

# Protocol Layering & Cross Layer Design

EE4204: Computer Networks

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**Note:** Some slides & graphics adapted from:

- Vineet Srivastava, Cross-layer Design, MEng Thesis, NUS.
- Kurose & Ross, Computer Networking

## Outline

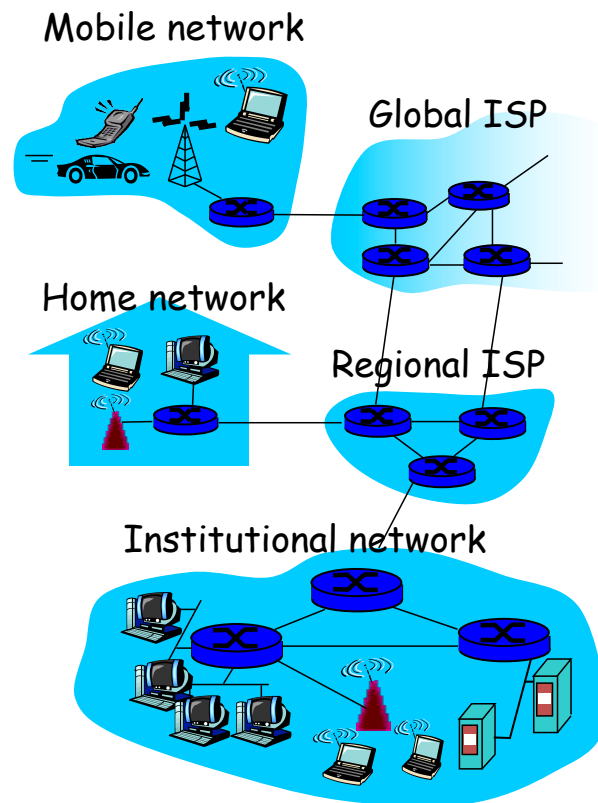
- A look inside the Network
- What is Layering?
- The OSI model and its seven layers
- TCP/IP Model
- Cross Layer Design
- Putting it all together

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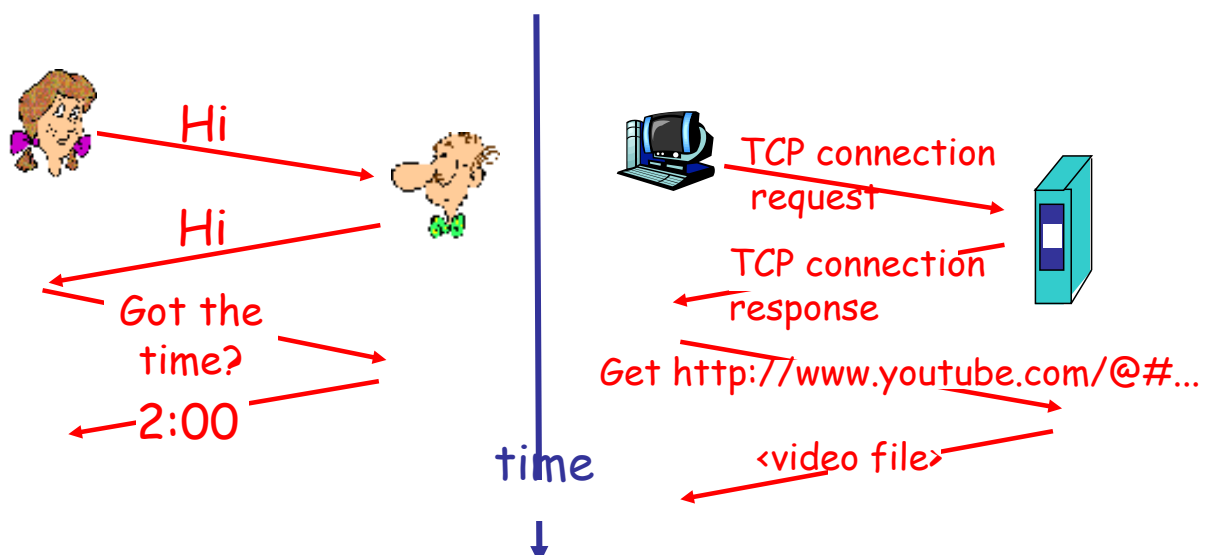
# Inside a computer/communication network

