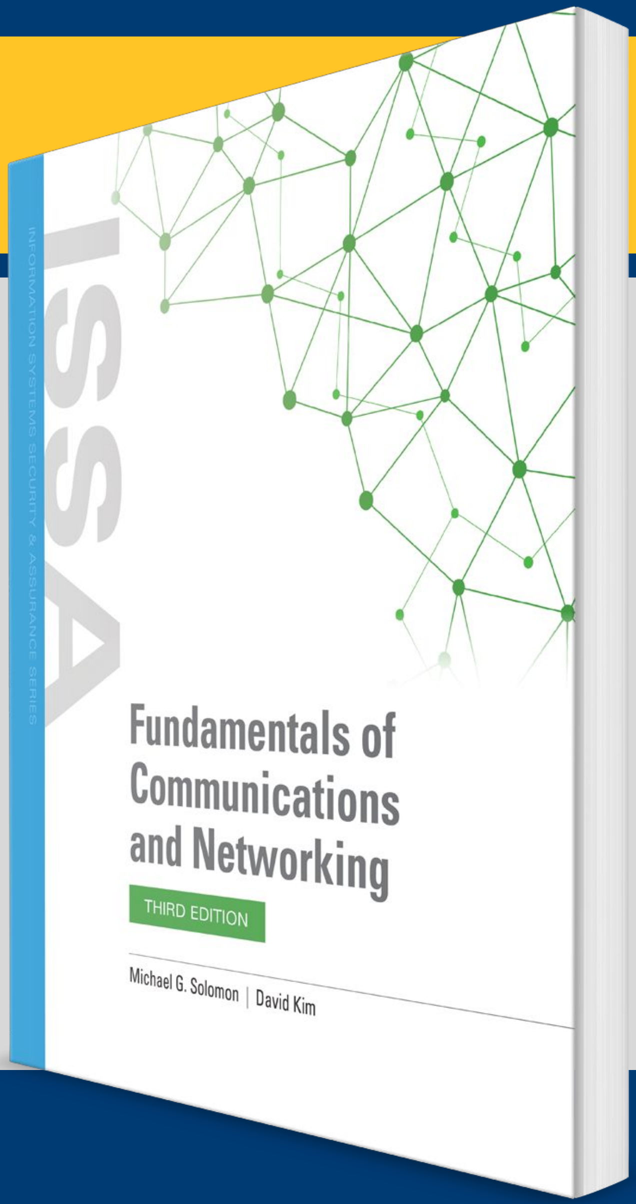
CHAPTER 5

The Network and Transport Layers



Learning Objective(s) and Key Concepts

Learning Objective(s)

- Differentiate between the standards, specifications, technologies, and infrastructure that drive current LAN connectivity.

Key Concepts

- The Network and Transport Layers of the OSI model
- Internet Protocol (IP)
- IP device addressing using IPv4 and IPv6
- IP-based communications
- Connectionless versus connection-oriented communications

