

Chapter 12 Objectives

- Become familiar with the fundamentals of network architectures.
- Be able to describe the ISO/OSI reference model and the TCP/IP standard.

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12.1 Introduction

- **Computer network** – an interconnection of computers and computing equipment using either wires or radio waves over small or large geographic areas.
- The network is a crucial component of today's computing systems.

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12.1 Introduction

- Resource sharing across networks has taken the form of multi-tier architectures having numerous disparate servers, sometimes far removed from the users of the system.
- If you think of a computing system as collection of workstations and servers, then surely the network is the **system bus** of this configuration.

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12.2 Early Business Computer Networks

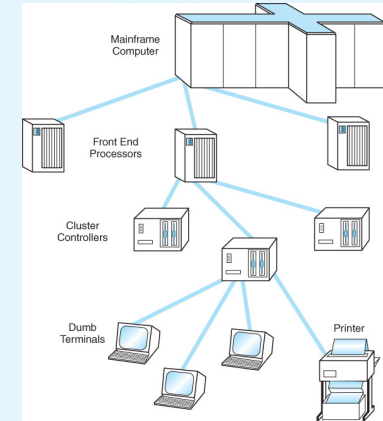
- The first computer networks consisted of a mainframe host that was connected to one or more front end processors. Predominant form in the 1960s and 1970s.
- Front end processors received input over dedicated lines from remote communications controllers connected to several dumb terminals.
- The [protocols](#) employed by this configuration were proprietary to each vendor's system.
- One of these, IBM's SNA (created in 1974) became the model for an international communications standard, the ISO/OSI Reference Model.

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12.2 Early Business Computer Networks

- Hierarchical, polled network

The front end processors poll each of the cluster controllers, which in turn poll their attached terminals



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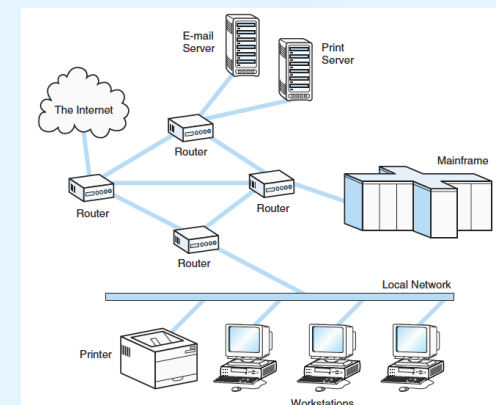
12.3 Early Academic and Scientific Networks

- In the 1960s, the [Advanced Research Projects Agency](#) funded research under the auspices of the U.S. Department of Defense.
- Computers at that time were few and costly. In 1968, the Defense Department funded an interconnecting network to make the most of these precious resources. The network, [DARPA](#)Net, had sufficient redundancy to withstand the loss of a good portion of the network.
- DARPA
Net was the world's first operational packet switching network, and the first to implement TCP/IP.- DARPA
Net later turned over to the public domain, and eventually evolved to become today's [Internet](#).

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12.3 Early Academic and Scientific Networks

- A modern internetwork configuration



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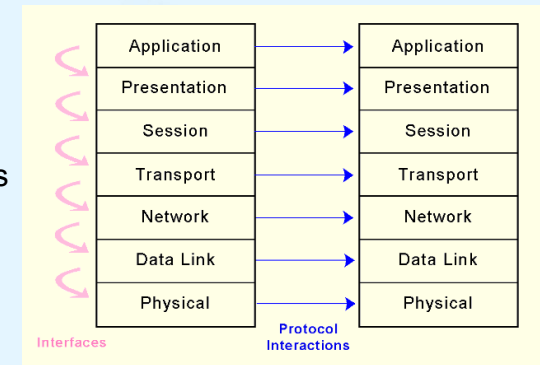
12.4 Network Protocols I ISO/OSI Reference Model

- To address the growing tangle of **incompatible proprietary** network protocols (also details were sometimes kept secret), in 1984 the ISO formed a committee to devise a unified protocol standard.
- The result of this effort is the ISO **Open Systems Interconnect Reference Model** (ISO/OSI RM).
- The ISO's work is called a reference model because virtually no commercial system uses all of the features precisely as specified in the model.
- The ISO/OSI model does, however, lend itself to understanding the concept of a unified communications architecture.

