

Network Layer

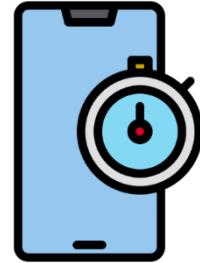
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Naryn, 6:41pm, September 28, 2022



Lessons learnt last time



- **Ethernet Frames:** Explain how the Ethernet sublayers are related to the frame fields
- **Ethernet MAC Address:** Describe the Ethernet MAC address
- **The MAC Address Table:** Explain how a switch builds its MAC address table and forwards frames
- **Switch Speeds and Forwarding Methods:** Describe switch forwarding methods and port settings available on Layer 2 switch ports

What we gonna discuss today?



- Network Layer Characteristics: Explain how the network layer uses IP protocols for reliable communications
- IPv4 Packet: Explain the role of the major header fields in the IPv4 packet
- IPv6 Packet: Explain the role of the major header fields in the IPv6 packet
- How a Host Routes: Explain how network devices use routing tables to direct packets to a destination network
- Router Routing Tables: Explain the function of fields in the routing table of a router

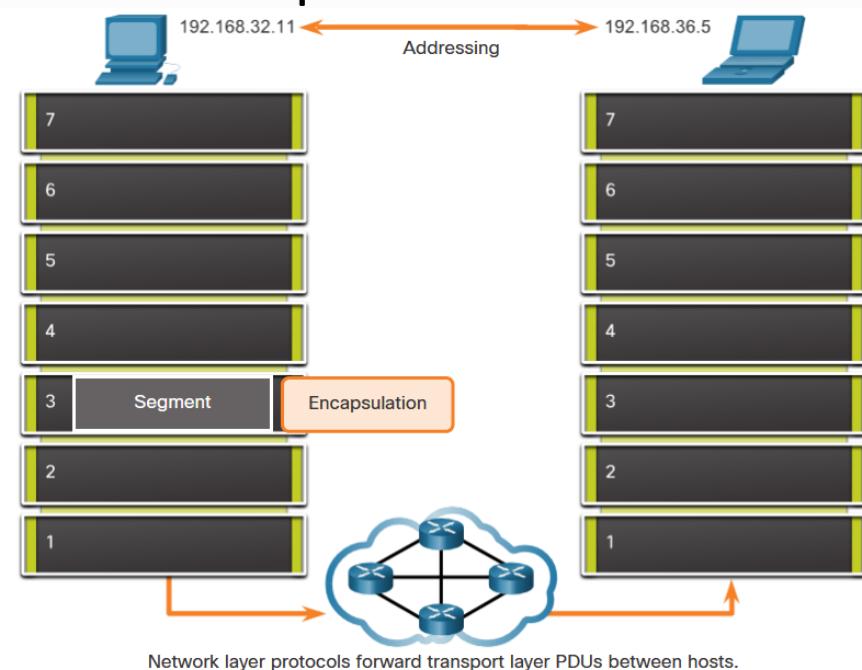
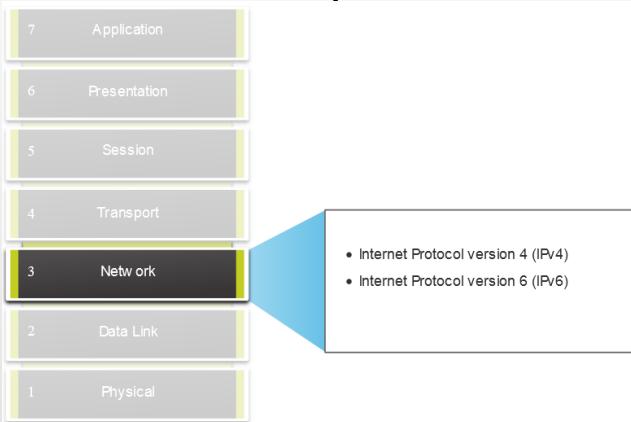
Network Layer Characteristics

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- Network Layer Characteristics

