

## Regulation and Policy in the Telecommunications Industry TM 612-WS

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## Lecture—03 Network Interconnections

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### Contents

- **Network Interconnection**
  - Interconnection Models
  - Considerations for Network Interconnections
  - Challenges of international treaties in interconnected Networks
- **Open System Interconnection (OSI Model)**
  - 7-Layers of OSI model
  - Advantages of OSI Model
  - OSI vs. TCP models

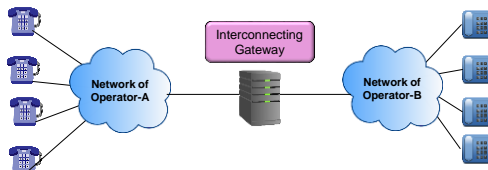
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## Network Interconnection

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### Network Interconnection

- **According to US Regulatory Law (47 C.F.R. 51.5)**
  - Interconnection is linking of two or more networks for the mutual exchange of network traffic



- Interconnection requirements are imposed by the regulatory laws

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### Why Regulate Interconnection

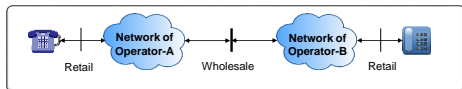
- **Interconnected (Larger) networks are more valuable because of:**
  - Positive network externalities (More revenue streams)
  - Subscriber externalities (More people to call-More revenue)
  - Scale & Scope economies (Lower costs)
  - Complementary goods (More choice)
- **Interconnected networks control market power**
  - Promote competition and facilitate entry
  - Protect consumers from monopoly power

Market power is company's ability to  
manipulate the price by manipulating the  
level of supply, demand or both

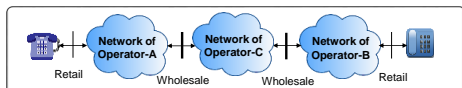
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## Interconnection Models

- International Long Distance (LD), Local/LD, Mobile/wireline



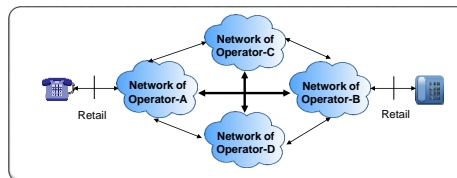
- Multi-hop Routing (B is transit network)



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## Interconnection Models

- Multilateral peering point



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## Network Interconnection

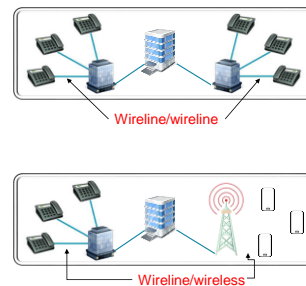
### Considerations for Interconnecting Networks

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## Interconnected Networks — Network Technologies

### Network Technologies

- Wireline/wireline
- Wireline/wireless
- Wireless/Wireless
- Packet/Packet
- Packet/Circuit
- Circuit/Circuit

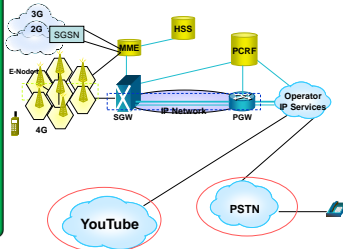


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## Interconnected Networks — Services Offered

### Services Offered

- Web Service
- Landline Voice Service
- Streaming Service
- Email Service
- Based on Symmetry
  - Symmetric U/L & D/L
  - Asymmetric U/L & D/L



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## Interconnected Networks — Traffic Attributes

### Traffic Attributes

- Based on N/W Speed
- Based on Generation
- Based on Geography
  - National/International
- Based on Regulation
  - Regulated or Negotiated (May have different interconnection requirements)

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## Interconnected Networks — Pricing

National (Local/Long Distance)	International	VoIP
<ul style="list-style-type: none"> <li>Flat Rate</li> <li>Pay per minute</li> <li>Time of use rate</li> </ul>	<ul style="list-style-type: none"> <li>Pay per minute</li> <li>Negotiated rates for:                             <ul style="list-style-type: none"> <li>Terminating calls</li> <li>Originating calls</li> </ul> </li> <li>Rates based on policy</li> </ul>	<ul style="list-style-type: none"> <li>May be free, e.g.                             <ul style="list-style-type: none"> <li>WhatsApp</li> <li>Skype</li> </ul> </li> <li>Out of homogenous network may still be much cheaper                             <ul style="list-style-type: none"> <li>May cost 1 cent/minute to \$1/minute, depending on call destination</li> </ul> </li> </ul>