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12.4 Network Protocols I ISO/OSI Reference Model

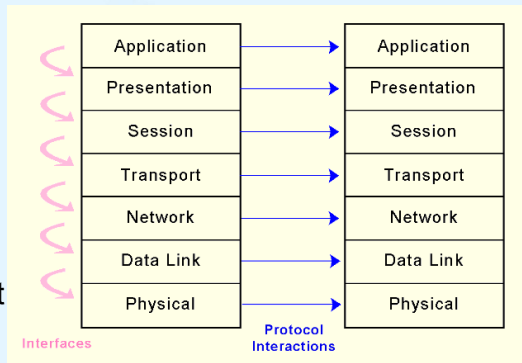
- The OSI RM contains **seven protocol layers**, starting with physical media interconnections at Layer 1, through applications at Layer 7.



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12.4 Network Protocols I ISO/OSI Reference Model

- The OSI model defines only the functions of each of the seven layers and the interfaces between them.
- Implementation details are not part of the model.



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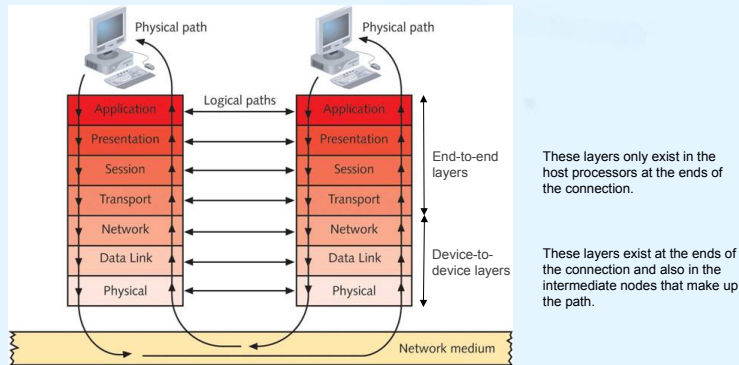
12.4 Network Protocols I ISO/OSI Reference Model

- The OSI model reduces complexity by breaking network communication into smaller simpler parts (layers).
- Each layer performs a subset of the required communication functions.
- Each layer relies on the next lower layer to perform more primitive functions.
- Each layer provides services to the next higher layer. No layer skipping is allowed.
- Changes in one layer should not require changes in other layers.

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12.4 Network Protocols I ISO/OSI Reference Model

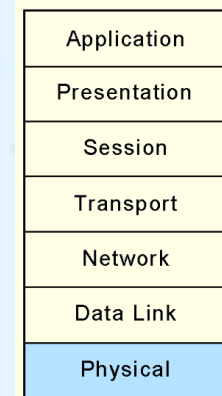
- Flow of data through the OSI model



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12.4 Network Protocols I ISO/OSI Reference Model

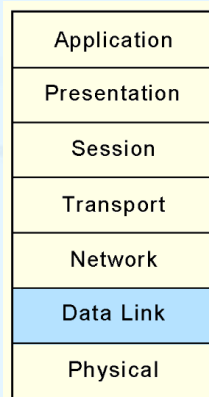
- The **Physical layer** receives a stream of bits from the Data Link layer above it, encodes them and places them on the communications medium.
- The Physical layer conveys transmission frames, called **Physical Protocol Data Units**, or **Physical PDUs**. Each physical PDU carries an address and has delimiter signal patterns that surround the **payload**, or **contents**, of the PDU.



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12.4 Network Protocols I ISO/OSI Reference Model

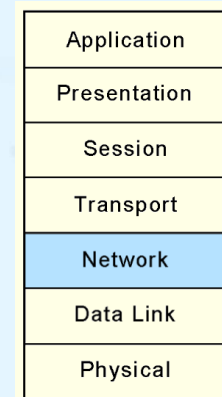
- The **Data Link layer** is responsible for taking the data and transforming it into a **frame** with header. It negotiates frame sizes and the speed at which they are sent with the Data Link layer at the other end.
 - The timing of frame transmission is called **flow control**.
- Data Link layers at both ends acknowledge packets as they are exchanged. The sender retransmits the packet if no acknowledgement is received within a given time interval.



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12.4 Network Protocols I ISO/OSI Reference Model

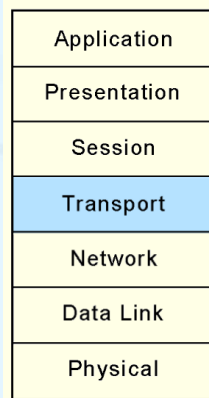
- At the originating computers, the **Network layer** adds addressing information to the Transport layer PDUs.
- The Network layer establishes the **route** and ensures that the PDU size is compatible with all of the equipment between the source and the destination.
- Its most important job is in moving PDUs across **intermediate** nodes.