Network and Transport Layers

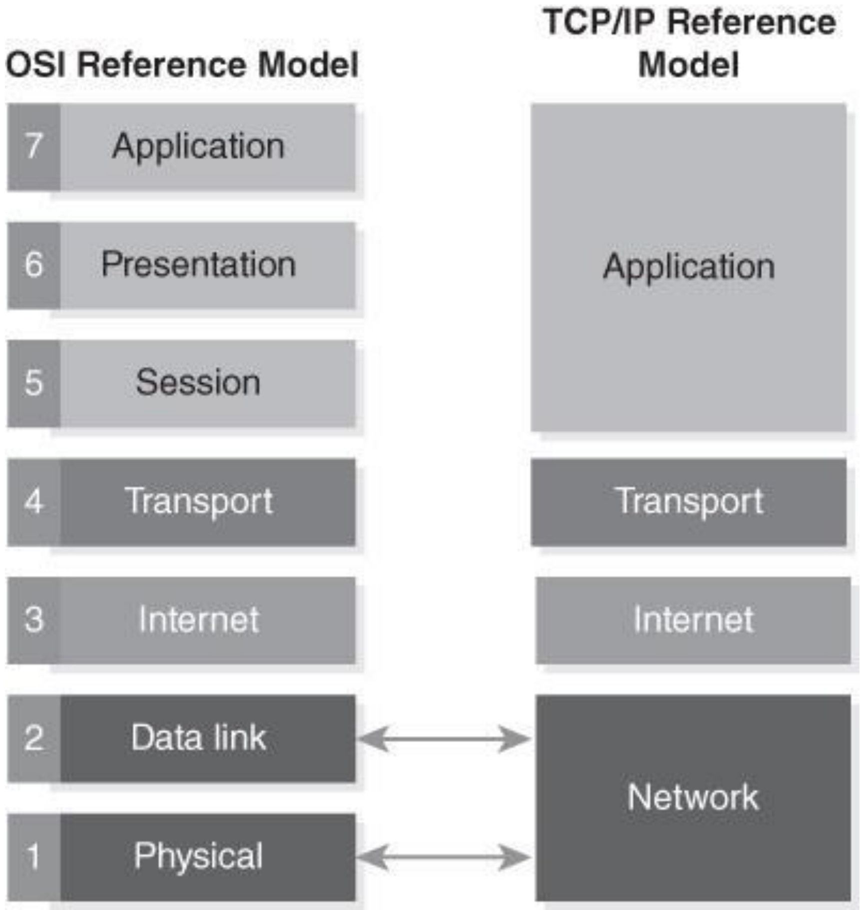


FIGURE 5-1 OSI model compared to the TCP/IP model.

The OSI Network Layer and Transport Layer

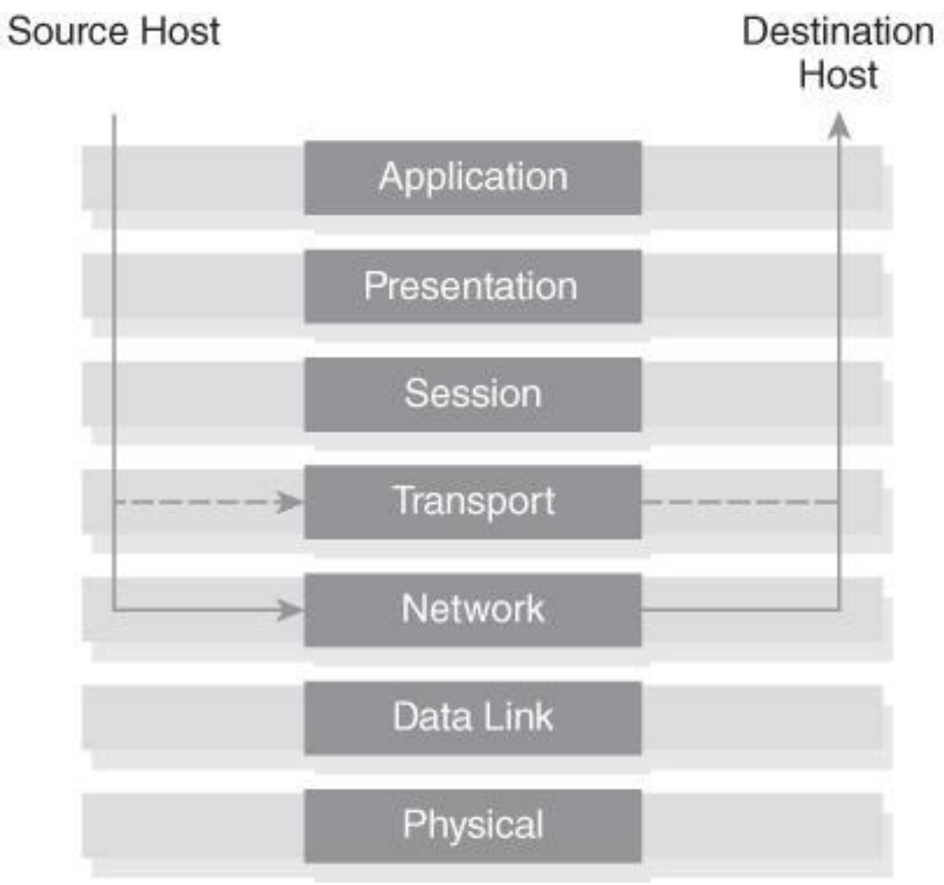


FIGURE 5-2 The OSI Network Layer and Transport Layer.

Network Layer: OSI Layer 3

- Provides network addressing for packets
- Provides and supports switching and routing technologies to direct packets to their destinations
- Is the first layer that addresses issues with how to get packets from the source to the destination
- Supports creating virtual circuits (predefined paths between two computers)
- Protocols that operate at OSI Layer 3 include:
  - Internet Protocol (IP)
  - Internet Control Message Protocol (ICMP)
  - Internet Protocol Security (IPSec)
  - AppleTalk

Transport Layer: OSI Layer 4

- Provides transparent and reliable data transfer between computers
- Accepts data from the upper layers and handles the details of getting the data to the destination computer
- Services provided include:
  - Flow control
  - Fragmentation/reassembly
  - Error control
  - Acknowledgment of delivery
- Protocols that operate at OSI Layer 4 include:
  - Transmission Control Protocol (TCP)
  - User Datagram Protocol (UDP)
  - Stream Control Transmission Protocol (SCTP)

