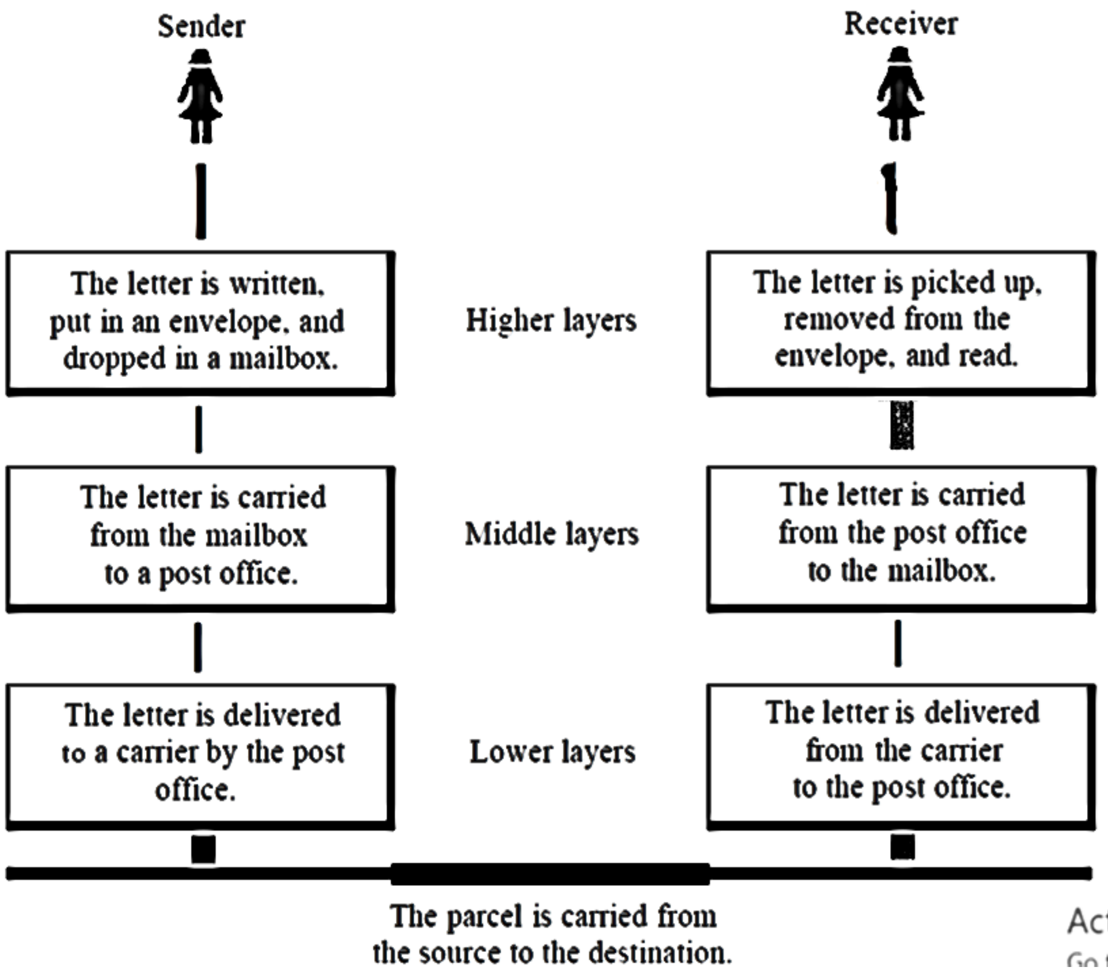
The Need for Protocol Architecture

- Let us consider that two friends communicate through postal mail.
- Instead of implementing entire logic as a single module , the entire process is divided into hierarchy of tasks.
- Each layer is responsible for a set of tasks.