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12.4 Network Protocols I ISO/OSI Reference Model

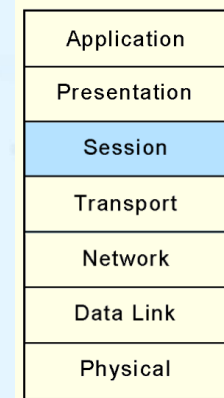
- The OSI **Transport layer** provides end-to-end acknowledgement and error correction through its **handshaking** with the Transport layer at the other end of the conversation.
 - The Transport layer is the lowest layer of the OSI model at which there is any awareness of the network or its protocols.
- Transport layer assures the Session layer that there are no network-induced errors in the PDU.



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12.4 Network Protocols I ISO/OSI Reference Model

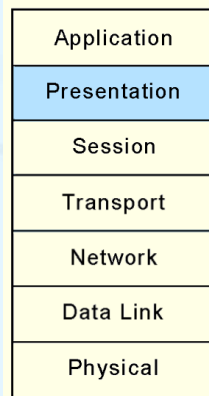
- The **Session layer** is responsible for establishing sessions between users. It arbitrates the dialogue between two communicating nodes, opening and closing that dialogue as necessary.
- It controls the direction and mode (**half-duplex** or **full-duplex**).
- It also supplies recovery **checkpoints** during file transfers.
- Checkpoints are issued each time a block of data is acknowledged as being received in good condition.



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12.4 Network Protocols I ISO/OSI Reference Model

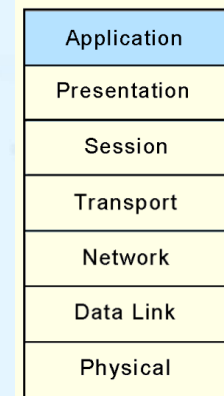
- The **Presentation layer** provides high-level data interpretation services for the Application layer above it, such as EBCDIC-to-ASCII translation.
- Presentation layer services are also called into play if we use **encryption** or certain types of data **compression**.



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12.4 Network Protocols I ISO/OSI Reference Model

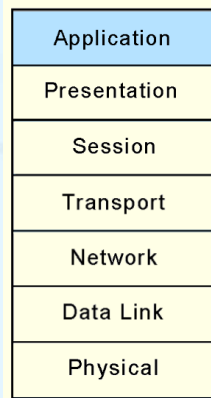
- The **Application layer** supplies meaningful information and services to users at one end of the communication and interfaces with system resources (programs and data files) at the other end of the communication.
- HTTP and FTP are examples of protocols at this layer.



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12.4 Network Protocols I ISO/OSI Reference Model

- Common network applications include web browsing, e-mail, file transfers, and remote logins.
- All that applications need to do is to send messages to the Presentation layer, and the lower layers take care of the hard part.



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12.4 Network Protocols I ISO/OSI Reference Model

- A way to remember the seven layers:

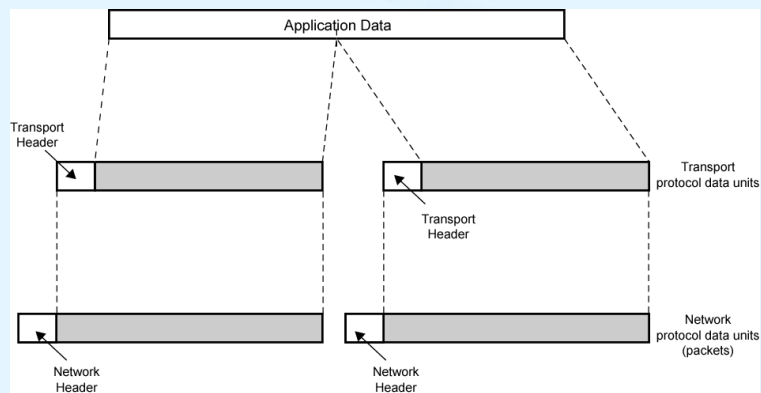
All People Seem To Need
Data Processing



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12.4 Network Protocols I ISO/OSI Reference Model