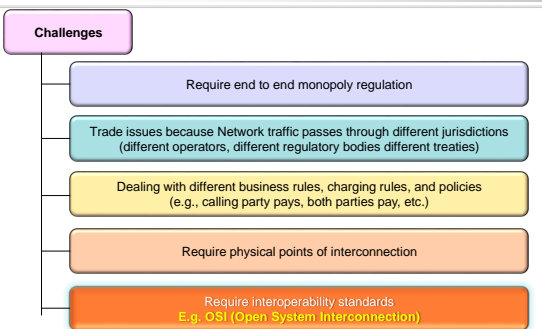
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## Interconnected Networks — Elements of Agreement

Scope and Purpose of Interconnection	Quality of Service and technical specifications	Billing and payment terms
<ul style="list-style-type: none"> <li>Who are the parties?</li> <li>Types of traffic?</li> <li>Networks architecture?</li> <li>Points of Interconnection</li> </ul>	<ul style="list-style-type: none"> <li>Quality of service and performance standards</li> <li>Technical interconnection specs and capacity</li> <li>Infrastructure sharing, collocation</li> <li>Traffic measurement and routing</li> </ul>	<ul style="list-style-type: none"> <li>Pricing</li> <li>Enforcement/Dispute Resolution</li> </ul>

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## Interconnected Networks — Challenges of international treaties (bilateral/multilateral)



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## Open System Interconnection (OSI Model)

Network Layers Defined by Open Systems Interconnection (OSI)

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## The Great Boston fire of 1872

### Largest fire in the history of USA

- Consumed 776 buildings of Boston's downtown
- Caused \$73.5 million in damage in 1872
- Fire engines of neighboring cities could not help control the fire



Why the fire could not be controlled?



One of the reasons:  
Lack of standard threads on hose and fire hydrant

Why fire is related with the NextGen Networks?

It Emphasize the value of technical standards

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## Technical Standards are Important

### OSI Model is communications standard Introduced By ISO

OSI = Open Systems Interconnection  
ISO = International Standards Organization

Bundles of Books are available on OSI Model

What is OSI Model?



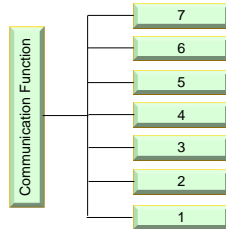
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## OSI Model for Communication Networks

### • OSI Model is :

- A Frame of Reference used in designing any network or any network products
- Divides the communication processes into 7 layers

Hence it is also known as  
The 7-Layer Model

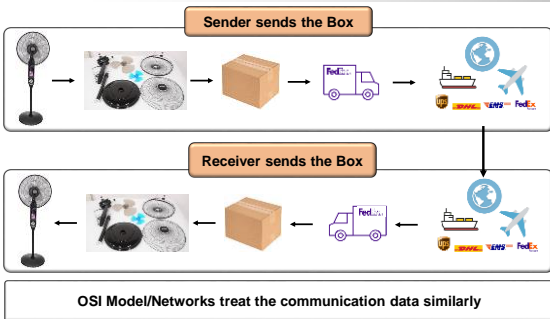


## Analogy

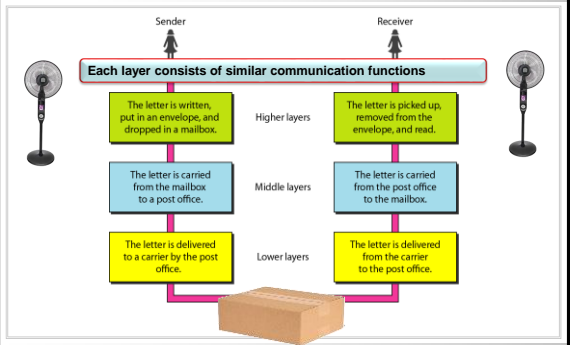
Sender wants to send this fan from point A to Point B