The Need for Protocol Architecture

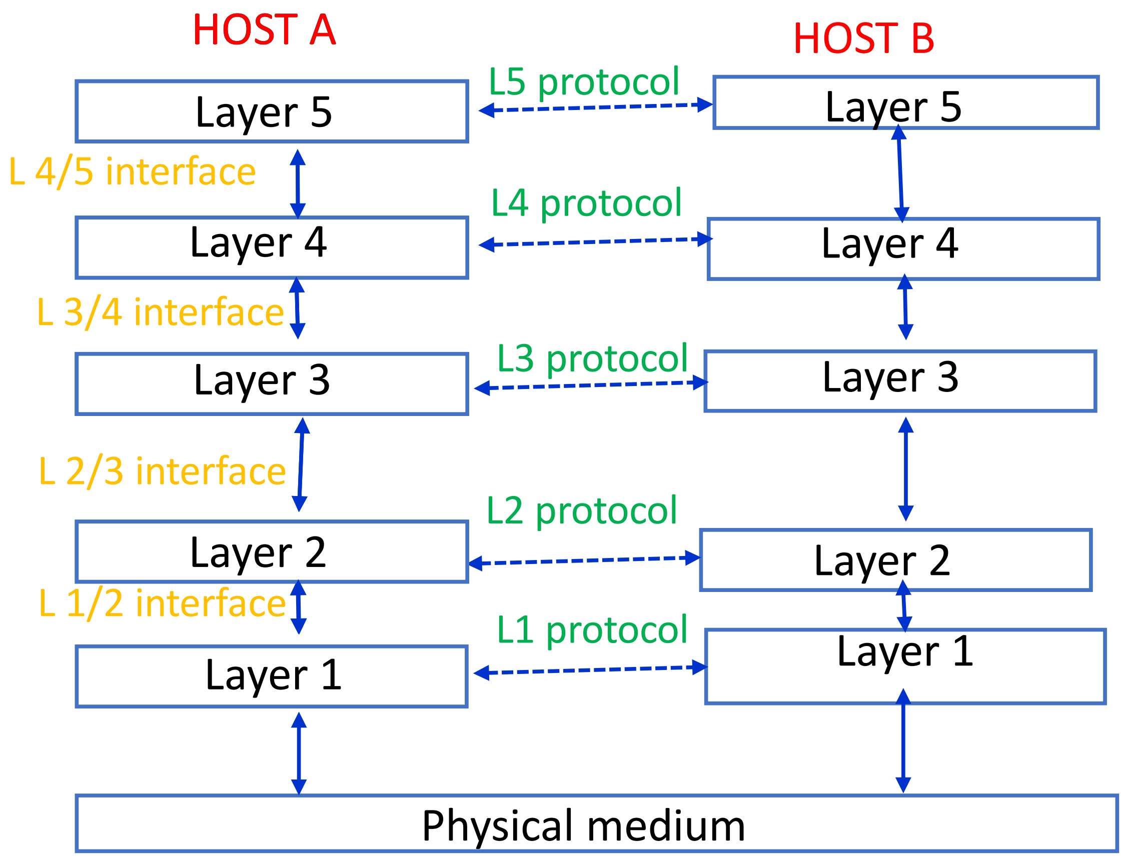
- A network is a combination of hardware and software that sends data from one location to another.
- The hardware consists of the physical equipment that carries signals from one point of the network to another.
- The software consists of instruction sets that provide services that we expect from a network.
- To reduce design complexity, most networks are designed as stack of layers, each one built upon below it.
- A key principle for networking software is layering: the functionality is decomposed into a chain of layers so that layer N offers services to layer N + 1 and itself is only allowed to use services offered by layer N – 1.