Network Layer Characteristics

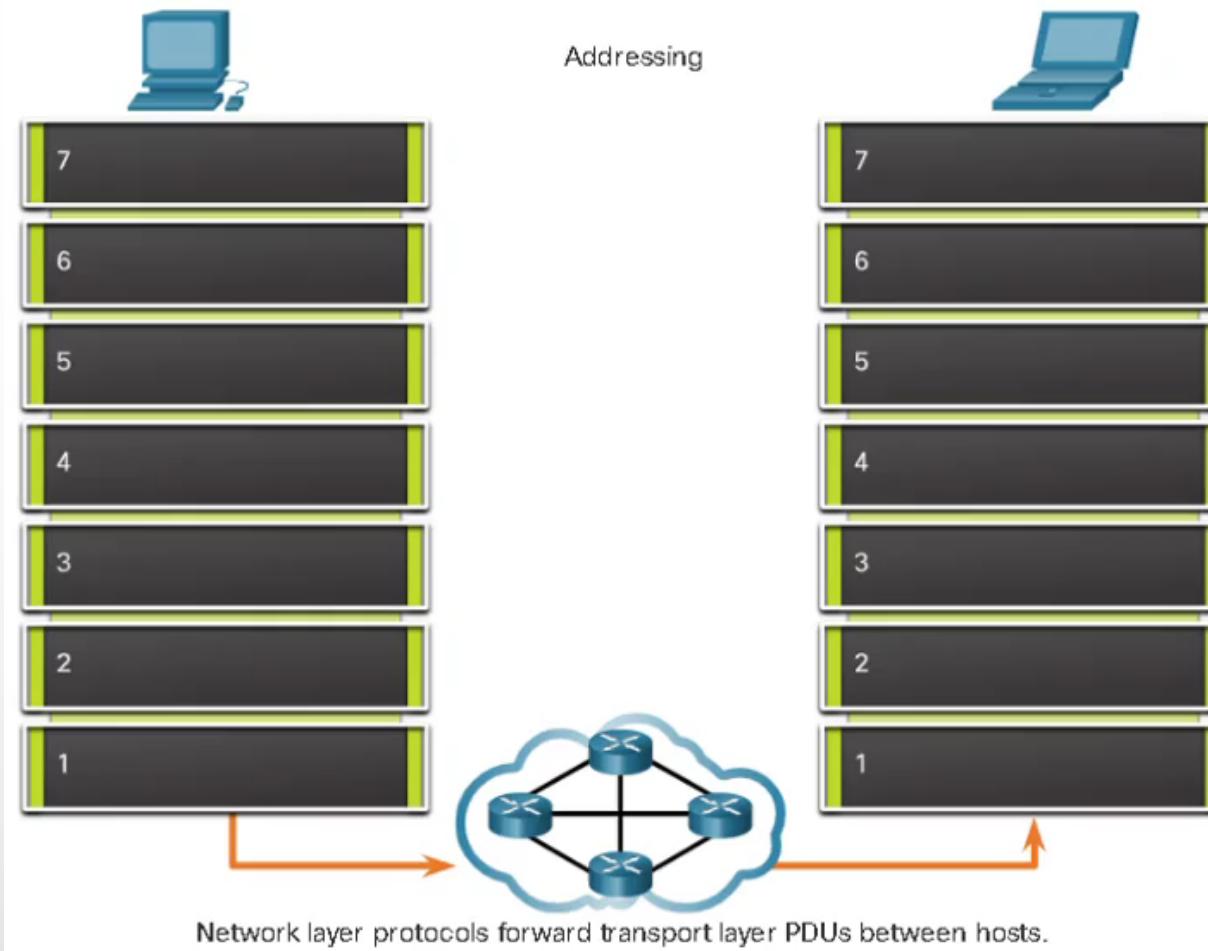
- The Network Layer

- Provides services to allow end devices to exchange data
- IP version 4 (IPv4) and IP version 6 (IPv6) are the principle network layer communication protocols
- The network layer performs four basic operations:
 - Addressing end devices
 - Encapsulation
 - Routing
 - De-encapsulation



Network Layer Characteristics

- The Network Layer: Exchange of data

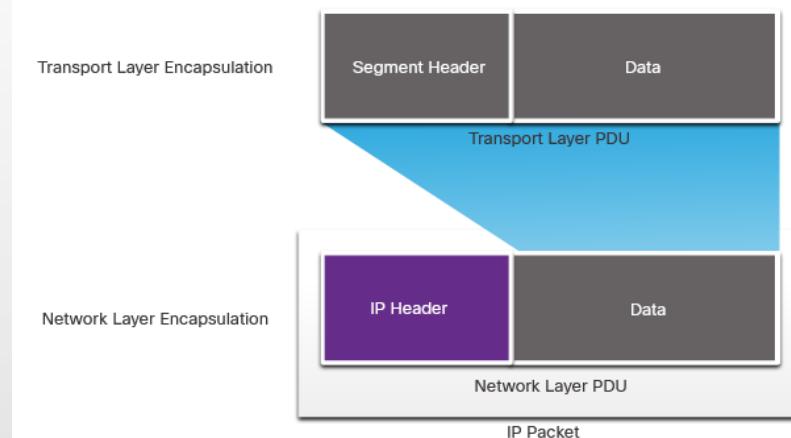


Network Layer Characteristics

- IP Encapsulation

- IP encapsulates the transport layer segment
- IP can use either an IPv4 or IPv6 packet and not impact the layer 4 segment
- IP packet will be examined by all layer 3 devices as it traverses the network
- The IP addressing does not change from source to destination

Note: NAT (Network Address Translation) changes addressing, but it's another story :)



Network Layer Characteristics



- Characteristics of IP (Internet Protocol)

- IP is meant to have low overhead and may be described as:
 - Connectionless
 - Best Effort
 - Media Independent

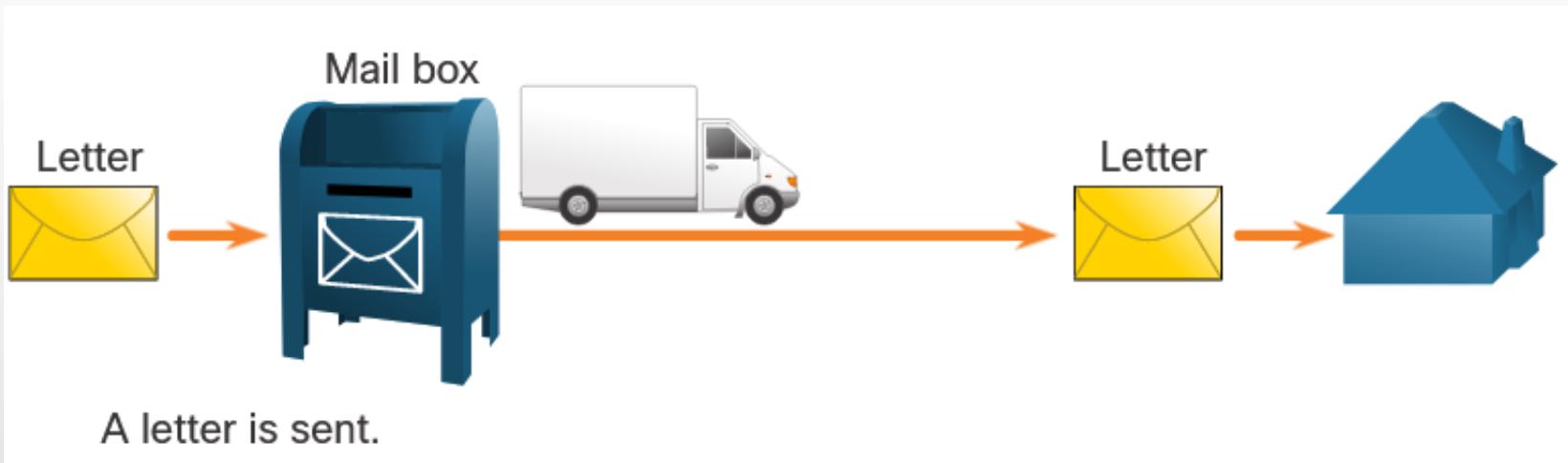
Note: The Internet Protocol (IP) is the network layer communications protocol in the Internet protocol suite for relaying datagrams across network boundaries. Its routing function enables internetworking, and essentially establishes the Internet (https://en.wikipedia.org/wiki/Internet_Protocol)

