King Fahd University of Petroleum & Minerals Computer Engineering Dept

COE 540 –Computer Networks

Term 081

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Lecture Contents

1. Historical Overview
2. Messages and Switching
3. Layering
   a. The OSI model
   b. The TCP/IP model

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Reading Assignment

➢ You are required to read the following chapters:
  ➢ Chapter 1 of Gallager's textbook
  ➢ Chapter 1 of Kurose's textbook

➢ The material is an overview of the field and serves as very "*basic*" introductory text.
➢ The material is required for subsequent quizzes and exam

Historical Overview

• Forms of data networks
  • Smoke signals - ?
  • Telegraphy – 19s century
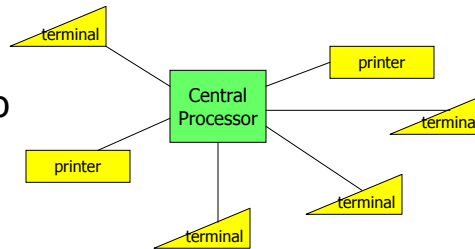
• Very primitive – manual "signal" encoding

Historical Overview (2)

- Time-shared Processors
  - 1950s
  - Proliferation of communication links
  - Peripheral devices (printers, terminals, etc.) connect to the "expensive" CPU.

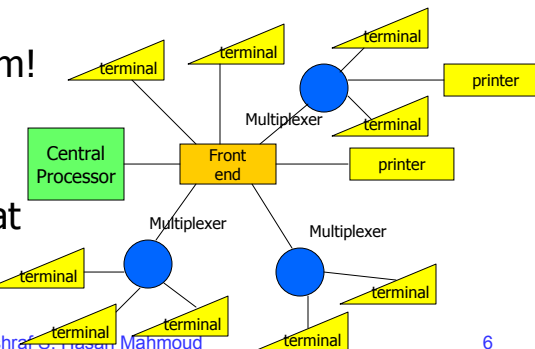- Note that the central CPU is also managing the communication links!

Historical Overview (3)

- Time-shared Processors – cont'd
- To relief the processor – a specialized "front end" processor is attached to the central processor to handle all communications

- Centralized system!

- Note the central processor is still at the center of the network

3

Historical Overview (4)

- ARPANET and TYMNET - ~70s
- General purpose data-networks
- Geographically distributed computer systems
- Interface Message Processors (IMPs) – computers specialized in routing messages
  - Routers/Switches
  - Connected using communication links
- Note, the "subnet" is now at the center of the network and not the shared computer

subnet

CPU

CPU
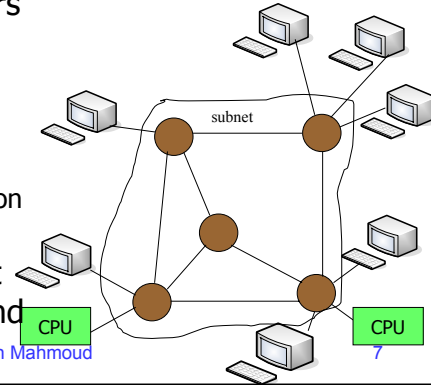
Historical Overview (5)

- Network of interconnected networks
- Explosive growth of wide area networks and local area networks
- The need for control algorithms or PROTOCOLs to handle data, gateways, bridges, etc.
- This shown network is similar to today's Internet!

Wide area network

Wide area network

subnet

Wide area network

CPU

CPU

4
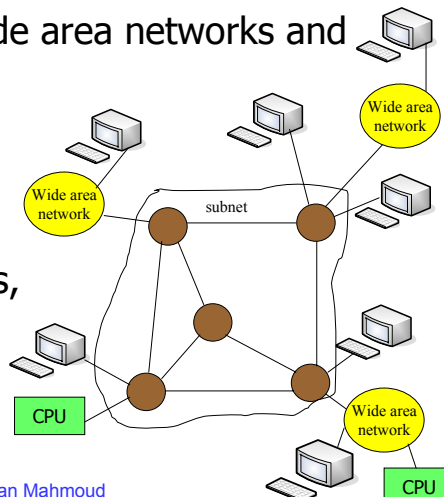
Historical Overview (6)

- What do think future networks will look like?
  - High speed (broadband)?
  - Integrated services: voice, data, multimedia, etc.
  - Quality of service (QoS) capable networks
  - Seamless services
  - Ubiquitous
  - Etc.