The Need for Protocol Architecture

- It takes two to communicate, so the same set of layered functions must exist in two systems.
- Layer N on one machine carries conversation with layer N on another machine.
- The rules and conventions used in this conversation are collectively called layer N protocol.
- A protocol is an agreement between the communicating parties on how communication is to proceed.
- The key features of a protocol are as follows:
  - Syntax: Describes the format of the data blocks
  - Semantics: Includes control information for coordination and error handling
  - Timing: Includes speed matching and sequencing

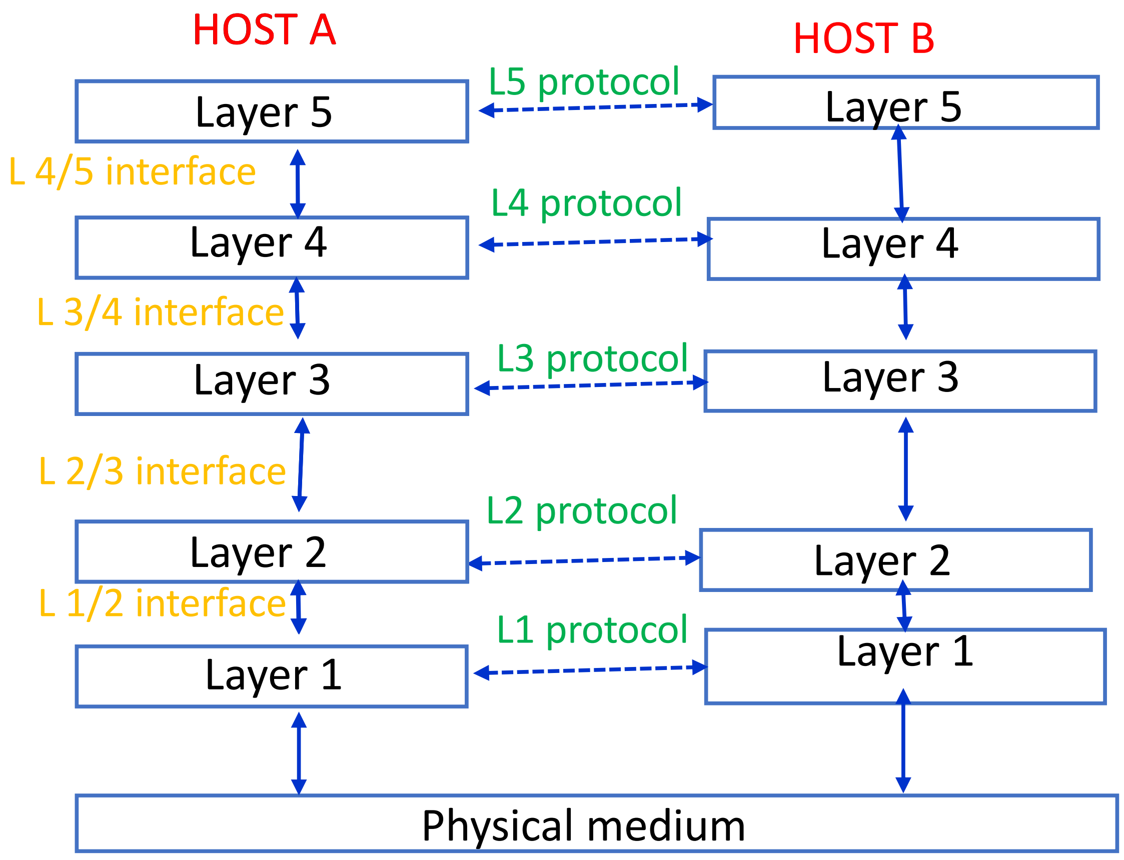
The Need for Protocol Architecture

- No data are directly transferred from layer N on one machine to layer N on another machine.
- Instead each layer passes data & control information to layer immediately below it, until the lower layer is reached.
- Below layer 1 is physical layer/medium through which actual communication occurs.