The Internet Protocol

- Primary protocol that relays packets across most of today's diverse networks
- Provides packet routing and host identification to deliver packets to their destinations
- Treats all packets, also called **datagrams**, separately
- Each packet contains a header with the destination's IP address

IPv4 Packet Header

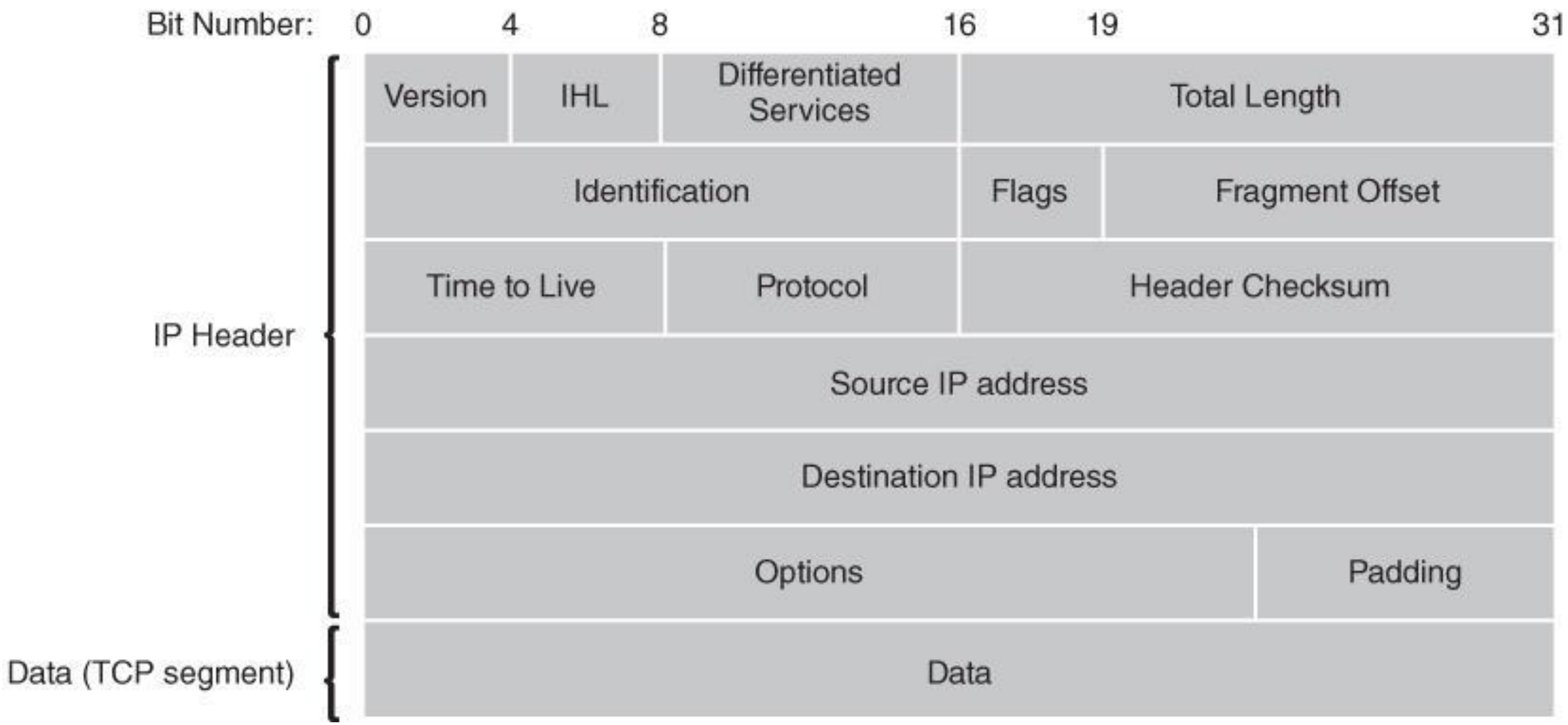


FIGURE 5-3 IPv4 packet header.

IPv6 Packet Header

FIGURE 5-4 IPv6 packet header.