Factors

- Technological and economy
  - Thanks to advances in VLSI, CPU prices are halved every six-to-twelve months with more processing power built in
  - Computers can do more – network has to cope
- Communication Technology
  - Evolution of link speeds: 2.4, 4.8, 9.6 and 56 kb/s
  - New links – 64 kb/s, 1.5 Mb/s, 45 Mb/s, etc.
  - Bandwidth sharing
  - Cost for media – TP versus optical
- Applications for data networks
  - Remote access of "super" computers – early
  - Email, FTP, HTTP – now (killer application?)
  - (distributed) database access
  - Etc.

Messages and Switching

- What is a message? – give a definition
- Depend on the application/context
  - Email – document or file
  - Interactive system – transaction
- Representation of messages
  - String of bits
  - Compression – how?
- Is transferring long messages between network entities efficient? Why?
- Usually, long message are broken into "packets"
- The network must "switch" or direct packets to the destination

Exercise:

- Consider the simple network shown in figure. One file of K>>1 bits must be sent from A to C. The file is decomposed into packets of P bits each. Each packet contains 16 error-control bits, 32 bits of address and sequence number, in addition to the P data bits. The transmission rate is R bits/sec. Each packet is first sent from A to B and then from B to C.
  a) Find the value of P that minimizes the transmission time from A to C, neglecting the propagation time.
  b) Repeat the problem when the file must go through N communication nodes between A and C.

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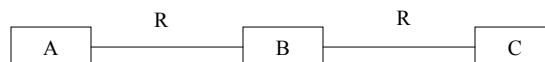
Sessions

- What is a session?
- Connection versus connectionless services
- Think of a "voice" session or an "HTTP" session

- What are the characteristics for connection-oriented communication?
- What are the characteristics for connectionless communication?
- Modeling of Traffic/Arrivals
  - Messages arrive at random points in time
  - Poisson process – approximations
  - Accuracy of model – voice (good), data (?)
  - On/Off models

important topic

Characteristics of Sessions

- Message arrival rate and variability of arrivals
- Session holding time
- Expected message length and length distribution
- Allowable delay
- Reliability
- Message and packet ordering

Circuit Switching versus Store-and-Forward Switching

- Circuit switching:
  - A dedicated path is established between two ends
  - Resources are reserved for session – justified when link utilization is expected to be high
  - Usually FDM, TDM, or CDMA based
  - Appropriate for CBR type traffic – rarely used for data
  - Eg. Telephony
  - Involves: call setup, data exchange, call termination
- Store-and-Forward switching:
  - The processing is done on the packet level
  - Intermediate nodes receive and process (switch) packets
  - Different packets may go different routes
  - No call setup
  - Resources are not reserved but utilized as required
  - Appropriate for VBR type traffic

Taxonomy of Store-and-Forward

- Message switching – messages sent as unit entities and not segmented into packets
  - Requires max message size
- Packet switching – messages are broken into packets (usually fixed length)
  - Same as store-and-forward
- Virtual circuit routing – path is setup when session is initiated; maintained for the life of the session (i.e. all packets follow same path)
- Dynamic (datagram) routing – every packet on its own

Link Utilization

More on this topic to be covered when queueing theory is discussed.