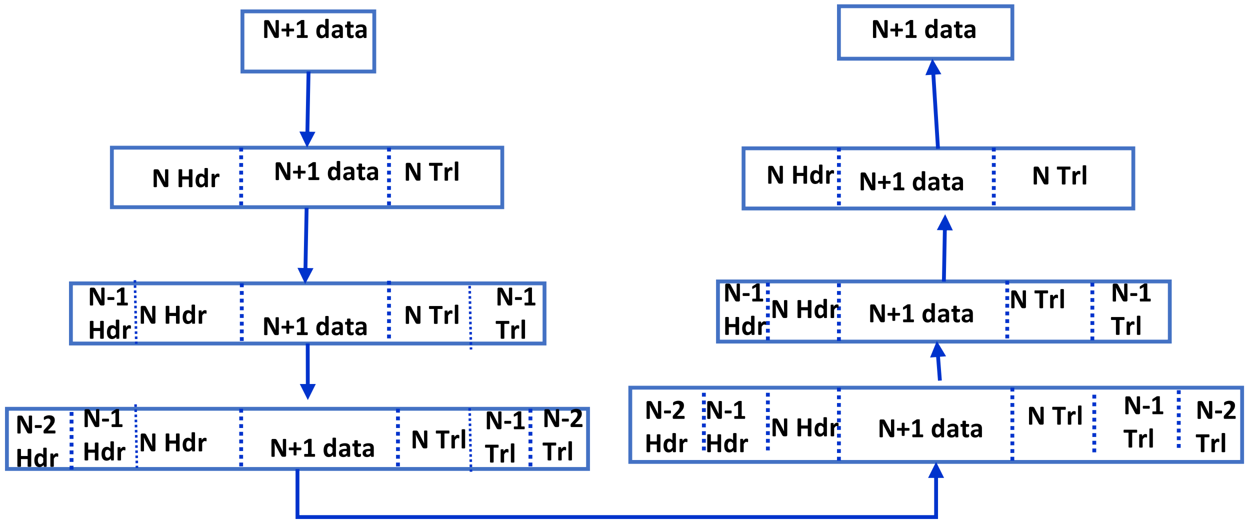
The Need for Protocol Architecture

- Between each pair of adjacent layer is an interface, called N-service interface.
- The N-interface offers services at service access point(SAP),the lower layer makes available to the upper one.
- The N-interface can offer several SAPs, this allows to multiplex between different layer N + 1 connections or sessions.
- The layer N-service is implemented through an N-protocol



The Need for Protocol Architecture

- A layer exchanges protocol data units (PDUs) with a peer N-protocol entity.
- It constructs these PDUs itself and hands them over to its local N – 1-layer to deliver them to peer N-protocol entity.
- An N-PDU is treated as payload / user data by the N – 1 layer.
- Each layer adds own header and trailer before handing down to lower layer.
- Receiving layer removes its header / trailer before handing payload to upper layer.



Design Issues for the Layers

- Some of the key design issues that occur in computer networks are present in several layers. They include:
  - Addressing - Networks have many communicating devices and some of them have multiple processes, therefore a mechanism is needed for a process on one machine to specify with whom it wants to talk i.e. addressing is needed to specify a specific destination in case of multiple destinations.
  - No of logical channels - Many networks provide at least two channels per connection, one for normal data transfer and one for urgent data.
  - Error Control - Both sender and receiver must agree on same set of error detecting and error correcting codes.
  - Sequencing - Reassembling of packets at receiver end that arrive out of order.
  - Flow Control - Avoid overflowing receiver with data from sender.
  - Routing - A suitable route must be chosen when there are multiple paths between source and destination.

Types of Service

- Layers can offer two types of services to the layers above them.
  - Connection Oriented Service – Service user first establishes the connection , uses the connection and then releases the connection. Order is preserved and the data arrives in order. Connection oriented service is modeled after telephone system.

  - Connection Less Service – Each message carries full destination address and is routed through the system independent of all others. Data sent may arrive out of order. Connection less service is modeled after postal system.