## Analogy (Contd.)

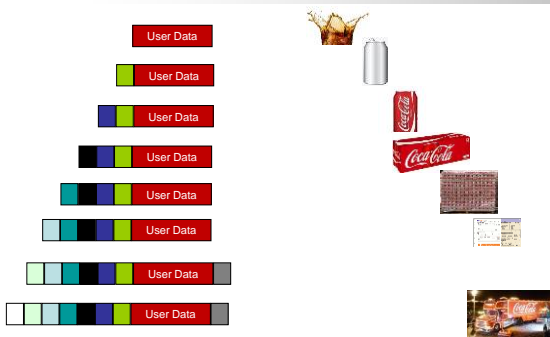


## Analogy (Contd.)



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## Another Analogy— Each Protocol Adds Additional Information



Few Facts about OSI Model

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## Names of the Seven Layers of OSI Model

SENDER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

RECEIVER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

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## Mnemonics

SENDER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

Away  
Pizza  
Sausage  
Throw  
Not  
Do  
Please

RECEIVER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

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## Nature of Each Layer

SENDER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

Software  
Software  
Software  
Heart of OSI model  
Hardware  
Hardware  
Hardware

RECEIVER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

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## Each Layer has its Specific Functions

SENDER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

Human machine interface  
Encrypt/convert data in usable format  
Controls/maintains session  
Decides the transport mechanism  
Defines physical path for data  
Defines format of data  
Transmits raw bit stream

RECEIVER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

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## Each Layer has its own Standardized Protocols

SENDER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

Application Layer Protocols  
Presentation Layer Protocols  
Session Layer Protocols  
Transport Layer Protocols  
Network Layer Protocols  
Data Link Layer Protocols  
Physical Layer Protocols

RECEIVER

Application Layer  
Presentation Layer  
Session Layer  
Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

### Protocols

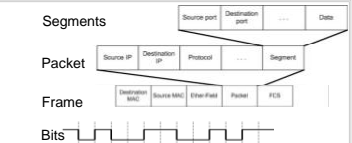
Rules that govern data communication, including error detection, message length, and transmission speed

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## Data Handling of Each Layer

SENDER

Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer



Segments  
Packets (or Datagrams)  
Frames  
BITS

Transport Layer  
Network Layer  
Data Link Layer  
Physical Layer

FCS= Frame Check Sequence

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## Data Handling of Each Layer

### 3 Sections of a Packet

#### Header Consists of:

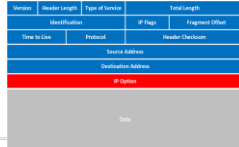
An alert signal, Source & destination addresses, Clock information

#### Data:

The user data or the payload

#### Trailer:

Error checking information



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## OSI Model

is a Reference Model  
(Not a Reference Model)

i.e.,

It is not essential  
that every architecture  
must have 7-layers

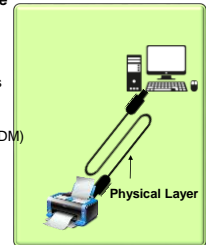
1

## Physical Layer

## Need and Functions of Physical Layer

Consider we want to print at home

- We connect computer-&-printer with cable
- Physical Layer defines
  - Wiring Standards
    - Ethernet Cable, HDMI Cable, USB cables
  - How bits physically travel on the wire
    - Modulation/Demodulation (FDM, TDM, CDM)
  - Transmission mode
    - Synchronous (Real time)
    - Asynchronous (Non real time)



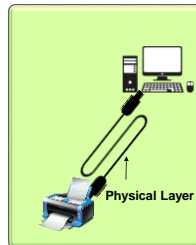
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## Need and Functions of Physical Layer (Contd.)

- PHY Layer Uses NIC (Network Interface Card)
  - To encode data to send it over a cable



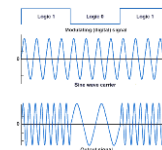
**Please Note:**  
In this case, we need only one layer, i.e.  
Physical Layer



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## Why modulate?

