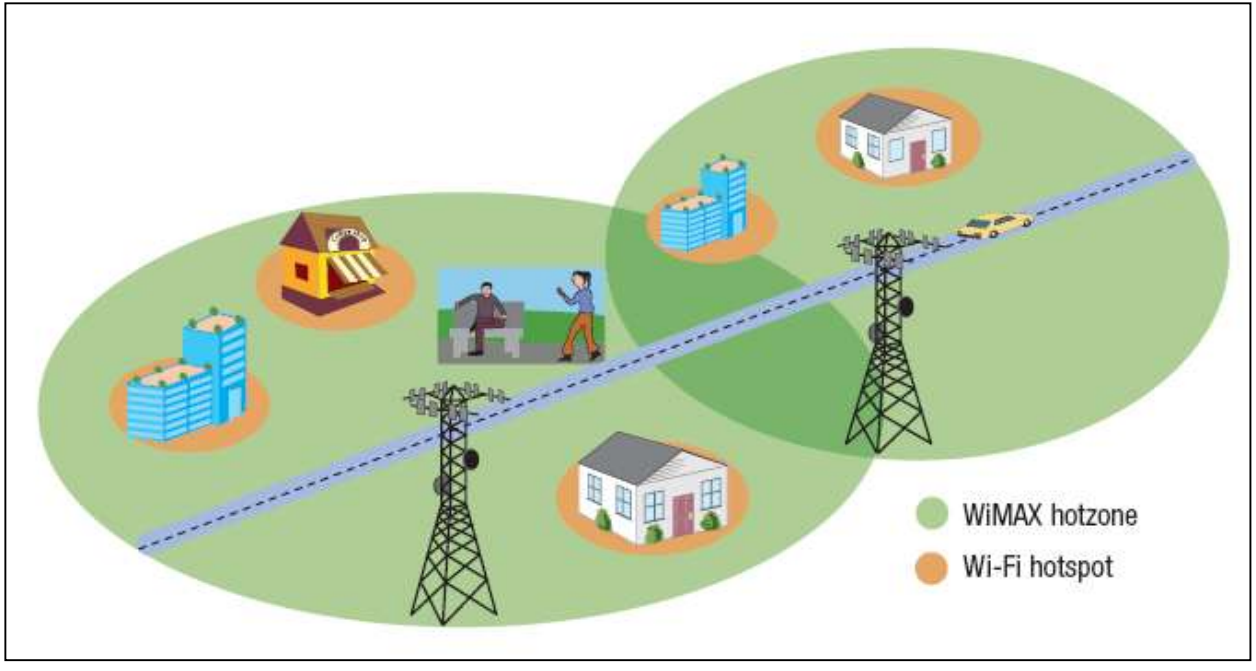


FIGURE 7-28
WiMAX vs. Wi-Fi. WiMAX hotzones can provide service to anyone in the hotzone, including mobile users, while the range of Wi-Fi hotspots is fairly limited.

Network Interface card (NIC)

- It allows a device (computer) to connect to a network by turning binary (1 and 0s) into an electrical signal.
- A NIC is usually integrated into the motherboard on most computers.
- Each NIC has a unique code called Media access control (MAC) address

Media access control (MAC) address or physical address

- The MAC address is a 48 bits number which uniquely identifies a device connected on a network.
- The MAC address constitute the manufacturers code and device serial number.
- Very useful when trouble shooting a network as they do not change

Example of MAC address

MM – MM – MM – DD – DD - DD
Manufacturer's code device serial number

Internet protocol (IP) addresses

- A unique address assigned to a device by an internet service provider (ISP) each time the device connects to the internet.
- Internet protocols define the rules for communicating through a network by its users.
- The IP address identifies the location of every user device on a network.
- The IP address changes whenever a device changes its location or connects from a different location.
- Two IP versions are currently being used; IPv4 (32 bits) and IPv6 (128 bits)

254.25.28.77

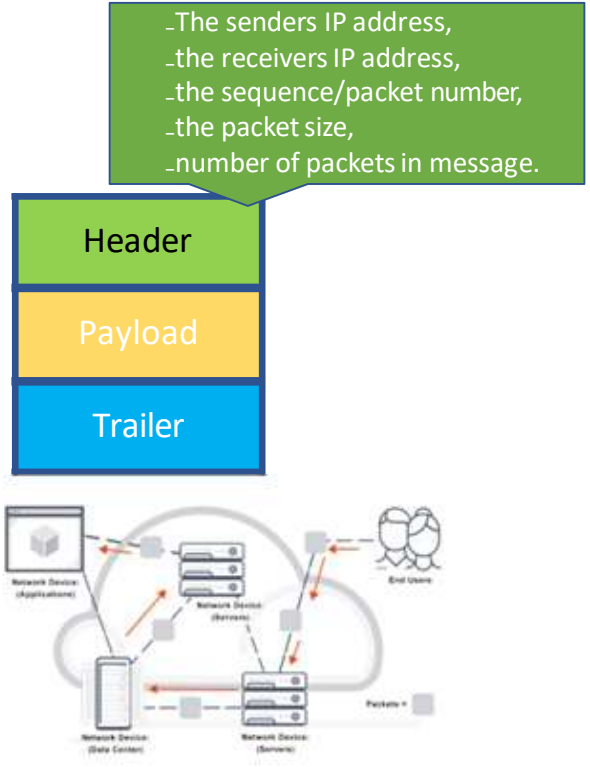
IPv4 address

A8FB:7A88:FFF0:0FFF:3D21:2085:66FB:F0FA

IPv6 – 128 bits

Data Packets

- Data sent from a sender to a receiver is usually split up and transmitted in the form of packets.
- Each data packet is transmitted separately from sender to receiver
- A data packet has a header which contains the following:
  - The senders IP address
  - The receivers IP address
  - The sequence/packet number
  - The packet size
  - Number of packets that make up the message
- This sent data hops through the router and is moved to the receivers IP address.



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