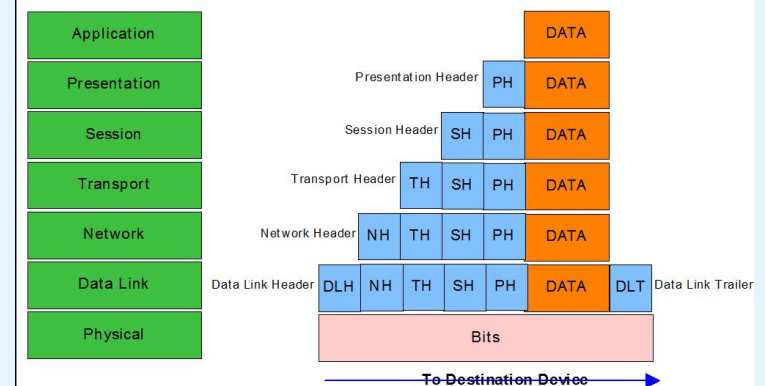
- Protocol data units (PDUs)



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12.4 Network Protocols I ISO/OSI Reference Model

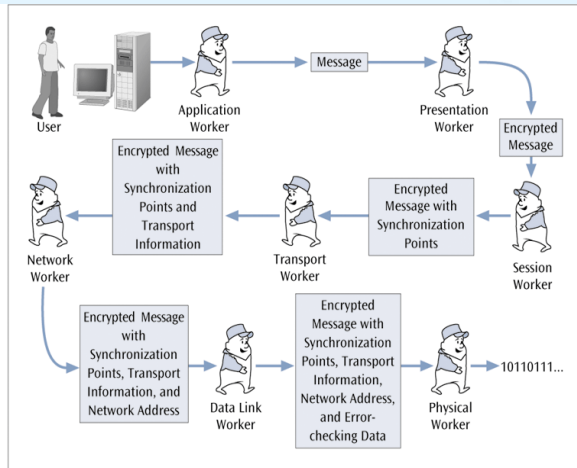
Encapsulation



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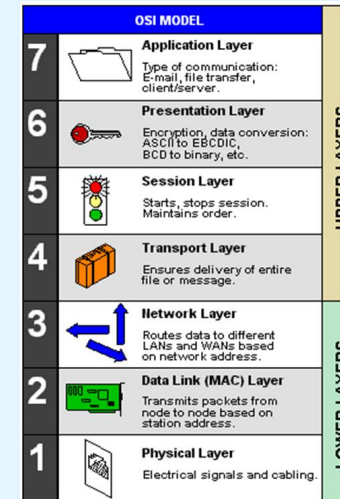
12.4 Network Protocols I ISO/OSI Reference Model

Figure 1-13
Network workers perform their job duties at each layer in the model



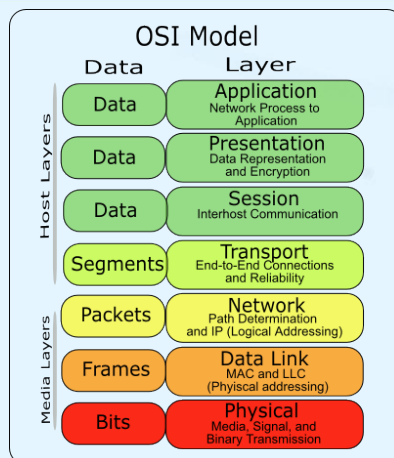
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12.4 Network Protocols I ISO/OSI Reference Model



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12.4 Network Protocols I ISO/OSI Reference Model



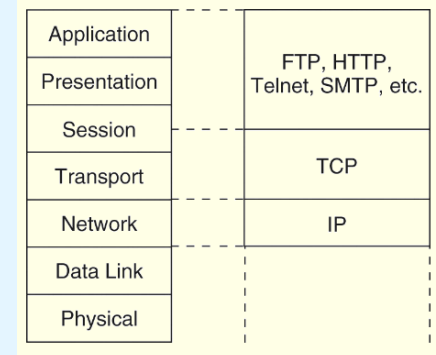
MAC: Media Access Control
LLC: Logical Link Control

The LLC sublayer acts as an interface between the MAC sublayer and the Network layer.

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12.5 Network Protocols II TCP/IP Architecture

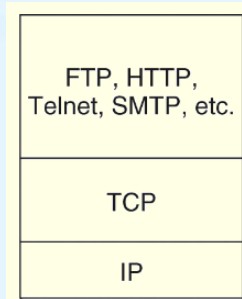
- **TCP/IP** is the de facto global data communications standard.
- It has a lean 3-layer protocol stack that can be mapped to five of the seven in the OSI model.
- TCP/IP can be used with any type of network, even different types of networks within a single session.



