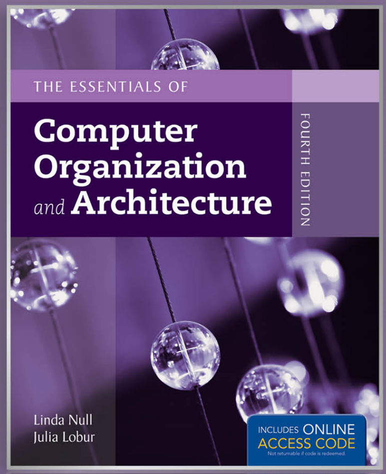
Chapter 12

Network Organization and Architecture



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.

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.

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.

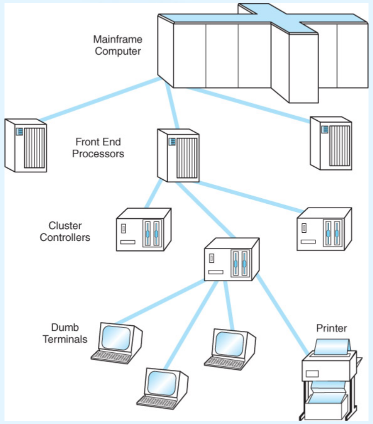
12.2 Early Business Computer Networks

- 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.

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

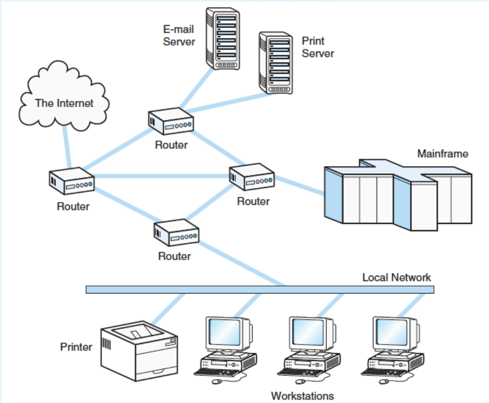


12.3 Early Academic and Scientific Networks

- 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, DARPANet, had sufficient redundancy to withstand the loss of a good portion of the network.
- DARPANet was the world's first operational packet switching network, and the first to implement TCP/IP.
- DARPANet later turned over to the public domain, and eventually evolved to become today's Internet.

12.3 Early Academic and Scientific Networks

- A modern internetwork configuration

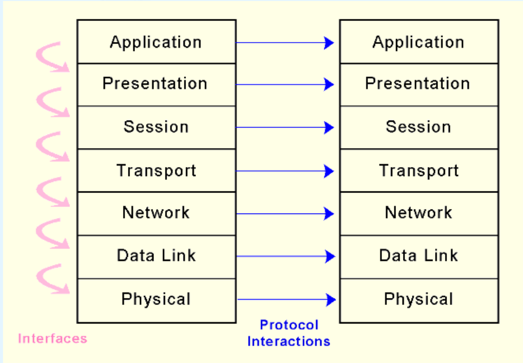


12.4 Network Protocols I
ISO/OSI Reference Model

- 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.

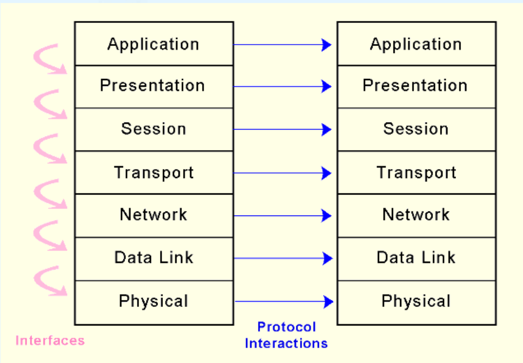
12.4 Network Protocols I
ISO/OSI Reference Model

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



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.

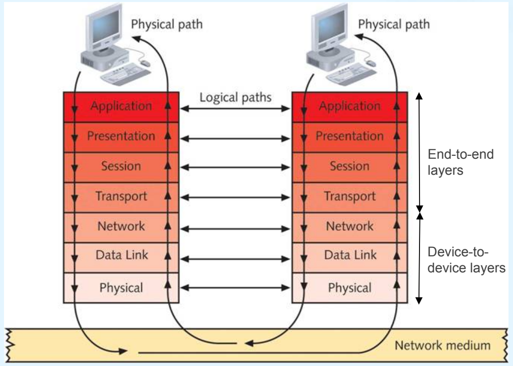


12.4 Network Protocols I
ISO/OSI Reference Model

- 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.