- Millions of connected computing devices running network apps
- Communication links - fiber, copper, radio, satellite
- Routers & Base Stations - route and forward data
- Protocols control sending, receiving of messages
  - e.g., TCP, IP, HTTP, Skype, Ethernet
  - E.g., GSM, GPRS, 3G, 4G
- Internet standards
- RFC: Request for comments
- IETF: Internet Engineering Task Force



# What's a protocol?

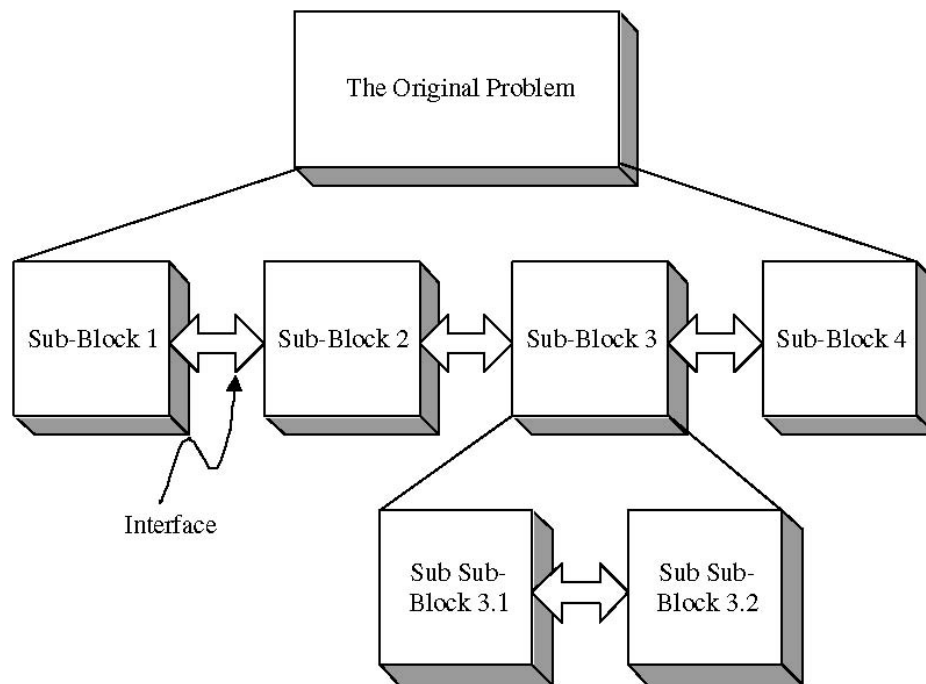
- Defines acceptable behaviour
- Agreed data format: Handshake, Message, Response



**Q:** Can you think of other protocols?

# Protocol layering – Divide and Conquer

**Question:** How do we organize a complex network to make it more manageable?



## Layering – Sending a letter to a friend



### Hand Deliver

- Write the letter
- Travel to your friend's house and hand deliver letter.

### Use the Post Office

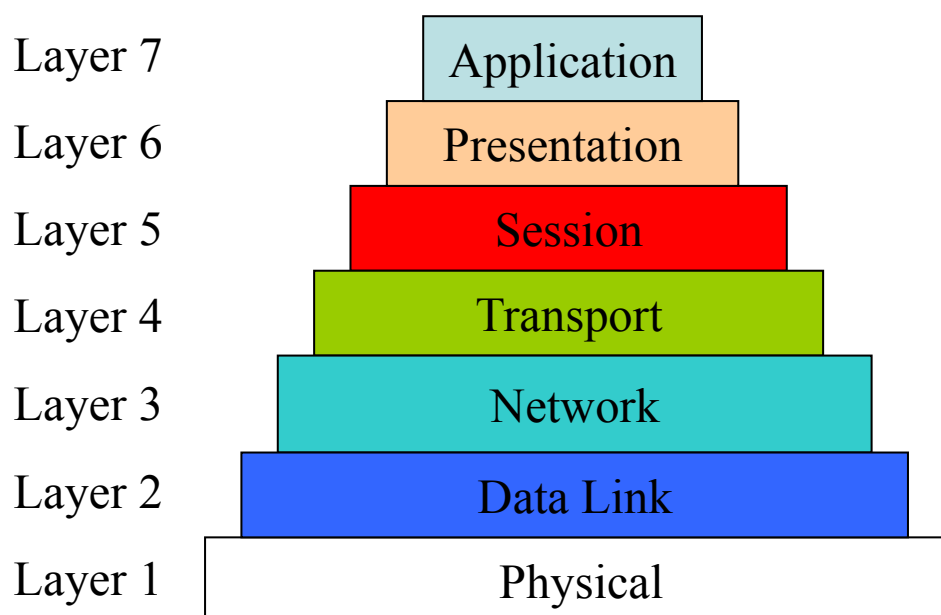
- Write the letter
- Address, Stamp, and Put in mailbox
- Postman collects and brings to local post office
- Post office routes letter to remote post office
- Postman delivers letter to your friend