Network Layer Characteristics

- Connectionless

- IP is Connectionless:

- IP does not establish a connection with the destination before sending the packet
 - There is no control information needed (synchronizations, acknowledgments, etc.)
 - If there is a need for connection-oriented traffic, then another protocol will handle this (typically TCP at the transport layer)

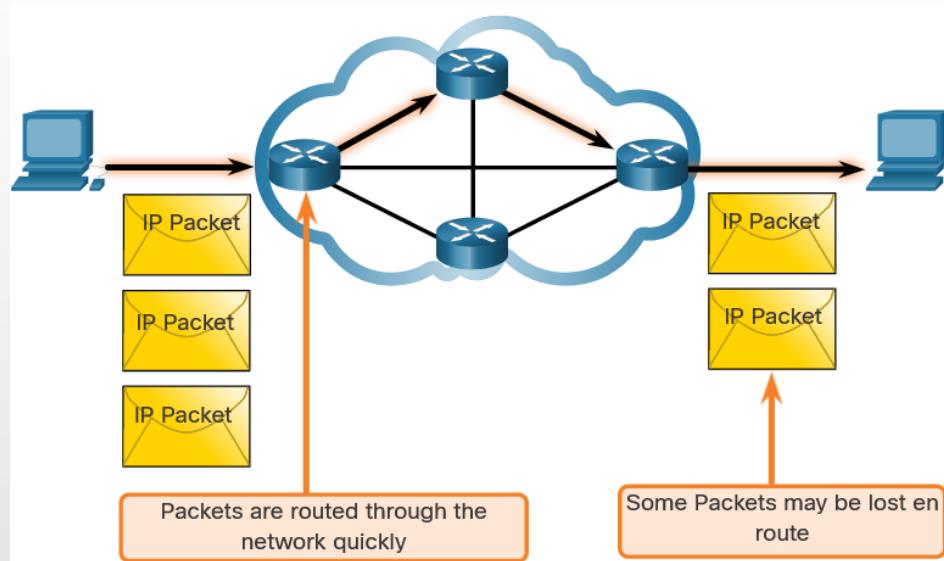


Network Layer Characteristics

- Best Effort

- IP is Best Effort:

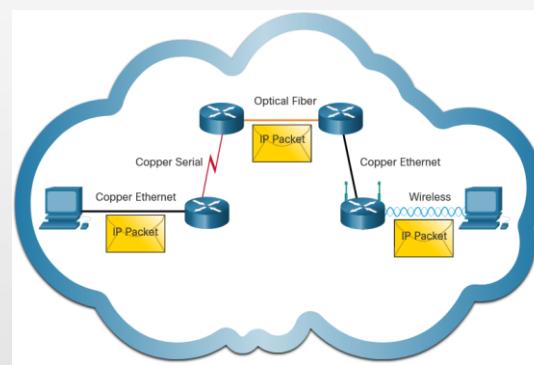
- IP will not guarantee delivery of the packet
 - IP has reduced overhead since there is no mechanism to resend data that is not received
 - IP does not expect acknowledgments
 - IP does not know if the other device is operational or if it received the packet



Network Layer Characteristics

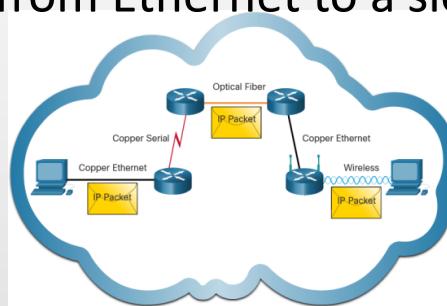
- Media Independent

- IP is unreliable:
 - It cannot manage or fix undelivered or corrupt packets
 - IP cannot retransmit after an error
 - IP cannot realign out of sequence packets
 - IP must rely on other protocols for these functions
- IP is media Independent:
 - IP does not concern itself with the type of frame required at the data link layer or the media type at the physical layer
 - IP can be sent over any media type: copper, fiber, or wireless



Network Layer Characteristics

- Media Independent (cont.)
 - The network layer will establish the Maximum Transmission Unit (MTU):
 - Network layer receives this from control information sent by the data link layer
 - The network then establishes the MTU size
 - Fragmentation is when Layer 3 splits the IPv4 packet into smaller units:
 - Fragmenting causes latency
 - IPv6 does not fragment packets
 - Example: Router goes from Ethernet to a slow WAN with a smaller MTU