Reference Models

- A reference model is a conceptual blueprint of how communications should take place.
- It addresses all the processes required for effective communication and divides these processes into logical groupings called layers.
- Two popular reference models are:
  - OSI Reference Model
  - TCP/IP Reference Model

OSI Reference Model

- OSI (Open System Interconnection) reference model was developed by the International Organization for Standardization (ISO) as a model for a computer protocol architecture.
- The model was not commercially successful, but helped greatly to clarify networking architectures and to provide framework for developing protocol standards.
- OSI model consists of seven layers:
  - Application
  - Presentation
  - Session
  - Transport
  - Network
  - Data Link
  - Physical

Layer 7: Application

Layer 6: Presentation

Layer 5: Session

Layer 4: Transport

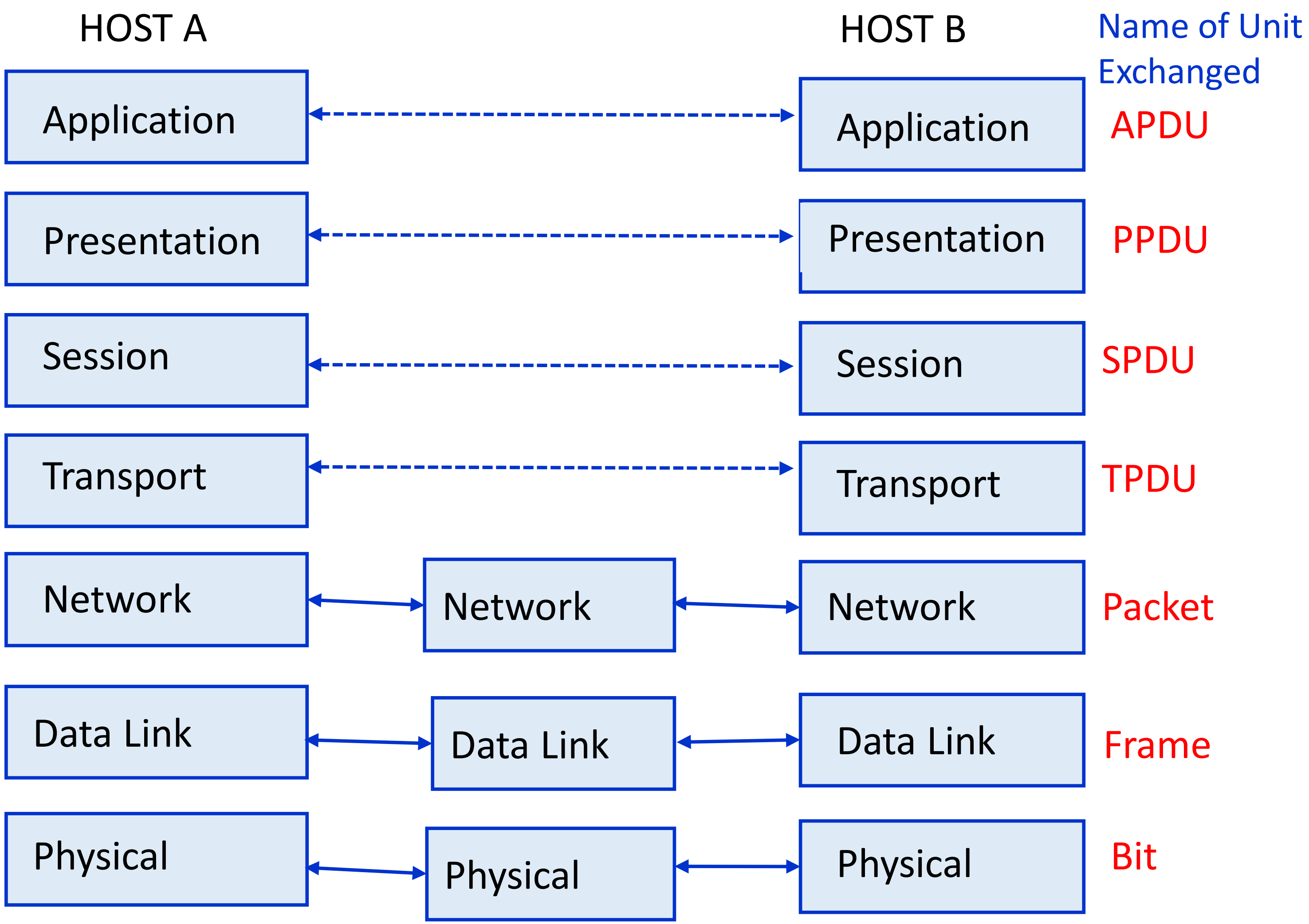
Layer 3: Network

Layer 2: Data Link

Layer 1: Physical

OSI Reference Model

- Layer 1, 2 & 3 exchange PDUs between physically connected hosts.
- Upper four layers exchange protocol messages between end hosts (over several intermediate nodes, called routers)
- Hop by Hop communication is shown by ⟷
- End to End communication is shown by ←------→



OSI RM - Physical Layer

- Responsible for transmission of bits over a physical medium.
- The protocols in this layer are link dependent and further depend on the actual transmission medium of the link (for example, twisted-pair ,copper wire, fiber optics).
- Often involves specification of:
  - Cable types (wired) or (wireless)
  - Connectors
  - Electrical specifications

OSI RM – Data Link Layer

- (Reliable) transfer of messages over physical link .