- Variables of interest:
  - t1, t2, t3, … : interarrival times
  - X1, X2, X3, … : message duration
- Arrival rate, $\lambda = E[t_i]$
- Link utilization, $\rho = \lambda E[X_i] = E[X_i]/E[t_i]$
  - $\rho << 1 \rightarrow$ low utilization,
  - $\rho = 1 \rightarrow$ 100% utilization
  - $\rho > 1 \rightarrow$ unstable link/system
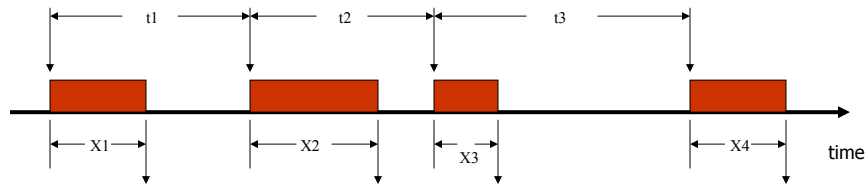
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The Concept of Layering

- **Source: http://en.wikipedia.org/wiki/OSI_model**

10/13/2008   Dr. Ashra   RM – OSI and letter communication parallel

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Protocols - Definition

- **What is a Protocol:**
  - **Convention between two communicating entities governing exchange of data**
- **Elements of Protocol:**
  - **Syntax: data format, signal levels, etc.**
  - **Semantics: control info coordination and error handling**
  - **Timing: matching speeds and sequencing (synchronization)**
- **What is a "*communicating entity*"?**
  - **Node,**
  - **Module,**
  - **Process,**
  - **Etc.**

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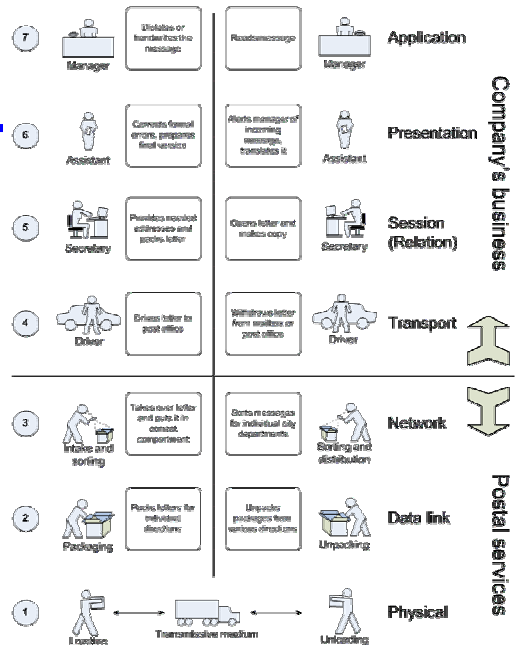
The OSI Model - Environment

- **Layer i establishes a PEER relationship with layer i on the target node**
- **This means Layer i requires service from layer i-1**
- **And so on**
- **The use of the PDUs**
- **No direct communication except for the physical layer – all other communication is indirect or virtual**
- **Encapsulation of user data**
- **Each layer may segment SDU to accommodate its own requirement – These are reassembled at the other end**

Outgoing PDU Construction

AH	User Data
PH	A-PDU
SH	P-PDU
TH	S-PDU
NH	T-PDU
LH	N-PDU	LT
	DL-PDU	

Application X

Application
Presentation
Session
Transport
Network
Data Link
Physical

Communications Path (e.g., point-to-point link, network)