IPv4 Packet



- IPv4 Packet

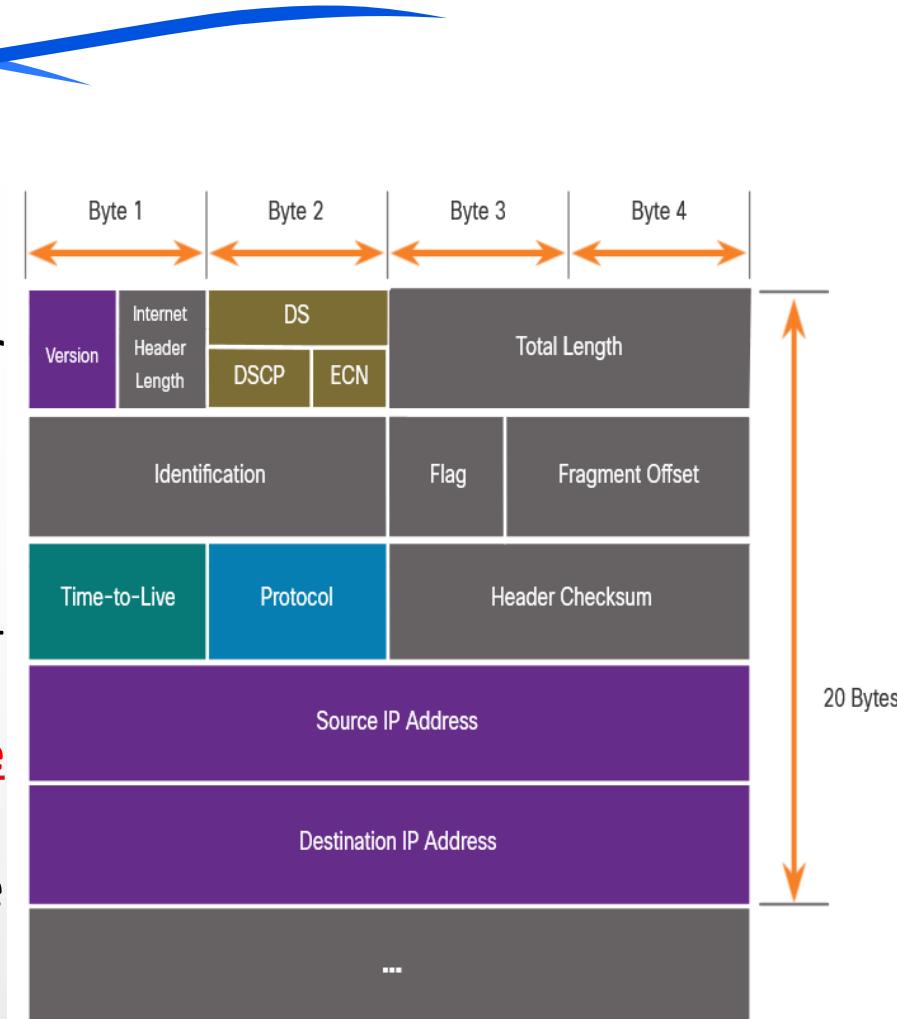
IPv4 Packet



- IPv4 Packet Header
 - IPv4 is the primary communication protocol for the network layer
 - The network header has many purposes:
 - ° It ensures the packet is sent in the correct direction (to the destination)
 - ° It contains information for network layer processing in various fields
 - ° The information in the header is used by all layer 3 devices that handle the packet

IPv4 Packet

- IPv4 Packet Header Fields
 - The IPv4 network header characteristics:
 - It is in binary
 - Contains several fields of information
 - Diagram is read from left to right, 4 bytes per line
 - **The two most important fields are the source and destination**
 - Protocols may have one or more functions



IPv4 Packet

- IPv4 Packet Header Fields
 - Significant fields in the IPv4 header:

Function	Description
Version	This will be for v4, as opposed to v6, a 4-bit field= 0100
Differentiated Services	Used for QoS: DiffServ – DS field or the older IntServ – ToS or Type of Service
Header Checksum	Detect corruption in the IPv4 header
Time to Live (TTL)	Layer 3 hop count. When it becomes zero the router will discard the packet.
Protocol	I.D.s next level protocol: ICMP, TCP, UDP, etc.
Source IPv4 Address	32-bit source address
Destination IPV4 Address	32-bit destination address

IPv4 Packet

- Sample IPv4 Headers in Wireshark

Video – Sample IPv4 Headers in Wireshark

This video will cover the following:

- IPv4 Ethernet packets in Wireshark
- The control information
- The difference between packets

IPv6 Packets

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- IPv6 Packets

IPv6 Packets



- Limitations of IPv4

- IPv4 has three major limitations:
 - ° IPv4 address depletion – We have basically run out of IPv4 addressing
 - ° Lack of end-to-end connectivity – To make IPv4 survive this long, private addressing and NAT were created. This ended direct communications with public addressing
 - ° Increased network complexity – NAT was meant as temporary solution and creates issues on the network as a side effect of manipulating the network headers addressing. NAT causes latency and troubleshooting issues

NAT - Network Address Translation

IPv6 Packets



- IPv6 Overview
 - IPv6 was developed by Internet Engineering Task Force (IETF)
 - IPv6 overcomes the limitations of IPv4
 - Improvements that IPv6 provides:
 - ° **Increased address space** – based on 128-bit address, not 32 bits
 - ° **Improved packet handling** – simplified header with fewer fields
 - ° **Eliminates the need for NAT** – since there is a huge amount of addressing, there is no need to use private addressing internally and be mapped to a shared public address

IPv6 Packets

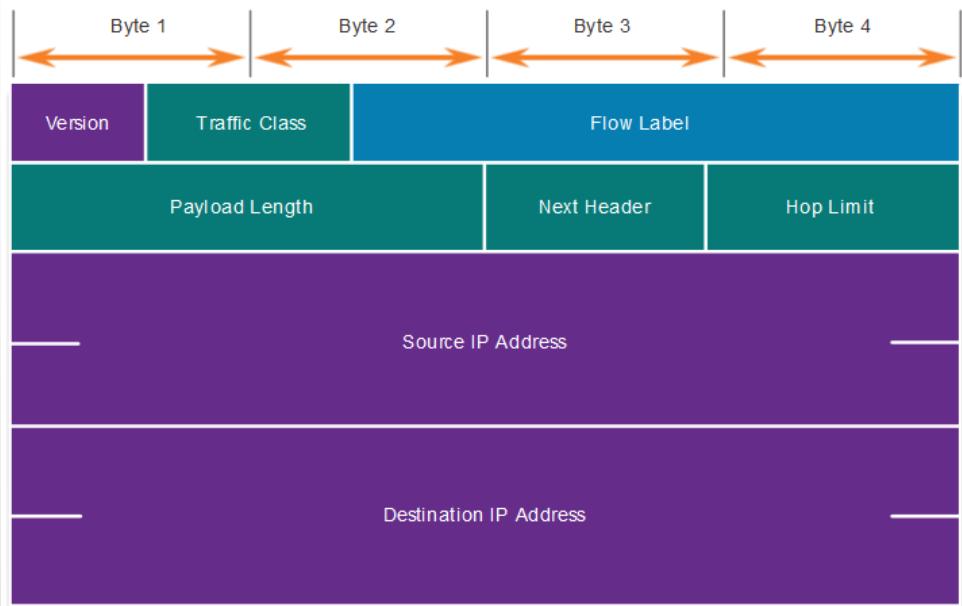
IPv4 and IPv6 Address Space Comparison

Legend

- There are 4 billion IPv4 addresses
 - There are 340 undecillion IPv6 addresses

IPv6 Packets

- The IPv6 header is simplified, but not smaller
- The header is fixed at 40 Bytes
- Several IPv4 fields were removed to improve performance
- Some IPv4 fields were removed to improve performance:
 - Flag
 - Fragment Offset
 - Header Checksum