- The Data Link layer will ensure that messages are delivered to the proper device on a LAN using hardware addresses and will translate messages from the Network layer into bits for the Physical layer to transmit.
- The Data Link layer formats the message into pieces, each called a data frame, and adds a customized header containing the hardware destination and source address.
- Involves specification of:
  - Framing - determining the frame start and end , choice of frame size
  - Error Detection and Correction - coding or retransmission-based
  - Medium access control – control access to shared channel , often considered as a separate "sub-layer" of link layer
  - Flow control - Avoid overwhelming a slow receiver with too much data

OSI RM – Network Layer

- Concerned with:
  - Addressing and routing
  - End-to-end delivery of messages (transmission of data packets between devices that are not locally connected)
- Network layer messages are called packets
- Involves specification of:
  - Addressing formats
  - Exchange of routing information and route computation
  - Depending on technology: establishment, maintenance and teardown of connections

OSI RM – Transport Layer

- Concerned with reliable, in-sequence, transparent end-to-end data transfer.
- Transport layer data packet is called segment.
- The functions of the transport layer are:
  - Break messages into packets and reassemble packets of size suitable to network layer
  - Multiplex sessions with same source/destination nodes
  - Resequencing packets at destination
  - Error Control
  - Provide end-to-end flow control

OSI RM – Presentation & Session Layer

- Session layer:
  - Concerned with establishing communication sessions between applications
  - A session can involve several transport layer connections in parallel or sequentially
  - The Session layer basically keeps different applications’ data separate from other applications’ data.