# Layering and the OSI Model

## Dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered **reference model** for discussion
- Open Systems Interconnection (OSI) reference model for communications between network devices.
- Modularization eases maintenance, updating of system
- Change of implementation of layer's service transparent to rest of system
- Q: Can layering be considered harmful?

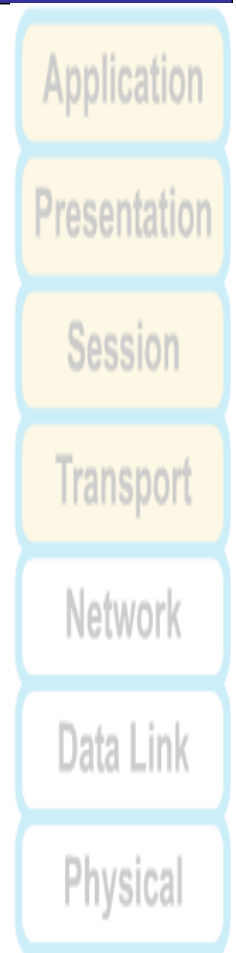
# Seven Layers of the OSI



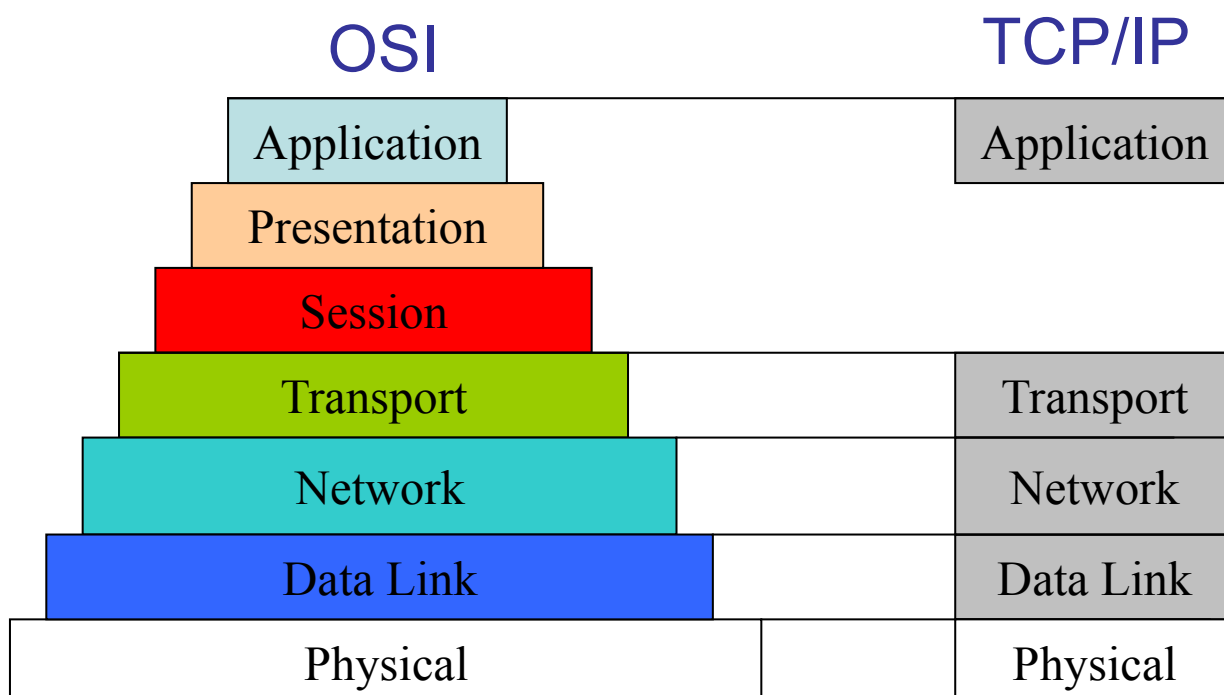
Check out: [http://en.wikipedia.org/wiki/OSI\\_model](http://en.wikipedia.org/wiki/OSI_model)