12.4 Network Protocols I
ISO/OSI Reference Model

- Flow of data through the OSI model



These layers only exist in the host processors at the ends of the connection.

These layers exist at the ends of the connection and also in the intermediate nodes that make up the path.

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.

Application
Presentation
Session
Transport
Network
Data Link
Physical

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.

Application
Presentation
Session
Transport
Network
Data Link
Physical

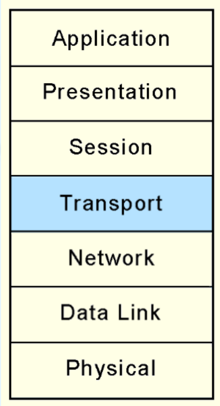
12.4 Network Protocols I
ISO/OSI Reference Model

- 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.

Application
Presentation
Session
Transport
Network
Data Link
Physical

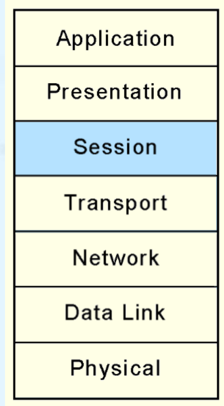
12.4 Network Protocols I
ISO/OSI Reference Model

- 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.



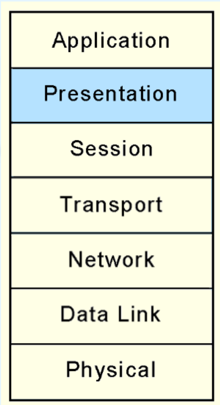
12.4 Network Protocols I
ISO/OSI Reference Model

- 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.



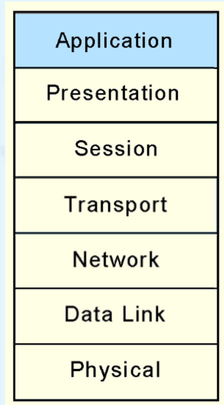
12.4 Network Protocols I
ISO/OSI Reference Model

- 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.



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.



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.

Application
Presentation
Session
Transport
Network
Data Link
Physical

12.4 Network Protocols I
ISO/OSI Reference Model

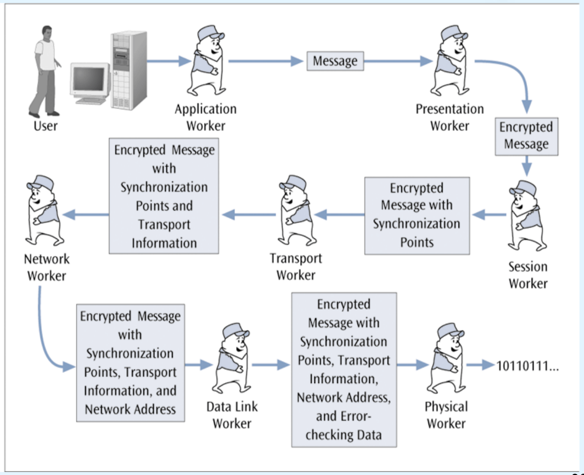
- A way to remember the seven layers:

All People Seem To Need
Data Processing

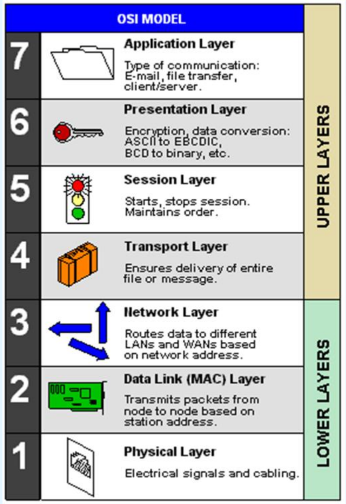
Application
Presentation
Session
Transport
Network
Data Link
Physical