The Internet Protocol—Decentralization

- IP networks are decentralized and dynamic
- Packet might not reach its destination node or, if it reaches its destination, might be different from the original packet
- A network node can use a checksum to tell if a packet header has changed

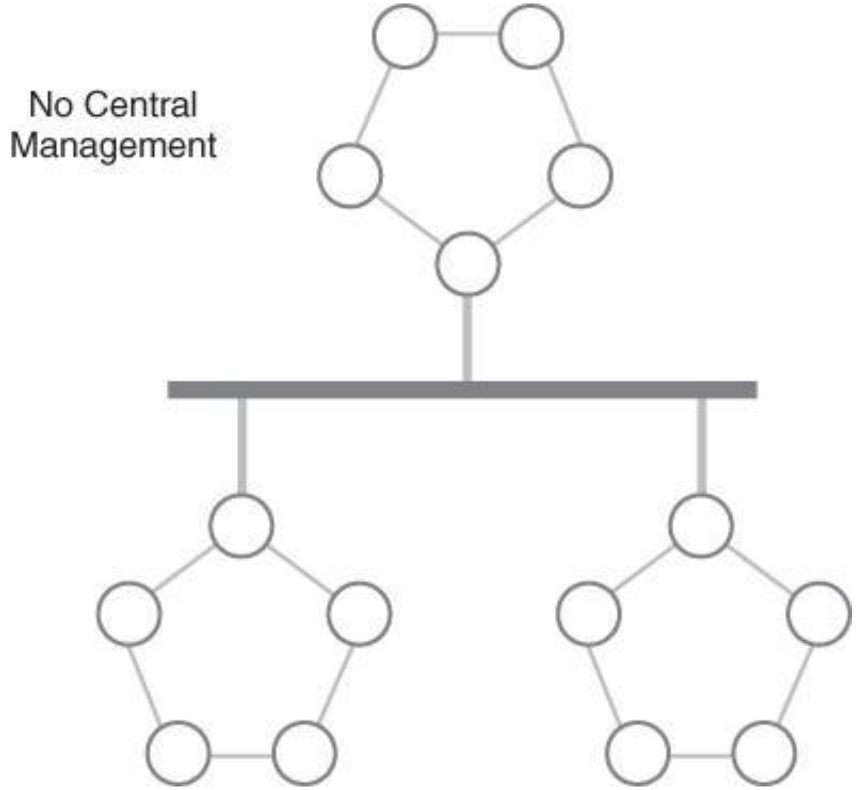


FIGURE 5-5 Decentralized IP network.