IPv6 Packets

- IPv6 Packet Header
 - Significant fields in the IPv6 header:

Function	Description
Version	This is for v6, as opposed to v4, a 4-bit field= 0110
Traffic Class	Used for QoS: Equivalent to DiffServ – DS field
Flow Label	Informs device to handle identical flow labels the same way, 20-bit field
Payload Length	This 16-bit field indicates the length of the data portion or payload of the IPv6 packet
Next Header	I.D.s next level protocol: ICMP, TCP, UDP, etc.
Hop Limit	Replaces TTL field Layer 3 hop count
Source IPv4 Address	128-bit source address
Destination IPV4 Address	128-bit destination address

IPv6 Packets



- IPv6 Packet Header (cont.)
 - IPv6 packet may also contain extension headers (EH)
 - EH headers characteristics:
 - provide optional network layer information
 - they are optional
 - they are placed between IPv6 header and the payload
 - may be used for fragmentation, security, mobility support, etc.

Note: Unlike IPv4, routers do not fragment IPv6 packets.

IPv6 Packets

- Sample IPv6 Headers in Wireshark

Video – Sample IPv6 Headers in Wireshark

This video will cover the following:

- IPv6 Ethernet packets in Wireshark
- The control information
- The difference between packets

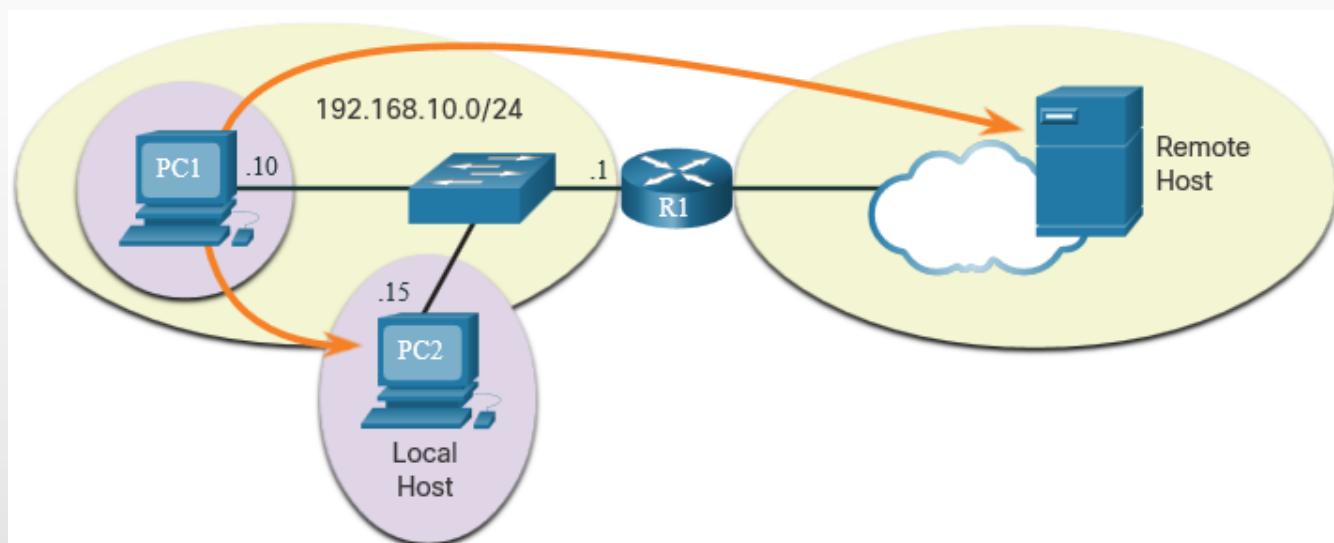
How a Host Routes

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- How a Host Routes

How a Host Routes

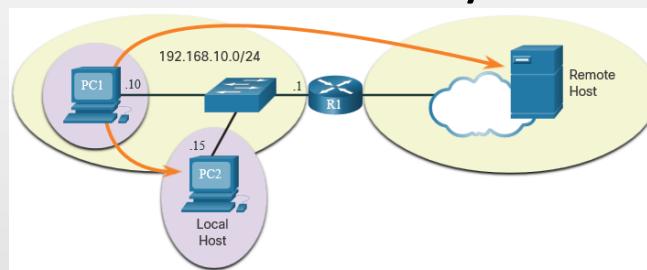
- Host Forwarding Decision

- Packets are always created at the source
- Each host devices creates their own routing table
- A host can send packets to the following:
 - ° Itself – 127.0.0.1 (IPv4), ::1 (IPv6)
 - ° Local Hosts – destination is on the same LAN
 - ° Remote Hosts – devices are not on the same LAN



How a Host Routes

- Host Forwarding Decision (cont.)
 - The Source device determines whether the destination is local or remote
 - Method of determination:
 - IPv4 – Source uses its own IP address and Subnet mask, along with the destination IP address
 - IPv6 – Source uses the network address and prefix advertised by the local router
 - Local traffic is dumped out the host interface to be handled by an intermediary device
 - Remote traffic is forwarded directly to the default gateway on the LAN



How a Host Routes



- Default Gateway
 - A router or layer 3 switch can be a default-gateway
 - Features of a default gateway (DGW):
 - It must have an IP address in the same range as the rest of the LAN
 - It can accept data from the LAN and is capable of forwarding traffic off the LAN
 - It can route to other networks
 - **If a device has no default gateway or a bad default gateway, its traffic will not be able to leave the LAN**

How a Host Routes

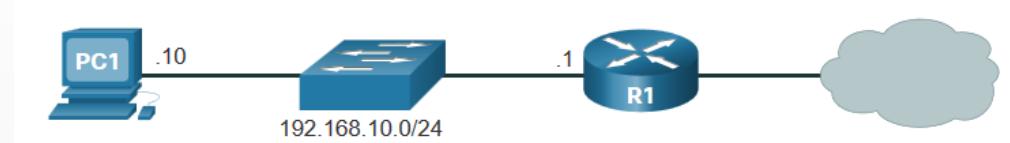


- A Host Routes to the Default Gateway
 - The host will know the default gateway (DGW) either statically or through DHCP in IPv4
 - IPv6 sends the DGW through a router solicitation (RS) or can be configured manually
 - A DGW is static route which will be a last resort route in the routing table
 - All device on the LAN will need the DGW of the router if they intend to send traffic remotely