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12.5 Network Protocols II TCP/IP Architecture

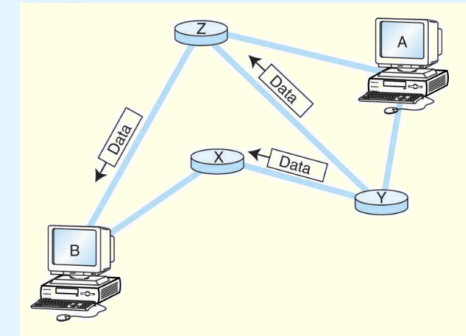
- The IP Layer of the TCP/IP protocol stack provides essentially the same services as the Network layer of the OSI Reference Model.
- It divides TCP packets into protocol data units called *datagrams*, and then attaches routing information.



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12.5 Network Protocols II TCP/IP Architecture

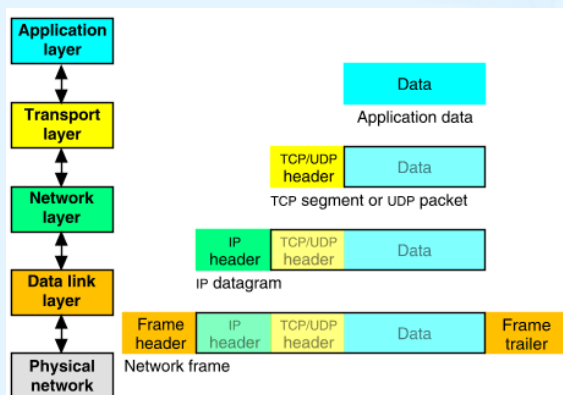
- The concept of the datagram was fundamental to the robustness of ARPANet, and now, the Internet.
- Datagrams can take any route available to them without human intervention.



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12.5 Network Protocols II TCP/IP Architecture

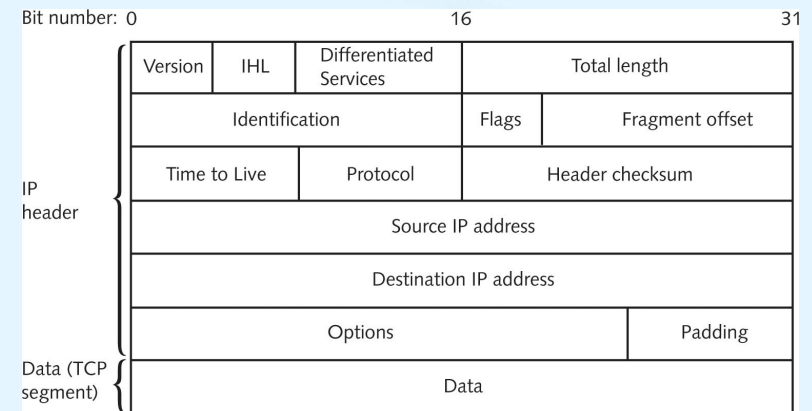
- Encapsulation/decapsulation of application data within the network stack.



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12.5 Network Protocols II TCP/IP Architecture

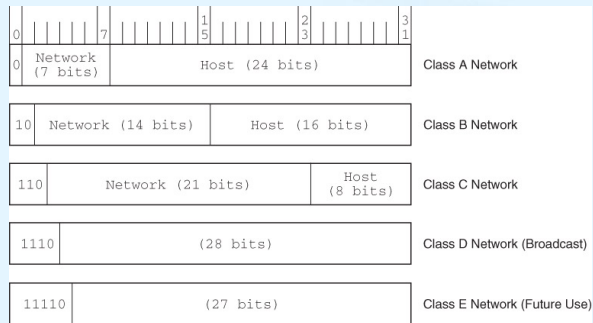
- IP datagram (IPv4)



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12.5 Network Protocols II TCP/IP Architecture

• IP address classes



IP addresses are written in dotted decimal notation: 130.225.220.8 (akira.ruc.dk), 192.168.1.x, x between 1 and 254 (private IP addresses).

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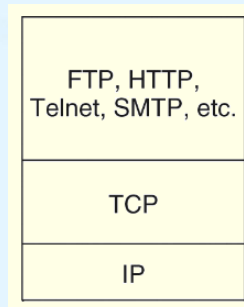
12.5 Network Protocols II TCP/IP Architecture

- The current version of IP, **IPv4**, was never designed to serve millions of network components scattered across the globe.
- Its limitations include 32-bit addresses, a packet length limited to 65,536 bytes, and that all security measures are optional.
- Furthermore, network addresses have been assigned with little planning which has resulted in slow and cumbersome routing hardware and software.
- We will see later how these problems have been addressed by **IPv6**.