- Why modulate?
  - So that the information can travel to a longer distance
  - Modulation shifts the low frequency signal to a much higher frequency
  - Higher frequency means shorter wavelength
  - Shorter wavelength means use of a much smaller antenna
  - (To be efficient, the antenna needs to be about 1/10th of wavelength)



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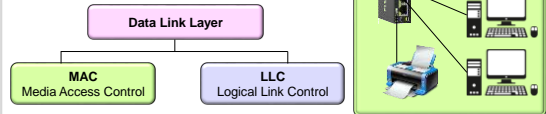
2

## Data Link Layer

### Need and Functions of Data Link Layer

Consider we want to print at the library (Not Home)

- We use switch to **access/share** the printer
- **Data link Layer** (i.e. **Layer 2 Switch**) enables:
  - Multiple computers to access/share one printer
- **Datalink layer performs several functions**
  - These are divided into two sub-layers



### Need and Functions of Data Link Layer

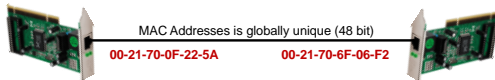
#### MAC (Media Access Control)

- Used to access the shared media
- Used to transmit data on a shared media
- Uses MAC protocols e.g. CSMA
- Uses Physical Address of Device

00 1A 3F F1 4C C6

#### LLC (Logical Link Control)

- Performs speed regulation
- Performs Error Correction and Detection
- Sends Notification (Ack/Nack)
- Manages data flow/Synchronization, i.e., when to start & to stop sending bits



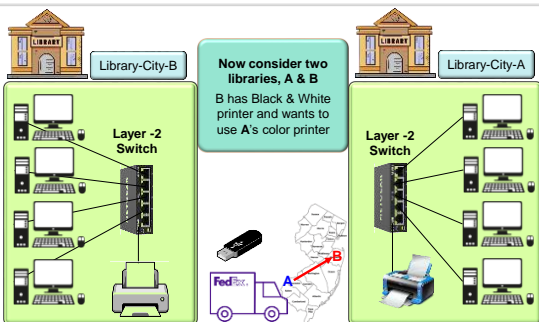
**Please Note:**  
In this case, we need two layers, i.e.  
Physical Layer and MAC Layer

CSMA = Carrier Sensed Multiple Access

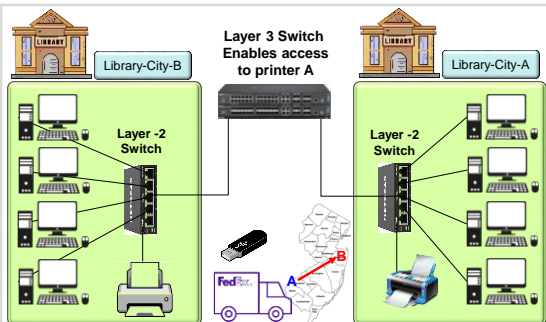
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## Network Layer

### Need of Network Layer



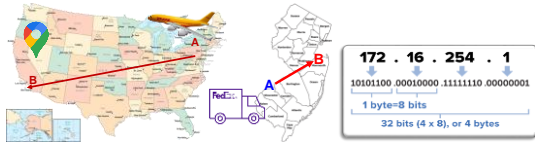
### Need of Network Layer



## Functions of Network Layer

- Finds the best routes from source to destination
- Provides Network Security and Privacy
- Provides congestion control
- Performs Data Fragmentation if NW can only handle smaller packets

Best Route is found by using routing algorithms. Decision is based IP address



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## Transport Layer

## Need of Transport Layer

- Data Link Layer uses: ??
  - MAC address for delivery of a frame to the correct machine
- Network Layer uses: ??
  - IP Address for correct routing of packets
- Transport Layer uses: ??
  - Port No. for delivery of segments to correct process running on a machine

172 . 16 . 254 . 1  
10101100.00010000.11111110.00000001  
1 byte=8 bits  
32 bits (4 x 8), or 4 bytes

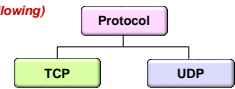
Port number is a 16-bit address  
 • Port 20 — FTP used for file transfer  
 • Port 25 — SMTP used for email  
 • Port 80 — HTTP used for accessing Webs



FTP = File Transfer Protocol  
 SMTP = Simple Mail Transfer Protocol  
 HTTP = Hypertext Transfer Protocol