How a Host Routes

- Host Routing Tables

- On Windows, route print or netstat -r to display the PC routing table
- Three sections displayed by these two commands:
 - ° Interface List – all potential interfaces and MAC addressing
 - ° IPv4 Routing Table
 - ° IPv6 Routing Table



IPv4 Routing Table for PC1

```
C:\Users\PC1> netstat -r

IPv4 Route Table
=====
Active Routes:
Network Destination      Netmask     Gateway       Interface     Metric
          0.0.0.0        0.0.0.0   192.168.10.1  192.168.10.10    25
        127.0.0.0    255.0.0.0   On-link        127.0.0.1    306
        127.0.0.1  255.255.255.255   On-link        127.0.0.1    306
  127.255.255.255  255.255.255.255   On-link        127.0.0.1    306
        192.168.10.0  255.255.255.0   On-link      192.168.10.10    281
        192.168.10.10 255.255.255.255   On-link      192.168.10.10    281
      192.168.10.255 255.255.255.255   On-link      192.168.10.10    281
        224.0.0.0        240.0.0.0   On-link        127.0.0.1    306
        224.0.0.0        240.0.0.0   On-link      192.168.10.10    281
      255.255.255.255 255.255.255.255   On-link        127.0.0.1    306
      255.255.255.255 255.255.255.255   On-link      192.168.10.10    281
```

Introduction to Routing

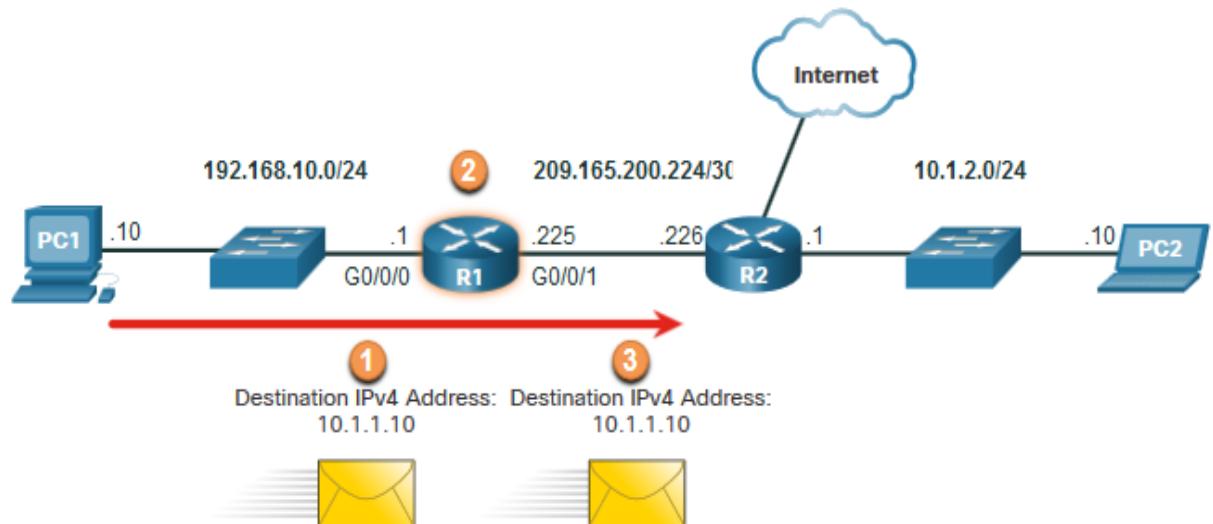
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- Introduction to Routing

Introduction to Routing

- Router Packet Forwarding Decision
 - What happens when the router R1 receives the frame from the host device?

R1 Routing Table

Route	Next Hop or Exit Interface
192.168.10.0 /24	G0/0/0
209.165.200.224/30	G0/0/1
10.1.1.0/24	via R2
Default Route 0.0.0.0/0	via R2

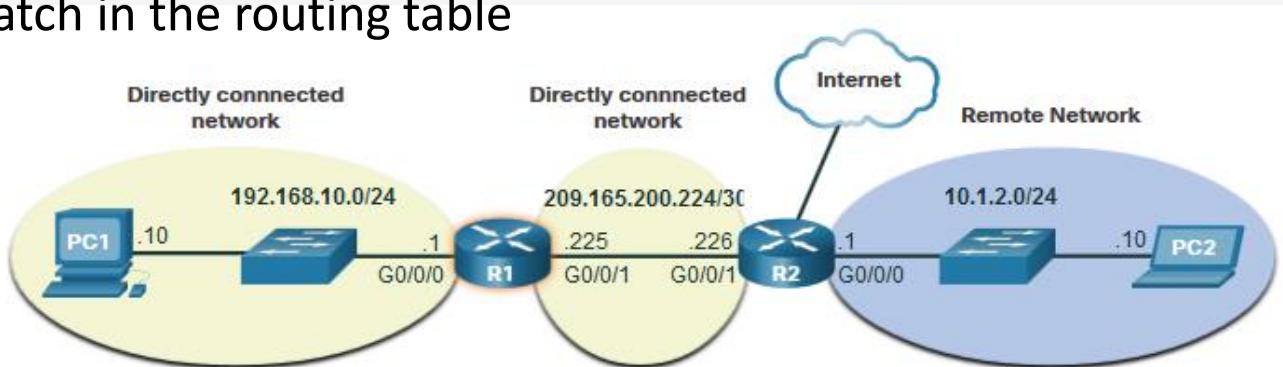


1. Packet arrives on the Gigabit Ethernet 0/0/0 interface of router R1. R1 de-encapsulates the Layer 2 Ethernet header and trailer.
2. Router R1 examines the destination IPv4 address of the packet and searches for the best match in its IPv4 routing table. The route entry indicates that this packet is to be forwarded to router R2.
3. Router R1 encapsulates the packet into a new Ethernet header and trailer, and forwards the packet to the next hop router R2.