# The Layers at Work

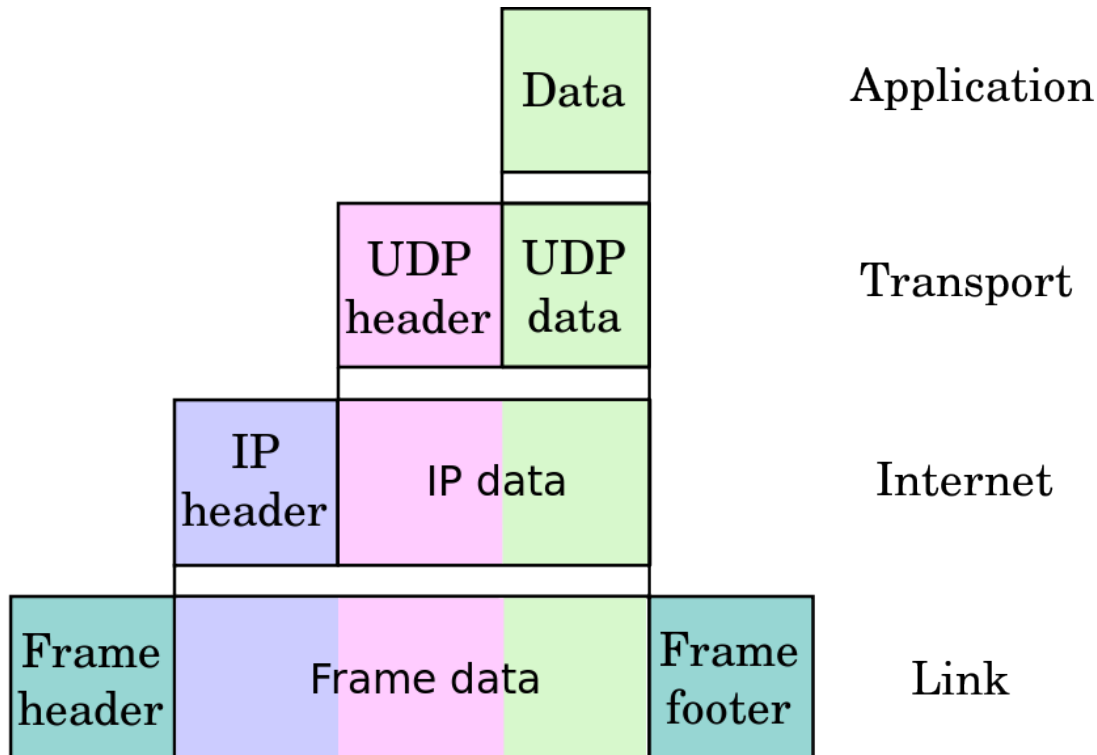
- Each layer is separate, independent and has its own function
- Each layer provides a service to those layers above and below itself
- Data packets start at the Application Layer & moves down through the layers.
- At the receiver, it travels up through the layers of the OSI model, reaching the user.
- As data moves down through the layers it is encapsulated - additional information is added as headers or trailers