12.4 Network Protocols I
ISO/OSI Reference Model

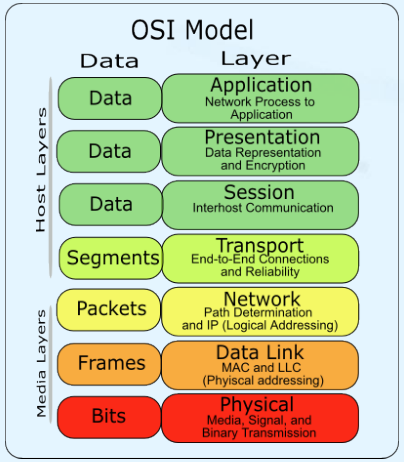
Figure 1-13
Network workers perform their job duties at each layer in the model



12.4 Network Protocols I
ISO/OSI Reference Model



12.4 Network Protocols I
ISO/OSI Reference Model

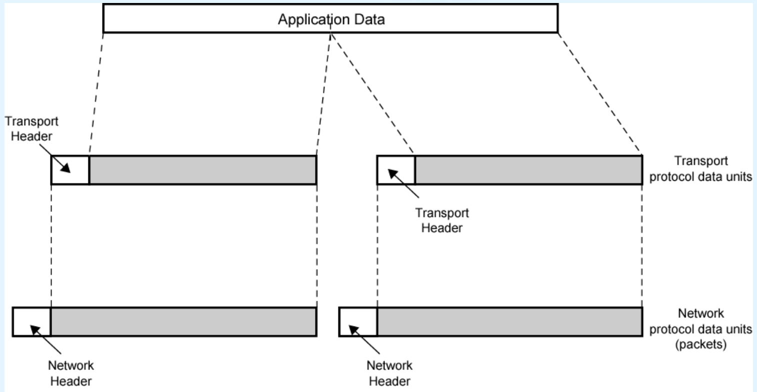


MAC: Media Access Control
LLC: Logical Link Control

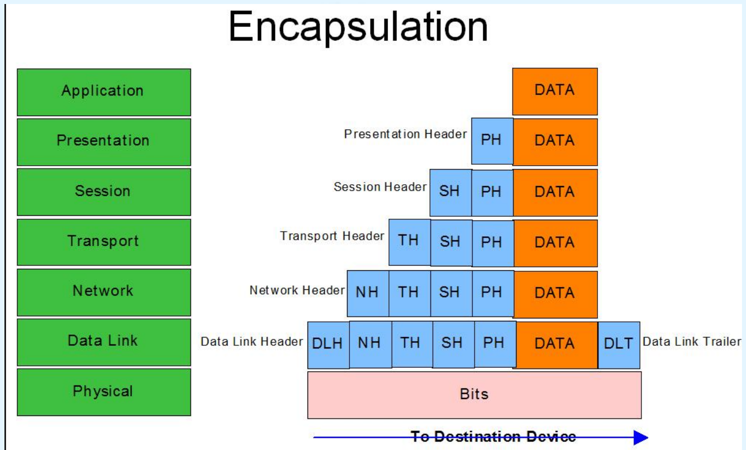
The LLC sublayer acts as an interface between the MAC sublayer and the Network layer.

12.4 Network Protocols I
ISO/OSI Reference Model

- Protocol data units (PDUs)

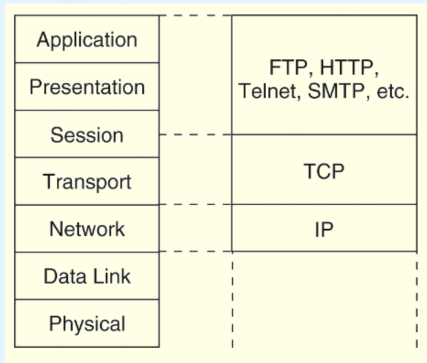


12.4 Network Protocols I
ISO/OSI Reference Model



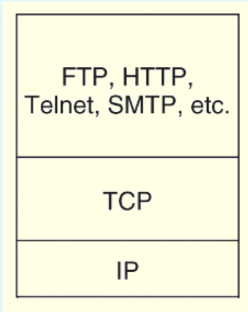
12.5 Network Protocols II
TCP/IP Architecture

- 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.



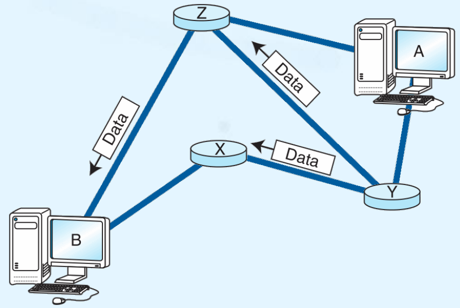
12.5 Network Protocols II
TCP/IP Architecture

- 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.