IPv4 Header Checksum

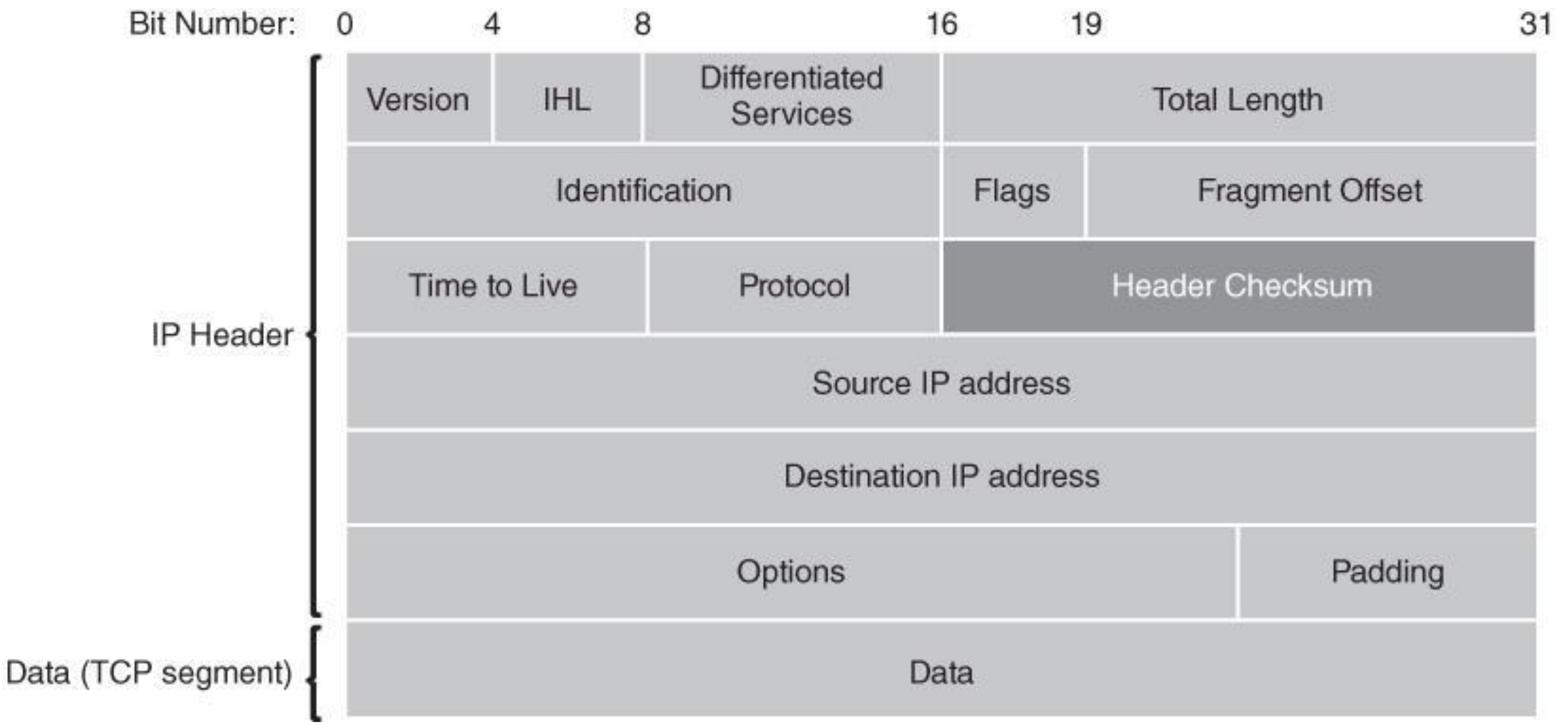
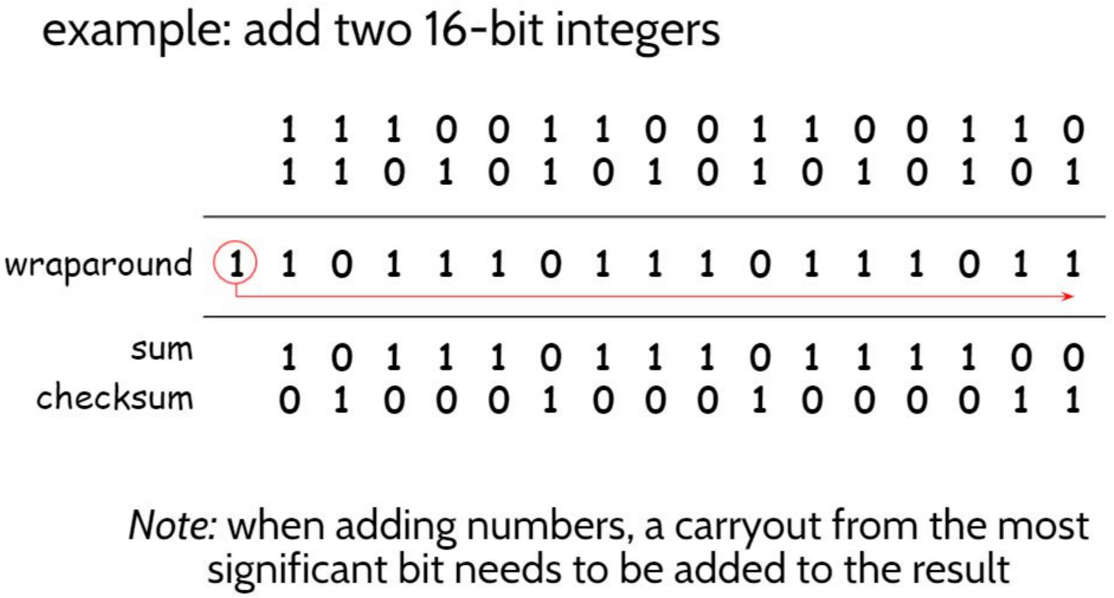


FIGURE 5-6 IPv4 Header Checksum.

IPv4 Header Checksum - Details 1/2

- Checksum - Used to verify data (Wiki)
  The checksum field is the 16-bit ones' complement of the ones' complement sum of all 16-bit words in the header. For purposes of computing the checksum, the value of the checksum field is zero.
- The sum of all 16-bit values in the header should sum to ffff, which when flipped is 0.
- How to compute value to put in checksum? Sum the rest, inverse the result and place that in the checksum part. (Base 10: Sum was 57? put in a -57 so the sum would be 0)
- Note: In one’s complement there is 0 and -0.