# Modern networks use TCP/IP



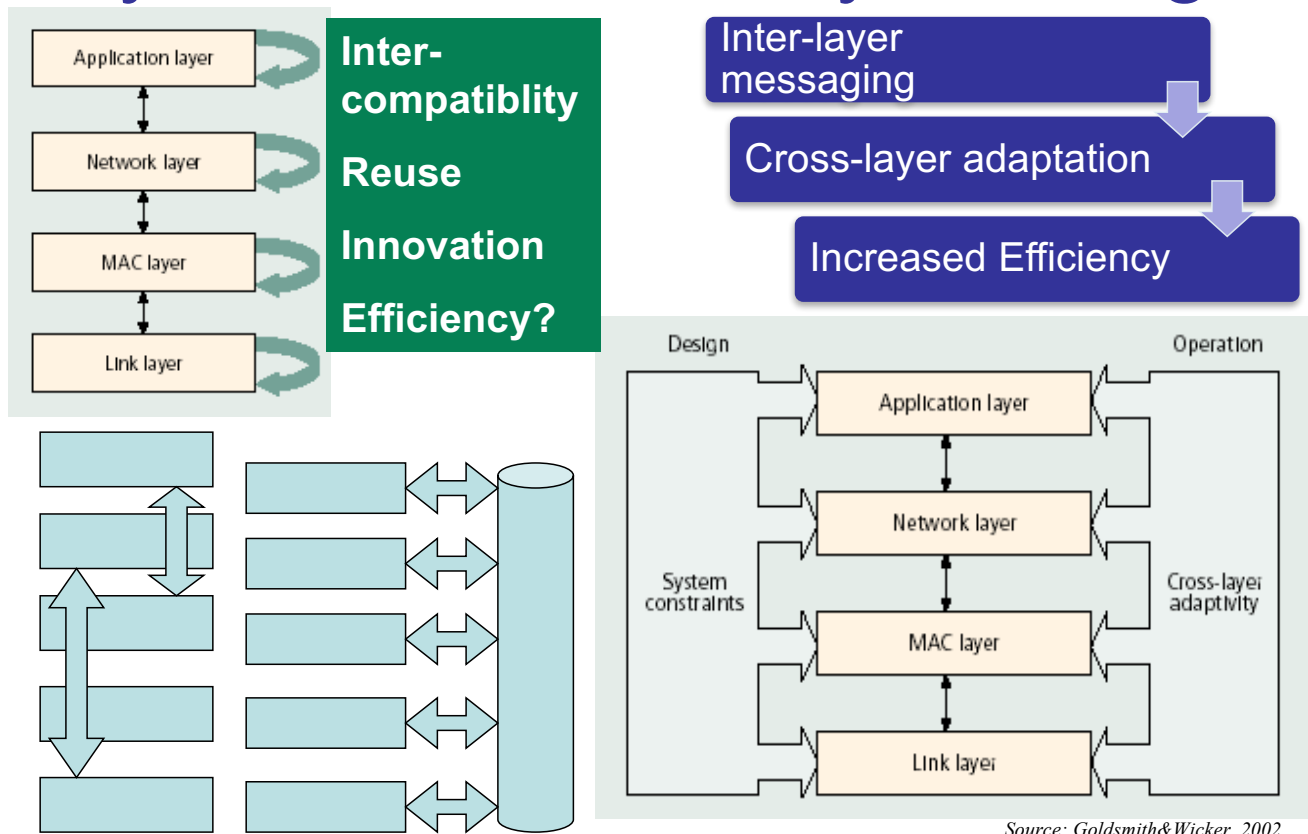
# Encapsulation in the TCP/IP model



## The TCP/IP Model

- **Application Layer** – concerned with how data at both ends is handled, user interface
- **Transport Layer** – manages end-to-end flow of data, reliability, congestion control
- **Network Layer** – consists of several protocols, primary protocol is IP – which performs routing and provides hierarchical addressing
- **Data Link Layer** – manages transmission of data on a link-by-link basis, link-level reliability
- **Physical Layer** – used for transmitting data on the physical medium

# Layered vs. Cross-layer Design



Source: Goldsmith&Wicker, 2002

## Additional Reading

### ➤ Required Reading:

V. Srivastava and M. Motani, Cross-layer design: a survey and the road ahead, IEEE Communications Magazine, Volume 43, Issue 12, Dec. 2005 Page(s):112-119.

<http://wine.dnsalias.org/~motani/html/pubs/CrossLayerCommMag.pdf>

### ➤ D. D. Clark, The Design Philosophy of the DARPA Internet Protocols, (Proc. SIGCOMM '88, Stanford, CA, August 1988, Vol. 18, No. 4)

<http://www.acm.org/sigs/sigcomm/ccr/archive/1995/jan95/ccr-9501-clark.pdf>

### ➤ Hubert Zimmermann, OSI Reference Model - The ISO Model of Architecture for Open Systems Interconnection, IEEE Transactions on Communications, vol. 28, no. 4, April 1980, pp. 425 - 432.