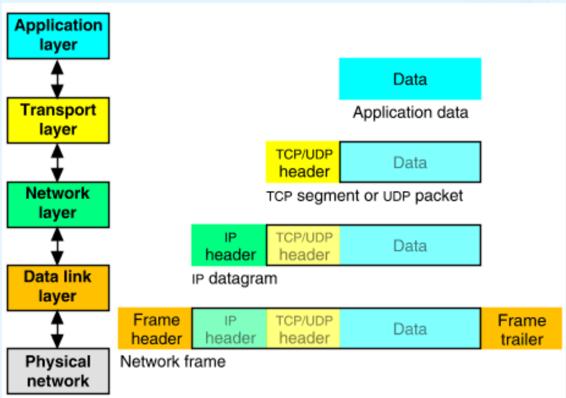
12.5 Network Protocols II
TCP/IP Architecture

- 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.



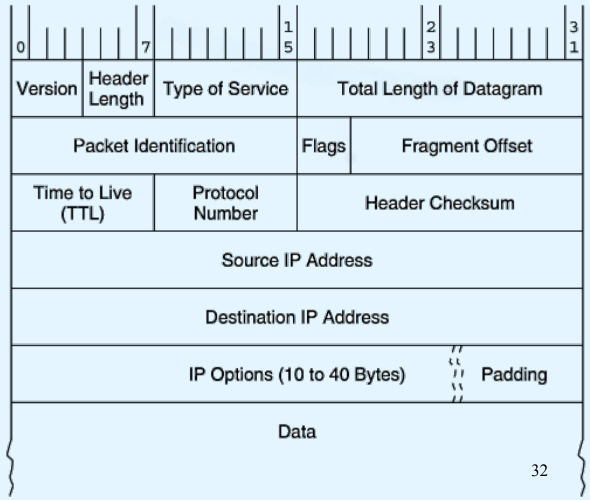
12.5 Network Protocols II
TCP/IP Architecture

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



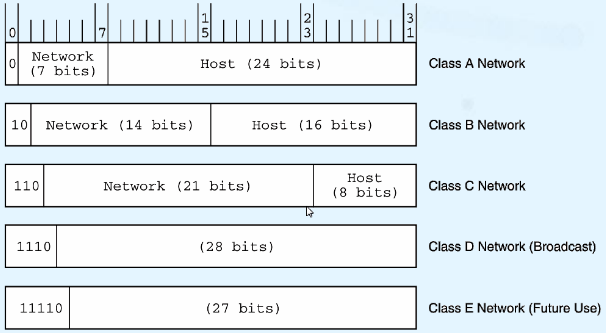
12.5 Network Protocols II
TCP/IP Architecture

- IPv4 Packet Header



12.5 Network Protocols II
TCP/IP Architecture

- IPv4 Address Space



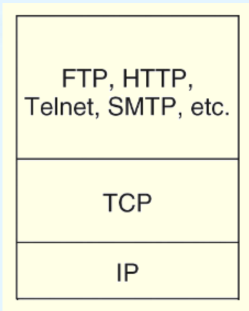
IP addresses are written in dotted decimal notation: 130.225.220.8 (akira.ruc.dk), 192.168.1.*x*, *x* between 1 and 254 (private IP addresses).

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.

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".



12.5 Network Protocols II
TCP/IP Architecture

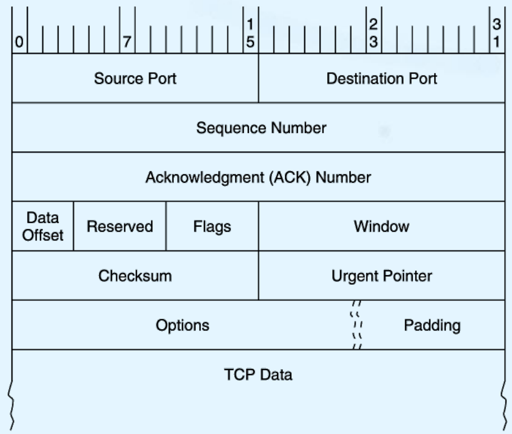
- As part of initiating a connection, TCP also opens a service access point (SAP) in the application running above it.
- In TCP, this SAP is a numerical value called a *port*.
- The combination of the port number, the host ID, and the protocol designation becomes a *socket*, which is logically equivalent 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.