Application Y

Application
Presentation
Session
Transport
Network
Data Link
Physical

Incoming PDU Reduction

AH	User Data
PH	A-PDU
SH	P-PDU
TH	S-PDU
NH	T-PDU
LH	N-PDU	LT
	DL-PDU	

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The OSI Model - Framework

- **Very similar to subroutine or function design in software engineering**
- **Boundaries and functionalities are well designed – development of one layer has little or no effect on other layers**
- **Protocol specification:**
  - **Format of PDUs, and the semantic of each field**
- **Service definition:**
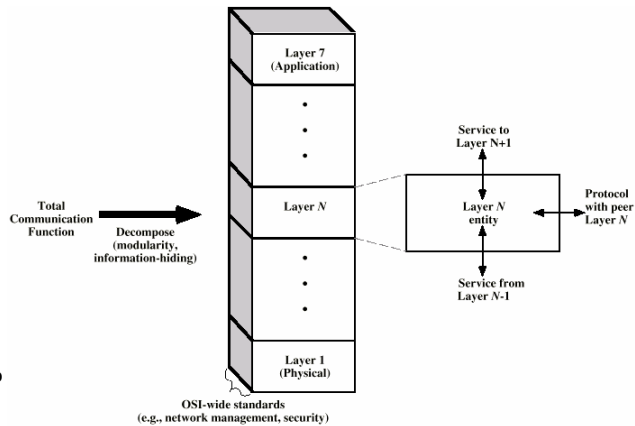 - **What are the services provided to upper layer and the lower one**
- **Addressing:**
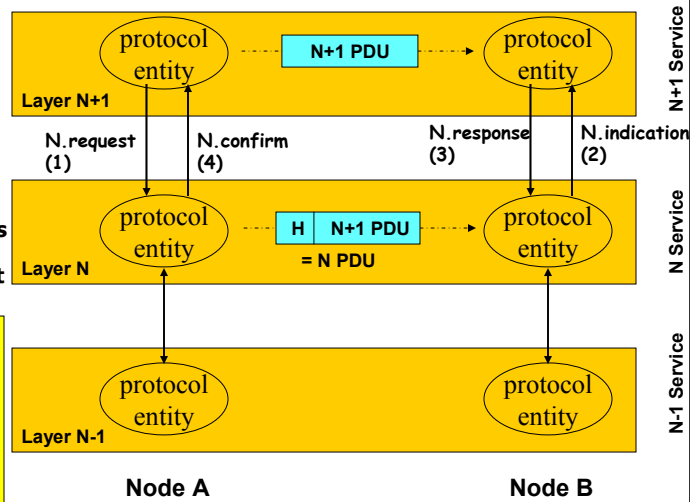 - **E.g: NSAP is the address of an entity in the transport layer who uses the network service**

Layer 7
(Application)

Total
Communication
Function

Decompose
(modularity,
information-hiding)

Layer N

Service to
Layer N+1

Layer N
entity

Protocol
with peer
Layer N

Service from
Layer N-1

Layer 1
(Physical)

OSI-wide standards
(e.g., network management, security)

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The OSI Model - Framework

- **Service Primitives:**
  - **Request:**
  - **Indication:**
  - **Respond**
  - **Confirm**
- **Note:**
  - **Encapsulation**
  - **Peer communication is virtual (dashed lines) – except at physical layer**
  - **Figure shows confirmed services case – For non confirmed services, the initiator receives no confirmation.**

protocol entity — N+1 PDU → protocol entity

Layer N+1

N.request (1)   N.confirm (4)   N.response (3)   N.indication (2)

protocol entity — H | N+1 PDU = N PDU → protocol entity

Layer N

protocol entity   protocol entity

Layer N-1

Node A   **Node B**

N+1 Service

N Service

N-1 Service

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Layering and Packet Headers

- **The example is NOT showing OSI layers – but some hypothetical system of (Application, Transport, Network, Data Link Control, and Physical Layer)**
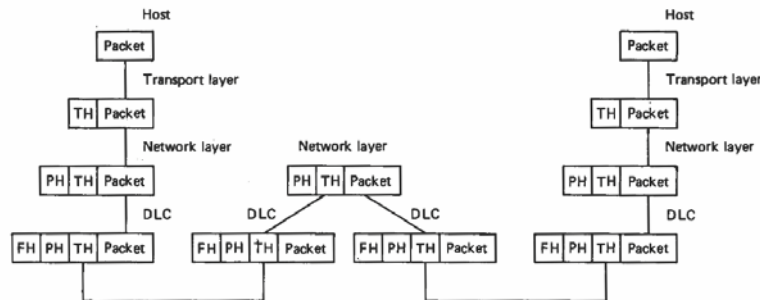

Host   Host

Packet

Transport layer

TH Packet

Network layer   Network layer

PH TH Packet   PH TH Packet

DLC   DLC   DLC   DLC

FH PH TH Packet   FH PH TH Packet   FH PH TH Packet   FH PH TH Packet

Figure 1.12 Illustration of various headers on a frame. Note that each layer looks only at its own header.