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12.5 Network Protocols II TCP/IP Architecture

- **Transmission Control Protocol (TCP)** is the consumer of IP services.
- It engages in a conversation -- a **connection** -- with the TCP process running on the remote system.
- A TCP connection is analogous to a telephone conversation, with its own protocol "etiquette".



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12.5 Network Protocols II TCP/IP Architecture

- As part of initiating a connection, TCP also opens a **service access point (SAP)** in the application running above it.
- In TCP, this SAP is a numerical value called a **port**.
- The combination of the port number, the host ID, and the protocol designation becomes a **socket**, which is logically equivalent to a file name (or **handle**) to the application running above TCP.
- Port numbers 0 through 1023 are called "well-known" port numbers because they are reserved for particular TCP applications.

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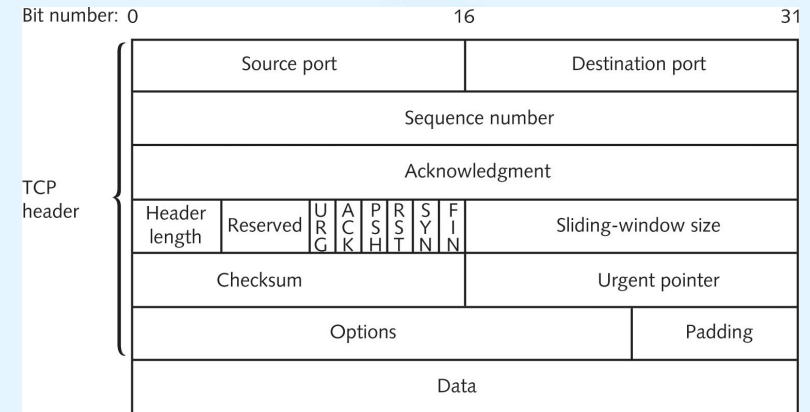
12.5 Network Protocols II TCP/IP Architecture

- TCP makes sure that the stream of data it provides to the application is complete, in its proper sequence and that no data is duplicated.
- TCP also makes sure that its segments aren't sent so fast that they overwhelm intermediate nodes or the receiver.
- A TCP segment requires at least 20 bytes for its header. The data payload is optional.
- A segment can be at most 65,515 bytes long, including the header, so that the entire segment fits into an IP payload.

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12.5 Network Protocols II TCP/IP Architecture

• TCP segment



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12.5 Network Protocols II TCP/IP Architecture

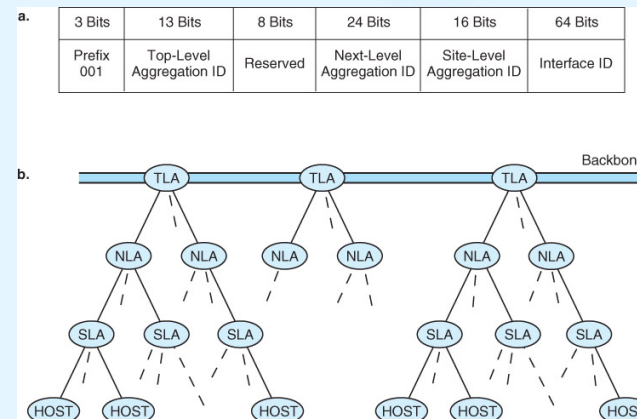
- In 1994, the Internet Engineering Task Force began work on what is now [IP Version 6](#).
- The IETF's primary motivation in designing a successor to IPv4 was, of course, to extend IP's address space beyond its current 32-bit limit to 128 bits for both the source and destination host addresses.
 - This is a seemingly inexhaustible address space, giving 2^{128} possible host addresses.
- The IETF also devised the **Aggregatable Global Unicast Address Format** to manage this huge address space.

IPv6 addresses are written in hexadecimal, separated by colons:
30FA:405A:B210:224C:1114:0327:0904:0225

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12.5 Network Protocols II TCP/IP Architecture

- a. Aggregatable Global Unicast Format
- b. Aggregatable Global Unicast Hierarchy



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Chapter 12 Conclusion

- The ISO/OSI RM describes a theoretical network architecture.
- TCP/IP using IPv4 is the protocol supported by the Internet. IPv6 has been defined and implemented by numerous vendors, but its adoption is incomplete.

End of Chapter 12