IPv4 Header Checksum - Details 2/2

- IPv4 Checksum
  - MUST be recomputed anytime the IP header data changes
    - When? TTL!
    - Computationally expensive & limits ‘streaming’
  - Can detect bit-level errors
  - Can’t detect ordering issues

IP Addressing: IPv4 versus IPv6

Devices on IP-based networks, like the Internet, need IP addresses

Internet Engineering Task Force (IETF) develops and promotes Internet standards, and publishes IPv4 and IPv6

Internet Assigned Numbers Authority (IANA)

- Is responsible for coordinating IP addresses and resources around the world
- Reported that it exhausted the primary address pool of IPv4 addresses on February 3, 2011

IPv4 still in primary use; slow transition to IPv6 - Why? NAT (wiki)

IPv4

- 32-bit addresses (4 bytes)
- Usually displayed in dot notation
- Four separate 8-bit numbers (octets)
- Octets separated by periods
- Octet value is between 0 and 255
- Example: **192.168.0.1**
- IPv4 networks can be classful or classless

Dynamic Host Configuration Protocol (DHCP)

- A standard method for internal devices to request and receive IP addresses and configuration information

- Network address translation (NAT) and private IP addresses make it possible to continue using IPv4 well into the future

IPv4 Classful Network Architecture

- Addressing architecture created five different types of networks based on their required number of nodes
- IP addresses originally organized into five classes: A, B, C, D, and E
- A, B, and C used for networks
- Each class restricted to a particular IP address range
- Range based on number of nodes needed
- Maximum number of 4,294,967,296 addresses (2^{32})

Classful Network Classes

Class	Leading Bits	Size of Network Field	# of Networks	Number of Nodes	Address Range
A (large)	0	8	128	16,777,216	0.0.0.0 to 127.255.255.255
B (medium)	10	16	16,384	65,536	128.0.0.0 to 191.255.255.255
C (small)	110	24	2,097,152	256	192.0.0.0 to 223.255.255.255
D (multicast)	1110	N/A	N/A	N/A	224.0.0.0 to 239.255.255.255
E (future use)	1111	N/A	N/A	N/A	240.0.0.0 to 255.255.255.255

IPv4 CIDR and Subnet Mask

CIDR

- Replacement for classful network architecture
- Temporary solution for IP address shortage address format
- Is similar to the IP address dot notation
- Networks are split into groups of IP addresses called CIDR blocks

Subnet Mask

- Is a binary number that contains all 1's in the leftmost prefix length positions
- Subnet mask for the CIDR address block 168.12.0.0/16 would be:

11111111.11111111.00000000.00000000

- Helps determine which network a given IP address belongs to by indicating which part of an IP address denotes the network and which part denotes the host

IPv4 Private Networks

- Contains private IP addresses
- Are not routable
- Purpose of private IP addresses is to allow organizations to assign their own device IP addresses from the private network ranges
- Network address translation (NAT) maps internal addresses to public routable addresses
- Port address translation (PAT) allows you to share a single, public-facing IP address with a range of internal, private IP host addresses

Private Address Ranges
10.0.0.0 to 10.255.255.255
172.16.0.0 to 172.31.255.255
192.168.0.0 to 192.168.255.255

Resolving Addresses

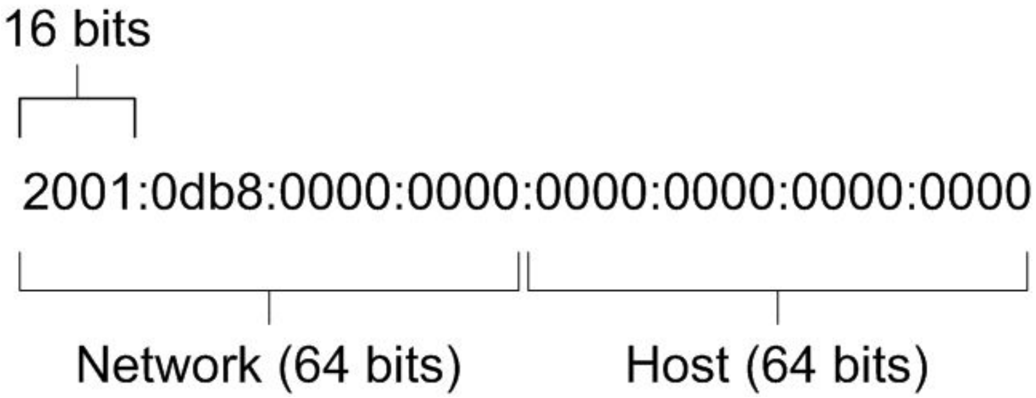
- **Address resolution** is the process of finding an IP address for a host name
- Domain Name System (DNS) is a hierarchical naming system that allows organizations to associate host names with IP address names spaces
- Example: **amazon.com > 72.21.211.176**
- DNS
  - Servers store these associations and make the tables available for network users
  - Servers keep up with the changing host names and make it easy to react to any organization that changes its IP addresses
  - Is crucial to making the Internet a usable network

IPv6 (1 of 2)