[http://www.comsoc.org/livepubs/50\\_journals/pdf/RightsManagement\\_eid=136833.pdf](http://www.comsoc.org/livepubs/50_journals/pdf/RightsManagement_eid=136833.pdf)

### ➤ L. Kleinrock. Research Areas in Computer Communication. ACM Computer Communication Review, 25(1), 1995.

<http://www.acm.org/sigs/sigcomm/ccr/archive/1995/jan95/ccr-9501-kleinrock.pdf>

### ➤ Kurose & Ross, Chapter 1 (general), Section 1.5 (Layers)

### ➤ Bertsekas & Gallager, Data Networks, Section 1.3 on Layering, pp 17-32

# SUMMARY of OSI Model (from Cisco)

- There was no standard for networks in the early days and as a result it was difficult for networks to communicate with each other.
- The International Organisation for Standardisation (ISO) recognised this. and researched various network schemes, and in 1984 introduced the Open Systems Interconnection (OSI) reference model.
- The OSI reference model has standards which ensure vendors greater compatibility and interoperability between various types of network technologies.
- The OSI reference model organizes network functions into seven numbered layers.
- Each layer provides a service to the layer above it in the protocol specification and communicates with the same layer's software or hardware on other computers.
- Layers 1-4 are concerned with the flow of data from end to end through the network and Layers 5-7 are concerned with services to the applications.

From Cisco Systems

## LAYER 7: APPLICATION

- The application layer is the OSI layer that is closest to the user.
- It provides network services to the user's applications.
- It differs from the other layers in that it does not provide services to any other OSI layer, but rather, only to applications outside the OSI model.
- Examples of such applications are spreadsheet programs, word processing programs, and bank terminal programs.
- The application layer establishes the availability of intended communication partners, synchronizes and establishes agreement on procedures for error recovery and control of data integrity.

From Cisco Systems



# LAYER 6: PRESENTATION

- The presentation layer ensures that the information that the application layer of one system sends out is readable by the application layer of another system.
- If necessary, the presentation layer translates between multiple data formats by using a common format.
- Provides encryption and compression of data.
- Examples :- JPEG, MPEG, ASCII, EBCDIC, HTML.

From Cisco Systems

# LAYER 5: SESSION

- The session layer defines how to start, control and end conversations (called sessions) between applications.
- This includes the control and management of multiple bi-directional messages using dialogue control.
- It also synchronizes dialogue between two hosts' presentation layers and manages their data exchange.
- The session layer offers provisions for efficient data transfer.
- Examples : SQL, ASP(AppleTalk Session Protocol).
- Examples: SSL

From Cisco Systems

# LAYER 4: TRANSPORT

- The transport layer regulates information flow to ensure end-to-end connectivity between host applications reliably and accurately.
- The transport layer segments data from the sending host's system and reassembles the data into a data stream on the receiving host's system.
- The boundary between the transport layer and the session layer can be thought of as the boundary between application protocols and data-flow protocols. Whereas the application, presentation, and session layers are concerned with application issues, the lower four layers are concerned with data transport issues.
- Layer 4 protocols include TCP (Transmission Control Protocol) and UDP (User Datagram Protocol).

From Cisco Systems

# LAYER 3: NETWORK

- Defines end-to-end delivery of packets.
- Defines logical addressing so that any endpoint can be identified.
- Defines how routing works and how routes are learned so that the packets can be delivered.
- The network layer also defines how to fragment a packet into smaller packets to accommodate different media.
- Routers operate at Layer 3.
- Examples :- IP, IPX, AppleTalk.

From Cisco Systems

# LAYER 2: DATA LINK

- The data link layer provides access to the networking media and physical transmission across the media and this enables the data to locate its intended destination on a network.
- The data link layer provides reliable transit of data across a physical link by using the Media Access Control (MAC) addresses.
- The data link layer uses the MAC address to define a hardware or data link address in order for multiple stations to share the same medium and still uniquely identify each other.
- Concerned with network topology, network access, error notification, ordered delivery of frames, and flow control.
- Examples :- Ethernet, Frame Relay, FDDI.

From Cisco Systems

# LAYER 1: PHYSICAL

- The physical layer deals with the physical characteristics of the transmission medium.
- It defines the electrical, mechanical, procedural, and functional specifications for activating, maintaining, and deactivating the physical link between end systems.
- Such characteristics as voltage levels, timing of voltage changes, physical data rates, maximum transmission distances, physical connectors, and other similar attributes are defined by physical layer specifications.
- Examples :- EIA/TIA-232, RJ45, NRZ, 802.11

From Cisco Systems