The OSI Model – Physical Layer

- **Specifications:**
  - **Mechanical: dimensions, connectors, etc.**
  - **Electrical: signal levels, rates of change, etc**
  - **Functional: functions performed by each circuit**
  - **Procedural: steps required to transport bits from one end to the other**
- **Provides service to do "transmission of raw bits"**

The OSI Model – Data Link Layer

- **Coverts the raw bit stream service provided by the physical layer to a reliable stream:**
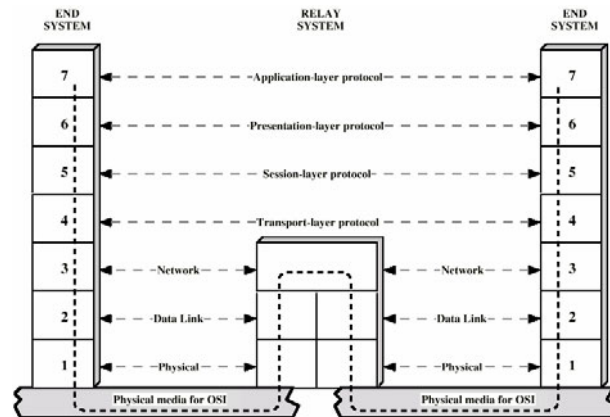 - **Performs error detection and error control**

- **Examples: HDLC, LAPB, LLC, etc**

The OSI Model – Network Layer

- **Service: transfer of information between two end systems across communication network – End to end delivery of packets**

- **Two end systems may be connected by:**
  - **Point-2-point: no need for network layer**
  - **Same network (see figure)**
  - **Different network**

The OSI Model – Transport Layer

- **Service: mechanism of exchanging data (or messages) between the two end systems:**
  - **For connection oriented networks:**
    - **Error-free delivery**
    - **Ordered delivery**
    - **No loss or duplication**
    - **Attempts to provide a certain quality of service (QoS) {certain max error rate, delay jitter, etc) through optimizing the the network layer services**
- **Example: TCP (connection oriented), UDP (connectionless)**

The OSI Model – Session Layer

- **Service: mechanism of controlling the dialogue between applications at end systems**
  - **Dialogue Discipline**
  - **Grouping**
  - **Recovery**

The OSI Model – Presentation

- **Service: defines format of data (format, encryption, and compression) to be exchanged between applications**

The OSI Model – Application

- **Service: A means for user applications (email, ftp, etc) to access the services provided by the OSI model**

The TCP/IP Model

- **TCP/IP is the result of R&D conducted on experimental packet switched network (ARPANET) and funded by Defense Advanced Research Agency (DARPA)**
- **TCP/IP is NOW the dominant commercial architecture – The foundation of the internet and its applications**

The TCP/IP Model

- **Model has five independent layers:**
  - **Application layer: comm between processes or applications on separate hosts**
  - **Transport layer: end-2-end transfer service – may include reliability mechanisms**
  - **Internet layer: routing data from source to destination through one or more networks**
  - **Network access layer: logical interface between end systems and the network**
  - **Physical layer: defines mechanism of transmitting raw bits depending on media characteristic**
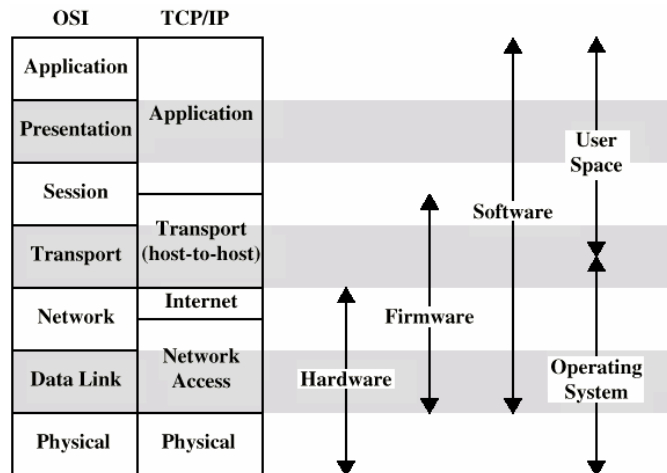
The TCP/IP Model (using the OSI Model as a reference)