## Functions of Transport Layer

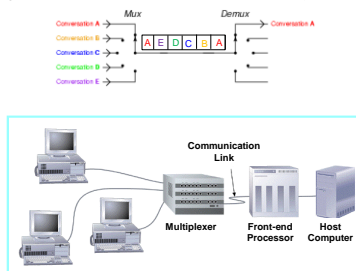
- Uses Transport Protocols (*one of the following*)
  - TCP (Transmission Control Protocol)
    - Connection Oriented
    - Ack/Nack
  - UDP (User Datagram Protocol)
    - Connection Less
    - No Ack/Nack
- Performs Flow Control via Windowing
  - First sends one segment
  - Keep doubling up if Ack received
  - Keeps reducing speed sender is fast and receiver is slow



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## Functions of Transport Layer

- Performs Multiplexing and De-multiplexing
  - Sending data from multiple applications simultaneously over a single path



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## Functions of Transport Layer

- Performs Multiplexing and De-multiplexing
  - Sending data from multiple applications simultaneously over a single path
- Performs Congestion Control via buffering
  - Provides congestion control if too many sources send data
  - Congestion occurs when **Router** buffers start overflowing causing packet loss
- Performs Error correction
  - Uses error detection and correction mechanisms
- Performs QoS

**Router**

- Network traffic routing device
- Contains specific software
- Chooses the best possible path for packets

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### Routers

- Network traffic routing device
- Contains specific software
- Chooses the best possible path for packets

**5** Session Layer

### Need of Session Layer


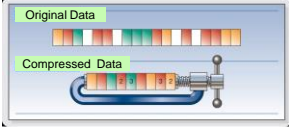
- **Need**
  - Provides the mechanism for opening, closing session
  - Maintaining a session (so that the connection does not get dropped)
- **In order to accomplish above; it**
  - Maps the session address to the shipping address
  - Selects the required QoS parameters
  - Perform negotiations between session parameters, Such as:
    - What port number?
    - What codec for voice?
  - Synchronizes information from different sources

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**6** Presentation Layer

### 6. Presentation Layer (aka Translation Layer)

- **Serves as a data translator**
  - Converts the data into an acceptable and compatible data format
  - E.g., Jpeg, Mpeg, ASCII
- **Compression/Expansion**



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## 6. Presentation Layer (aka Translation Layer)

- Carry out Encryption/Decryption

The diagram illustrates the Presentation Layer (aka Translation Layer) for encryption and decryption. It shows a process flow from a plaintext message to an encrypted message and back to the original message using a key.

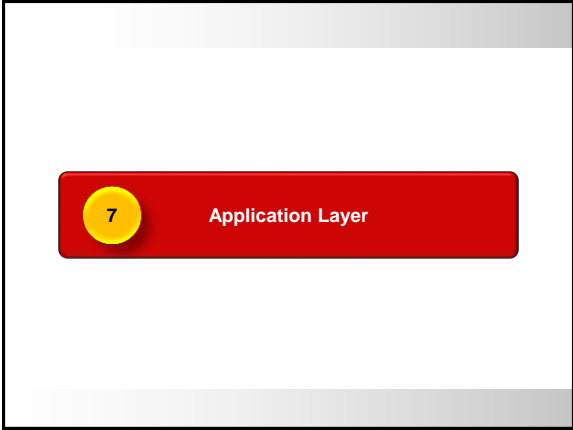
**Encryption:** The plaintext message "MEET ME IN THE PARK" is encrypted using a key to produce the ciphertext "NFFU NF JO UIF QBSL".

**Decryption:** The ciphertext "NFFU NF JO UIF QBSL" is decrypted using the same key to recover the original plaintext message "MEET ME IN THE PARK".

**Key Management:** A key is used for both encryption and decryption. The key is represented by a key icon and a question mark icon, indicating that the key is essential for the process.