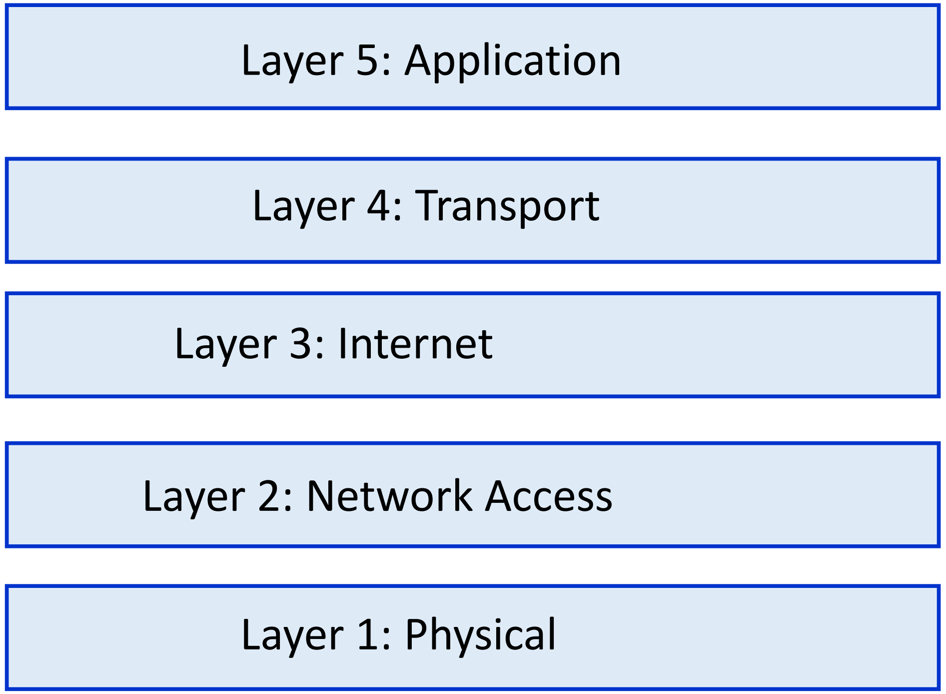
- Presentation layer:
  - Translates between different representations of data types used on different end hosts
  - Example: host A uses low-endian , host B big-endian

OSI RM – Application Layer

- Contains variety of protocols that are commonly needed by users.
- Examples:
  - HTTP(HyperText Transfer Protocol) – for Web document request and transfer
  - SMTP(Simple Mail Transfer Protocol) – for transfer of email messages
  - FTP(File Transfer Protocol) – for transfer of files between two end systems
- Packet of information at the application layer is called a message.
- Focus: Transport Layer and Lower.