OSI	TCP/IP
Application	Application
Presentation	
Session	
Transport	Transport (host-to-host)
Network	Internet
Data Link	Network Access
Physical	Physical

User Space

Software

Firmware

Hardware

Operating System

Example of TCP/IP Communications

- **A process (has port 1) on host A needs to communicate to another process: port 2 at host B**
- **The application layer on A hands the msg down to TCP with instructions to deliver it to (port2,host B)**
- **TCP hands msg down to IP with instructions to send it to host B:**
    - **The IP layer knows how to reach host B (or at least the first hop of the route) – does not care about port info**
- **IP hands down packets to network access (say Ethernet) with instructions to pass it to next router (first hop on the way to B)**

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Example of TCP/IP Communications

- **Does not show segmentation (or fragmentation in IP terms) process!**

User data	Application byte stream
TCP header ▓▓▓▓▓▓▓	TCP segment
IP header ▓▓▓▓▓▓▓	IP datagram
Network header ▓▓▓▓▓▓▓	Network-level packet
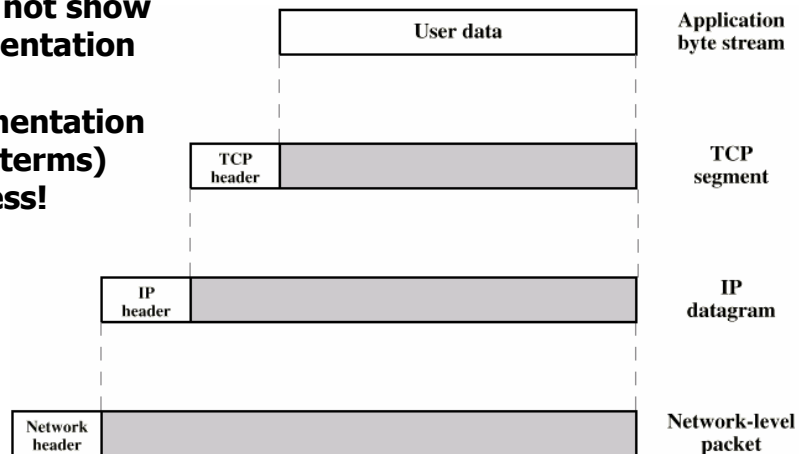
TCP/IP Control Information (Partial)

- **TCP control info:**
    - **Destination port number**
    - **Sequence number**
    - **Checksum**
- **IP control info:**
    - **IP address**
- **Network Access control info:**
    - **Destination network access address (this is not the IP!!)**
    - **Facilities request (e.g. priorities)**

TCP/IP Control Information (Partial)

Applications

MIME

BGP | FTP | HTTP | SMTP | TELNET | SNMP

Transport services

TCP | UDP

These applications do not require the TCP service

ICMP | IGMP | OSPF | RSVP

IP layer

IP

BGP	=	Border Gateway Protocol	OSPF =	Open Shortest Path First
FTP	=	File Transfer Protocol	RSVP =	Resource ReSerVation Protocol
HTTP	=	Hypertext Transfer Protocol	SMTP =	Simple Mail Transfer Protocol
ICMP	=	Internet Control Message Protocol	SNMP =	Simple Network Management Protocol
IGMP	=	Internet Group Management Protocol	TCP =	Transmission Control Protocol
IP	=	Internet Protocol	UDP =	User Datagram Protocol
MIME	=	Multi-Purpose Internet Mail Extension		

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