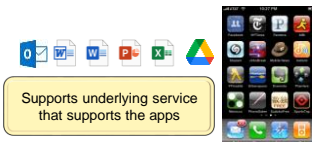
**Alphabet Mapping:** The diagram shows the mapping of the alphabet (A-Z) to the ciphertext (NFFU NF JO UIF QBSL) and back to the plaintext (MEET ME IN THE PARK). The mapping is as follows:

Plaintext (A-Z)	Ciphertext (NFFU NF JO UIF QBSL)
A	N
B	F
C	F
D	J
E	O
F	U
G	I
H	F
I	J
J	U
K	I
L	F
M	J
N	O
O	U
P	I
Q	F
R	J
S	O
T	U
U	I
V	F
W	J
X	O
Y	U
Z	I



## Application Layer

- **Supports underlying service that supports the apps**
  - E.g., an email app is supported by the service/protocol such as pop3,
  - SMTP, HTTP, FTP, DNS
  - Service advertisement (Wi-Fi network ID)
  - Provides user services like user login, naming network devices, etc.
  - Also performs error recovery



The diagram illustrates the application layer's role in supporting various services and applications. On the left, a row of icons represents different types of services: Outlook (email), Word (document), PowerPoint (presentation), Excel (spreadsheet), and Google Drive (cloud storage). Below these icons is a yellow rounded rectangle containing the text "Supports underlying service that supports the apps". To the right of this text is a smartphone screen displaying a grid of application icons, including social media, productivity, and utility apps, representing the user interface that interacts with these services.

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# Summary

**7. Application**  
Network process to application  
DNS, WWW/HTTP, P2P, EMAIL/POP, SMTP, Telnet, FTP

**6. Presentation**  
Data representation and encryption  
Recognizing data, HTML, DDCP, JPEG, MP3, AVI, Sockets

**5. Session**  
Interhost communication  
Session establishment in TCP, SIP, RTP, RPC-Named pipes

**4. Transport**  
End-to-end connections and reliability  
TCP, UDP, SCTP, SSL, TLS

**3. Network**  
Path determination and logical addressing  
IP, ARP, IPsec, ICMP, IGMP, GMP

**2. Data Link**  
Physical addressing  
Ethernet II, MAC/LLC, WAN, ATM, HDP, Fibre Channel, Frame Relay, HDLC, PPP, Q.931, Token Ring

**1. Physical**  
Media, signal, and binary transmission  
RS-232, RJ45, V.34, 100BASE-TX, SDH, DSL, RS-485

## Advantages of OSI Model

The diagram illustrates the advantages of the OSI model, categorized into two groups: For Operators and For Manufacturers. A central vertical line connects the categories to the specific advantages.

- For Operators**
  - Helps determine the required hardware and software to build their network
  - Helps understand the process followed by the network components
  - Helps identify the problem layer to perform troubleshooting
- For Manufacturers**
  - Helps create open and interoperable devices and software
  - Helps define which parts of the network their products should work with
  - Helps communicate to users at which network layers their product operates

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The diagram illustrates the relationship between the seven layers of the OSI model and the four layers of the TCP/IP model, along with the specific protocols associated with each TCP/IP layer.

**OSI vs. TCP Models**

OSI Model Layer	TCP Model Layer
Application Layer	Application Layer
Presentation Layer	
Session Layer	
Transport Layer	Transport Layer
Network Layer	Network Layer
Data Link Layer	Data Link Layer
Physical Layer	Physical Layer

**TCP/IP Protocol Suite**

The TCP/IP model is divided into four layers, each with associated protocols:

- Application Layer:** HTTP, SMTP, Telnet, FTP, DNS, RIP, SNMP
- Transport Layer:** TCP, UDP
- Network Layer:** IP
- Link Layer:** Ethernet, Token Ring, ATM, Frame Relay

The diagram illustrates the 7-layer OSI model, organized into four rows of colored boxes. The top row contains seven boxes: HTTP (teal), SMTP (orange), Telnet (light green), FTP (green), DNS (light green), RIP (light purple), and SNMP (light blue). The second row contains two boxes: TCP (orange) and UDP (light green). The third row contains a single wide box: IP (teal). The bottom row contains four boxes: Ethernet (teal), Token Ring (orange), ATM (light green), and Frame Relay (light blue).