- Primary motivation for creating IPv6 was to increase the network address space
- Uses 128-bit addresses
  - Increases address size from the IPv4 32 bits to 128 bits
- Maximum number of 2^{128} addresses (> 340 undecillion)
- 1 undecillion = **1,000,000,000,000,000,000,000,000,000,000,000,000**
- Header does not have a checksum - rely on other layers to verify
  - Routers have less work to do

IPv6 (2 of 2)

- Eight groups of 4 hexadecimal numbers
- First 64 bits identify network
- Last 64 bits identify host (based on MAC address)



IPv6 Address Format

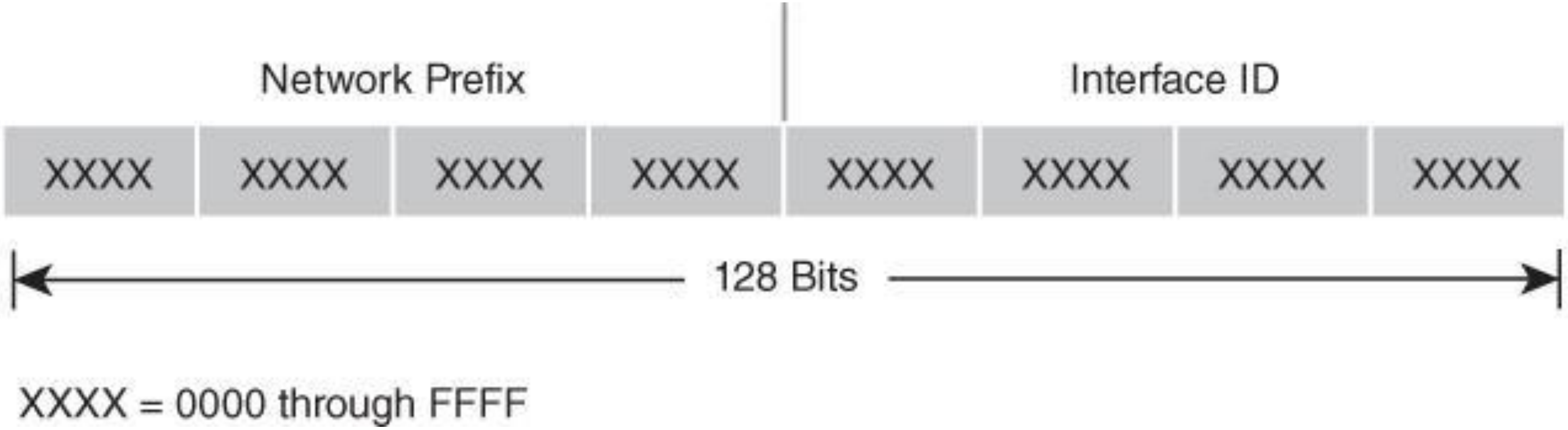


FIGURE 5-7 IPv6 address format.

IPv6 Address Compression

- Drop leading 0s in each group

2001:0db8:0000:0000:0000:0053:0000:0004

becomes

2001:db8:0:0:0:53:0:4

- Replace the first group of 0s with ::

2001:0db8:0000:0000:0000:0053:0000:0004

becomes

2001:db8::53:0:4

- Only one set of :: can exist in an address

IPv6 Network Methodologies

Unicast—Sending a packet to a single destination

Anycast—Sending a packet to the nearest node in a specified group of nodes

Multicast—Sending a packet to multiple destinations

- Broadcast address sends a packet to a complete range of IP addresses

IPv4 to IPv6

- Dual IP stack operating systems support both IPv4 and IPv6 using two separate network stacks for IP
- Literal IPv6 addresses
  - Colon character is a reserved character in network resource identifiers and UNC path names
  - For network resource identifiers, add square brackets around literal IPv6 addresses

    http://[2001:db8::206:0:a80c:52b]:8080
  - For UNC path names, convert colon characters to dashes and append ".ipv6-literal.net" domain to IPv6 literal addresses

    2001:db8::206:0:a80c:52b

    would be written as

    2001-db8--206-0-a80c-52b.ipv6-literal.net

IP Communications (1 of 2)

- When a packet enters its destination network, the network stack needs to know the packet's local destination.
- IPv4 networks use Address Resolution Protocol (ARP) to provide local Media Access Control (MAC) addresses
- IPv6 networks use the Neighbor Discovery Protocol (NDP)
- ARP and NDP make it possible to use IP to transport traffic within local networks and between networks, including those connected to the Internet

IP Communications (2 of 2)