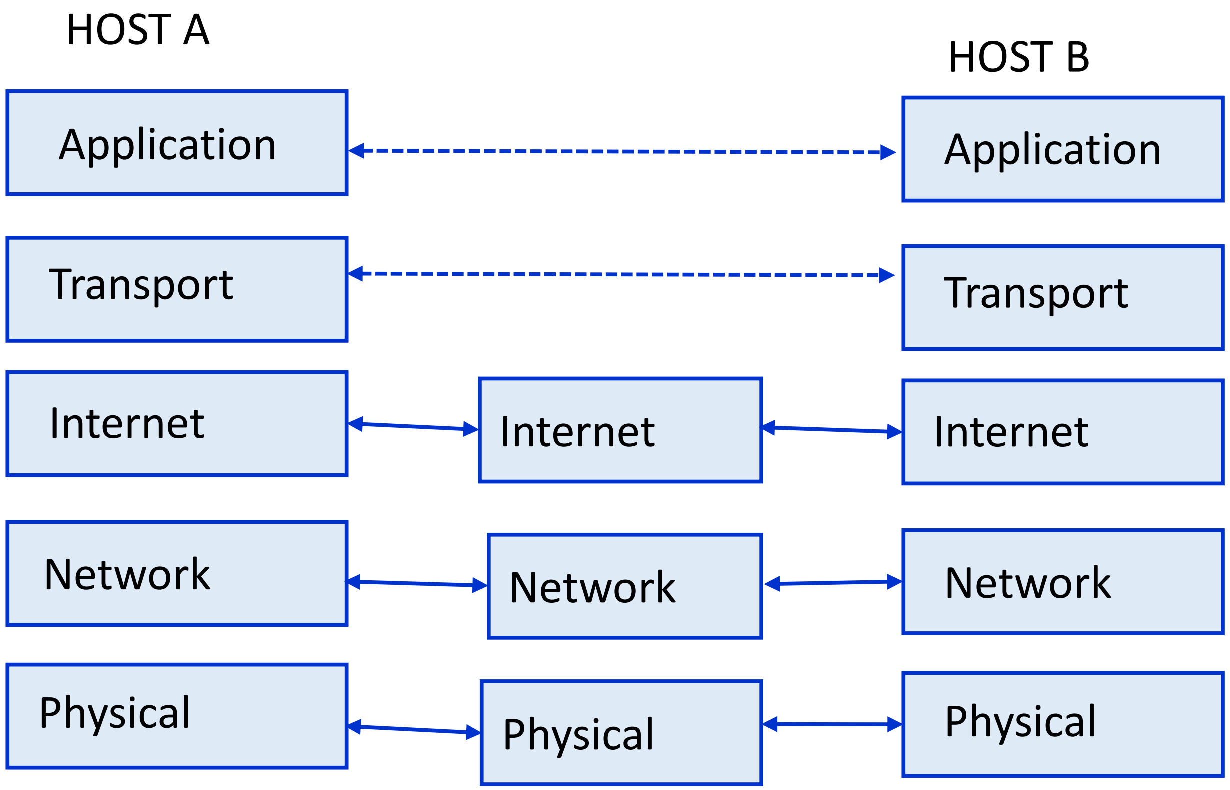
TCP/IP Reference Model

- The TCP/IP protocol architecture is a result of protocol research and development conducted on the experimental packet-switched network, ARPANET, funded by the Defense Advanced Research Projects Agency (DARPA).
- It is generally referred to as the TCP/IP protocol suite.
- This model is used in the Internet.
- TCP/IP model consists of five layers:
  - Application
  - Transport
  - Internet
  - Network Access
  - Physical



TCP/IP Reference Model

- Hop by Hop communication is shown by ⟷
- End to End communication is shown by ←------→



TCP/IP RM – Application Layer

- A vast array of protocols combine at the Application Layer to integrate the various activities and duties spanning the focus of the OSI's corresponding top three layers (Application, Presentation, and Session).
- Accesses transport layer through socket interface
- Well known application layer protocols are:
  - Telnet
  - FTP
  - SMTP
  - HTTP/HTTPS
  - DNS
  - RTP

TCP/IP RM – Transport Layer

- Provides end-to-end communications to applications
- Offers its services through socket interface
- Standard transport layer protocols:
  - TCP: reliable, in-sequence byte-stream transfer
  - UDP: unreliable, un-ordered message transfer
- SAPs are called ports, used for application multiplexing
- Ports are identified by numbers
- Several applications / processes can use transport service
- One application is bound to one port
- The PDUs generated by TCP / UDP are called segments

TCP/IP RM – Internet Layer

- This is a key part of the TCP/IP reference model.
- Uses IP (Internet Protocol), its PDUs are called datagrams.
- IP looks at each packet's address. Then, using a routing table, it decides where a packet is to be sent next, choosing the best path.
- Other protocols found here are:
  - ARP
  - ICMP
  - IGMP
  - RARP

TCP/IP RM – Physical & Network Access Layer

- The physical layer is similar to the PHY of the OSI RM

- The Network Access Layer:
  - Accepts IP datagrams and delivers them over physical link
  - Receives IP datagrams and delivers them to local IP layer
  - Includes medium access control, framing, address resolution
  - May include link layer error and flow control

Encapsulation of Data

- The process of placing data behind headers (& before trailers) of data packet is called encapsulation.
- Application Layer(APDU): Creates application header and places the data (created by application) after the header.
- Presentation Layer(PPDU):Creates presentation header and places the data (received from application layer) after the header.
- Session Layer(SPDU):Creates session header and places the data (received from presentation layer) after the header.
- Transport Layer(Segment):Creates the header and places the data (received from session layer) after the header.
- Network Layer(Packet):Creates the header and places the data (received from transport layer) after the header.
- Data Link Layer(Frame):Creates the header and places the data (received from network layer) after the header and also adds the trailer.
- Physical Layer(Bits):Encodes the signal to transmit the data.

Encapsulation of Data