Introduction to Routing

- IP Router Routing Table

- There are three types of routes in a router's routing table:
 - **Directly Connected** – These routes are automatically added by the router, provided the interface is active and has addressing
 - **Remote** – These are the routes the router does not have a direct connection and may be learned:
 - * Manually – with a static route
 - * Dynamically – by using a routing protocol to have the routers share their information with each other
 - **Default Route** – this forwards all traffic to a specific direction when there is not a match in the routing table



Introduction to Routing



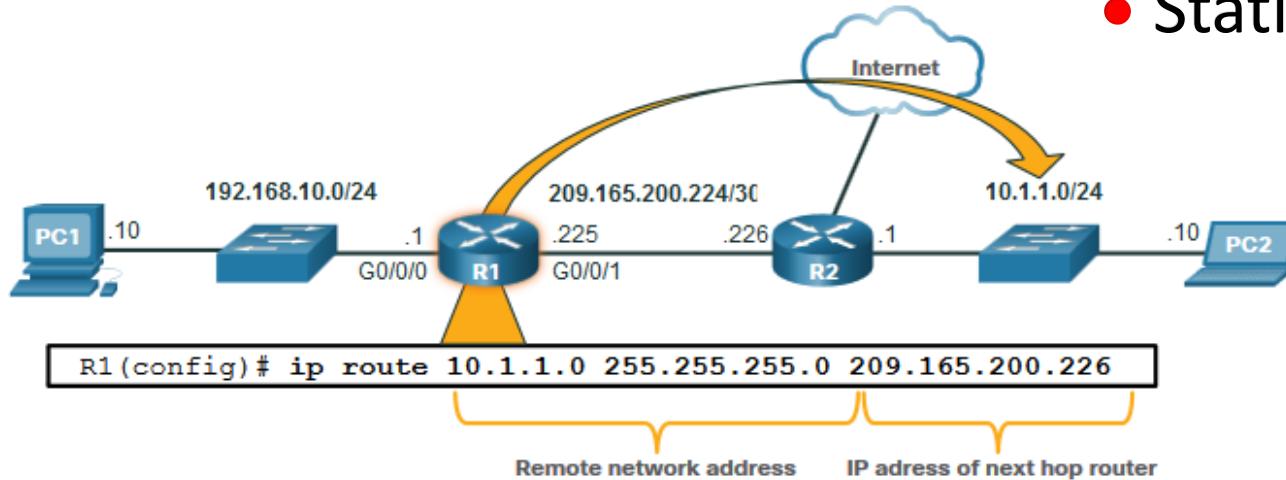
- Static Routing

- Static Route Characteristics:

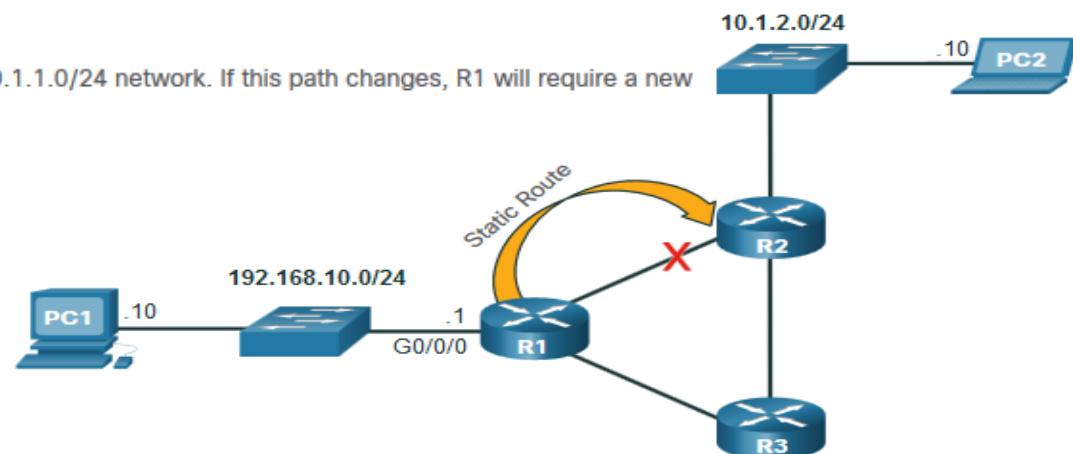
- Must be configured manually
 - Must be adjusted manually by the administrator when there is a change in the topology
 - Good for small non-redundant networks
 - Often used in conjunction with a dynamic routing protocol for configuring a default route

Introduction to Routing

• Static Routing (cont.)



R1 is manually configured with a static route to reach the 10.1.1.0/24 network. If this path changes, R1 will require a new static route.



If the route from R1 via R2 is no longer available, a new static route via R3 would need to be configured. A static route does not automatically adjust for topology changes.

Introduction to Routing



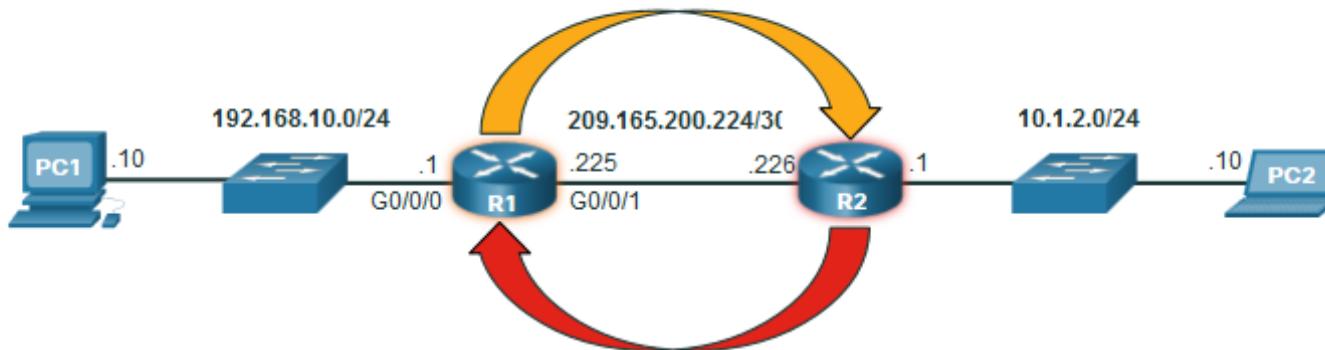
- Dynamic Routing

- Dynamic Routes Automatically:

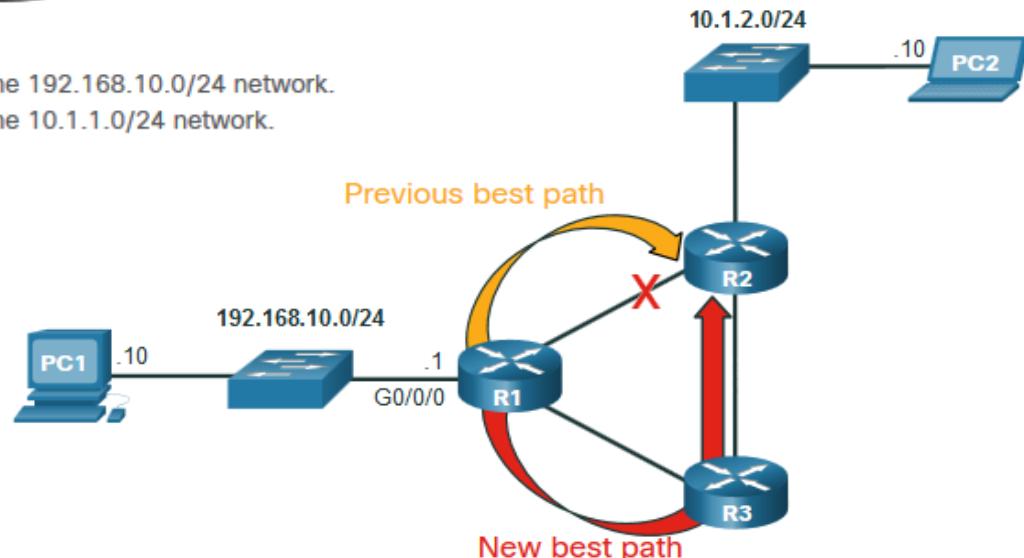
- Discover remote networks
 - Maintain up-to-date information
 - Choose the best path to the destination
 - Find new best paths when there is a topology change
 - Dynamic routing can also share static default routes with the other routers

Introduction to Routing

• Dynamic Routing (cont.)



- R1 is using the routing protocol OSPF to let R2 know about the 192.168.10.0/24 network.
- R2 is using the routing protocol OSPF to let R1 know about the 10.1.1.0/24 network.



R1, R2, and R3 are using the dynamic routing protocol OSPF. If there is a network topology change, they can automatically adjust to find a new best path.

Introduction to Routing

- IPv4 routing table

Video – IPv4 Router Routing Table

This video will explain the information in the IPv4 router routing table.

Introduction to Routing



- Intro to an IPv4 Routing Table

- The **show ip route** command shows the following route sources:

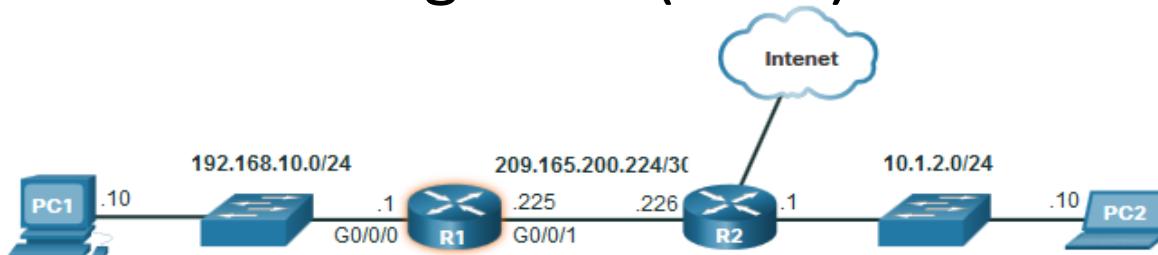
- **L** – Directly connected local interface IP address
 - **C** – Directly connected network
 - **S** – Static route was manually configured by an administrator
 - **O** – OSPF
 - **D** – EIGRP (Enhanced Interior Gateway Routing Protocol)

- This command shows types of routes:

- Directly Connected – C and L
 - Remote Routes – O, D, etc.
 - Default Routes – S*

Introduction to Routing

- Intro to an IPv4 Routing Table (cont.)



```
R1# show ip route
Codes: L - local, C - connected, S - static, R - RIP, M - mobile, B - BGP
      D - EIGRP, EX - EIGRP external, O - OSPF, IA - OSPF inter area
      N1 - OSPF NSSA external type 1, N2 - OSPF NSSA external type 2
      E1 - OSPF external type 1, E2 - OSPF external type 2
      i - IS-IS, su - IS-IS summary, L1 - IS-IS level-1, L2 - IS-IS level-2
      ia - IS-IS inter area, * - candidate default, U - per-user static route
      o - ODR, P - periodic downloaded static route, H - NHRP, l - LISP
      a - application route
      + - replicated route, % - next hop override, p - overrides from PfR
Gateway of last resort is 209.165.200.226 to network 0.0.0.0
S*   0.0.0.0/0 [1/0] via 209.165.200.226, GigabitEthernet0/0/1
      10.0.0.0/24 is subnetted, 1 subnets
O     10.1.1.0 [110/2] via 209.165.200.226, 00:02:45, GigabitEthernet0/0/1
      192.168.10.0/24 is variably subnetted, 2 subnets, 2 masks
C     192.168.10.0/24 is directly connected, GigabitEthernet0/0/0
L     192.168.10.1/32 is directly connected, GigabitEthernet0/0/0
      209.165.200.0/24 is variably subnetted, 2 subnets, 2 masks
C     209.165.200.224/30 is directly connected, GigabitEthernet0/0/1
L     209.165.200.225/32 is directly connected, GigabitEthernet0/0/1
R1#
```

Do you have any
questions or
comments?





Thank you
for your attention !

In this presentation:

- Some icons were downloaded from flaticon.com and iconscount.com