## Chapter Review Questions (CRQ)

### Chapter-03



### CRQ1

- **Pick the most accurate statement.**
- **Interconnected networks are more valuable due to**
  - A. Positive network externalities (More revenue streams)
  - B. Subscriber externalities (More people to call-More revenue)
  - C. Scale & Scope economies (Lower costs)
  - D. All the above noted statements are correct

### Q2

- **Pick the most accurate statement. OSI Model:**
  - A. Prepares market players that act as a role model in telecom industry
  - B. Presents a frame of reference used in designing network products
  - C. Is a model that provides Original Scientific Information (OSI)
  - D. None of the above is correct

### Q#3

- **Pick the most accurate statement**
- **Modulation/Demodulation is performed at Physical Layer so that**
  - A. Information may travel to a longer distance
  - B. Smaller antennas may be used by the devices in case of wireless network
  - C. Information may be protected from the hackers
  - D. Both A and B are correct

### Q4

- **Pick the most accurate statement**
- **Fragmentation at transport layer is used to**
  - A. To split the packet and inspect it for any possible security breach
  - B. Enhance Quality of Service (QoS) of the transport layer
  - C. Break the packets at sending end and reassemble at the receiving end
  - D. Teardown the session

### Q5

- **Pick the most accurate statement**
  - A. TCP provides connection oriented, whereas UDP connectionless less service
  - B. UDP provides connection oriented, where as TCP connectionless less service
  - C. UDP provides connectionless service for mobile networks only
  - D. TCP provides connection oriented service only when high QoS is needed

### Q6 (Bonus)

- **Pick the most accurate statement**

Data Link Layer is divided into MAC and LLC. The MAC layer:

- A. Comprises of software and is responsible for encryption decryption
- B. Consists Accessing the shared media
- C. Comprises of physical hardware and is responsible for access control in a shared media
- D. Is the heart of OSI model and uses CSMA (Critical Systems Management Agent)

**Bonus question**  
to compensate for selecting a  
wrong answer, but the maximum  
score remains 10

### Answers to CRQ



### CRQ1

- **Pick the most accurate statement.**

- **Interconnected networks are more valuable due to**

- A. Positive network externalities (More revenue streams)
- B. Subscriber externalities (More people to call-More revenue)
- C. Scale & Scope economies (Lower costs)
- D. All the above noted statements are correct

D. All the above noted statements are correct

### Q2

- **Pick the most accurate statement. OSI Model:**

- A. Prepares market players that act as a role model in telecom industry
- B. Presents a frame of reference used in designing network products
- C. Is a model that provides Original Scientific Information (OSI)
- D. None of the above is correct

B: Presents a frame of reference used in designing network products

### Q#3

- **Pick the most accurate statement**

- **Modulation/Demodulation is performed at Physical Layer so that**

- A. Information may travel to a longer distance
- B. Smaller antennas may be used by the devices in case of wireless network
- C. Information may be protected from the hackers
- D. Both A and B are correct

D: Both A and B are correct

### Q4

- **Pick the most accurate statement**

- **Fragmentation at transport layer is used to**

- A. To split the packet and inspect it for any possible security breach
- B. Enhance Quality of Service (QoS) of the transport layer
- C. Break the packets at sending end and reassemble at the receiving end
- D. Teardown the session

C. Break the packets at sending end and reassemble at the receiving end

### Q5

- **Pick the most accurate statement**

- A. TCP provides connection oriented, whereas UDP connectionless less service
- B. UDP provides connection oriented, where as TCP connectionless less service
- C. UDP provides connectionless service for mobile networks only
- D. TCP provides connection oriented service only when high QoS is needed

A. TCP provides connection oriented, whereas UDP connectionless less service

### Q6 (Bonus)

- **Pick the most accurate statement**

Data Link Layer is divided into MAC and LLC. The MAC layer:

- A. Comprises of software and is responsible for encryption decryption
- B. Consists Accessing the shared media
- C. Comprises of physical hardware and is responsible for access control in a shared media
- D. Is the heart of OSI model and uses CSMA (Critical Systems Management Agent)

**Bonus question**  
to compensate for selecting a  
wrong answer, but the maximum  
score remains 10

C. Comprises of physical hardware and is responsible for access control in a shared media

### HOME WORK

### Homework # 03

- **Q1.**

- What is OSI Model? Name the Seven Layers of OSI Model, and describe two functions of each layer

- **Q2.**

- What are the challenges of international treaties (bilateral/multilateral) in interconnected Networks

- **Q3.**

- Interconnection is linking of two or more networks for the mutual exchange of network traffic. Draw the network models for multi-hop routing, and multilateral peering points

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