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.

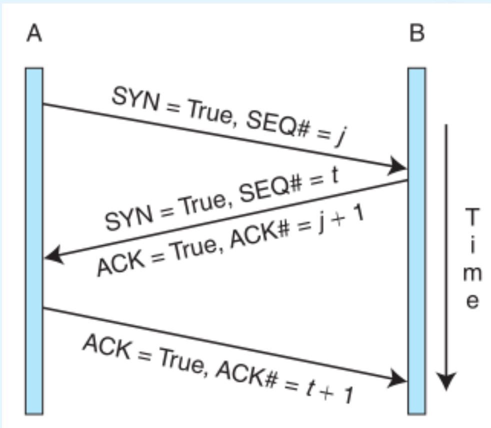
12.5 Network Protocols II
TCP/IP Architecture

- TCP segment format

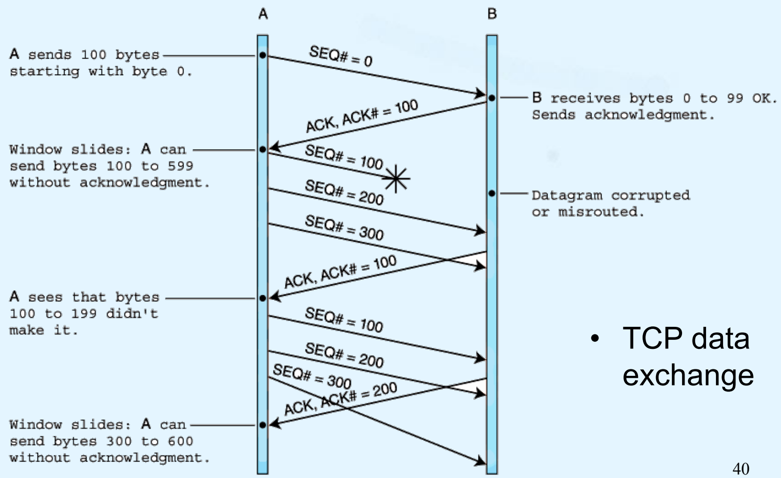


12.5 Network Protocols II
TCP/IP Architecture

- TCP session initiation handshake

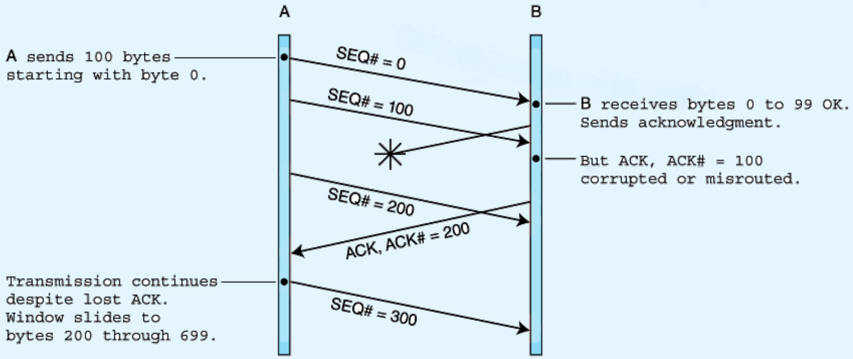


12.5 Network Protocols II
TCP/IP Architecture



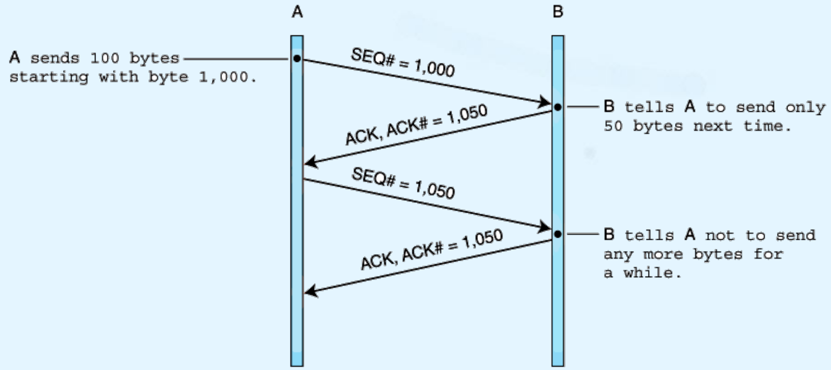
- TCP data exchange

12.5 Network Protocols II
TCP/IP Architecture



- TCP data exchange with lost acknowledgement

12.5 Network Protocols II
TCP/IP Architecture



- TCP flow control

12.5 Network Protocols II
TCP/IP Architecture

Difference between TCP and UDP

TCP	UDP
Reliability: TCP is connection-oriented protocol. When a file or message send it will get delivered unless connections fails. If connection lost, the server will request the lost part. There is no corruption while transferring a message.	*Reliability*: UDP is connectionless protocol. When you a send a data or message, you don't know if it'll get there, it could get lost on the way. There may be corruption while transferring a message.
Ordered: If you send two messages along a connection, one after the other, you know the first message will get there first. You don't have to worry about data arriving in the wrong order.	*Ordered*: If you send two messages out, you don't know what order they'll arrive in i.e. **no ordered**