- IP networks can exchange nearly any type of data between any two nodes on the network
- Types of supported traffic:
  - Email messages
  - Telephone calls
  - Video conferencing
  - Streaming audio and video
  - Large file transfers
  - Real-time data
  - Instant messages

Connectionless Versus Connection-Oriented Communications

- Most direct path to a destination may not be the best route if it's congested
- IP is a connectionless protocol
  - No notion of a connection between source and destination nodes
  - Treats each packet separately
- Alternative is a connection-oriented protocol
  - Sets up a connection between the source and destination
  - Treats each message separately
- Layered networking software enables a mix of connectionless and connection-oriented protocols
- Can use a connection-oriented protocol at Layer 4 or higher and still use IP for Layer 3

Connection-Oriented and Connectionless Protocols

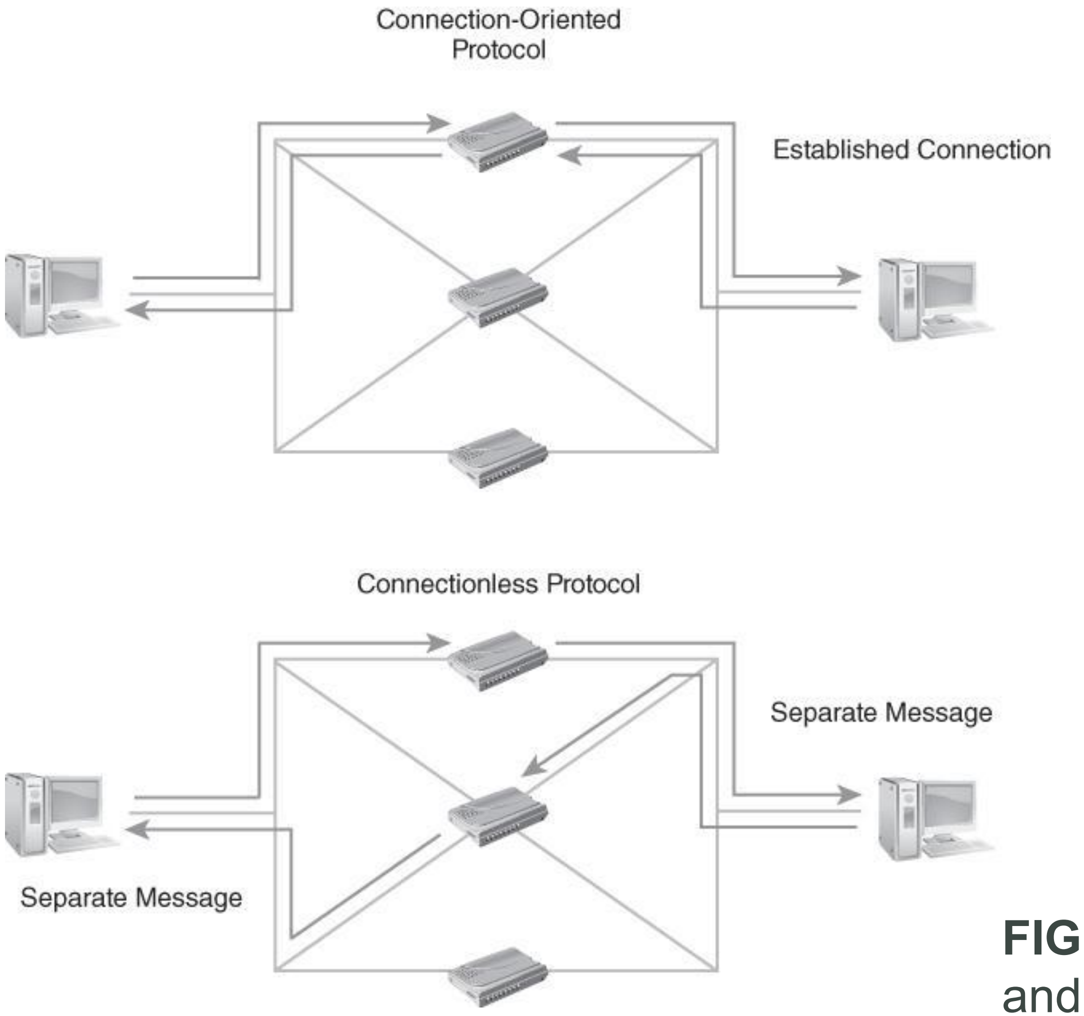


FIGURE 5-8 Connection-oriented and Connectionless Protocols.

Summary

- The Network and Transport Layers of the OSI model
- Internet Protocol (IP)
- IP device addressing using IPv4 and IPv6
- IP-based communications
- Connectionless versus connection-oriented communications