Heavyweight: - when the low level parts of the TCP "stream" arrive in the wrong order, resend requests have to be sent, and all the out of sequence parts have to be put back together, so requires a bit of work to piece together.	*Lightweight*: No ordering of messages, no tracking connections, etc. It's just fire and forget! This means it's a lot quicker, and the network card / OS have to do very little work to translate the data back from the packets.
Streaming: Data is read as a "stream," with nothing distinguishing where one packet ends and another begins. There may be multiple packets per read call.	*Datagrams*: Packets are sent individually and are guaranteed to be whole if they arrive. One packet per one read call.
Examples: World Wide Web (Apache TCP port 80), e-mail (SMTP TCP port 25 Postfix MTA), File Transfer Protocol (FTP port 21) and Secure Shell (OpenSSH port 22) etc.	*Examples*: Domain Name System (DNS UDP port 53), streaming media applications such as IPTV or movies, Voice over IP (VoIP), Trivial File Transfer Protocol (TFTP) and online multiplayer games etc

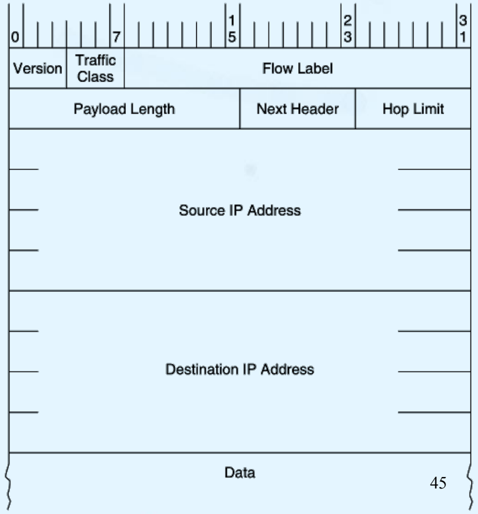
12.5 Network Protocols II
TCP/IP Architecture

- 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

12.5 Network Protocols II
TCP/IP Architecture

- IPv6 Header Format

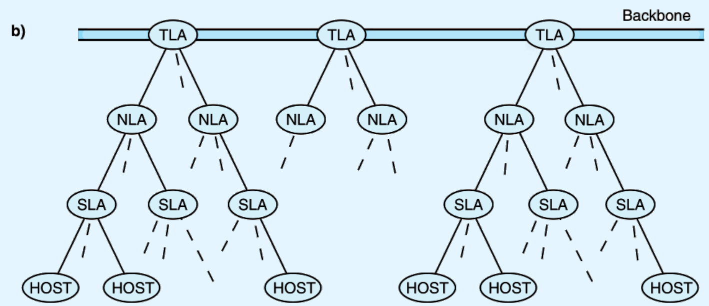


12.5 Network Protocols II
TCP/IP Architecture

a)

3 Bits	13 Bits	8 Bits	24 Bits	16 Bits	64 Bits
Prefix 001	Top-Level Aggregation ID	Reserved	Next-Level Aggregation ID	Site-Level Aggregation ID	Interface ID

b)



a) Aggregatable Global Unicast Address Format
b) Aggregatable Global Unicast Hierarchy

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