Chapter 1: Introduction

Some definitions

- **Computer Network**: A collection of autonomous computers interconnected by a technology.

- **Distributed System**: A software system built on top of a network, presenting a single coherent system to users.

- **Transmission types**:

  - When transmission occurs between a single sender and a single receiver in the network, it is known as **unicasting**.
  - When transmission occurs between a single sender and many receiver in the network, it is known as **multicast**.
  - When transmission occurs between a single sender and every receiver in the network, it is known as **broadcast**.

Network Types and Classifications

Point-to-Point Links

Point-to-point links create a **direct connection** between an individual **pair of machines**.

In such networks, messages, which are referred to as **packets**, may need to travel through several intermediate machines to get from the source to the final destination.

- It's possible for multiple routes of varying lengths to exist between the source and destination.
- A crucial aspect of point-to-point networks is finding the most **optimal routes** for data transmission.

Broadcast Networks

In broadcast networks, a **single communication channel** is **shared by all connected machines**.

When a packet is sent, it is **received by every machine** on the network. However, each machine only processes the packets addressed to it.

- **Wireless networks** are a primary example of broadcast links.

Classification of Networks

Networks can be classified based on their **scale** or the **physical distance** they cover. This is a crucial metric because different technologies are employed for networks of different sizes.

Interprocessor Distance	Location	Example
1 m	Same square meter	Personal Area Network (PAN)
10 m - 1 km	Same room, building, or campus	Local Area Network (LAN)
10 km	Same city	Metropolitan Area Network (MAN)

Interprocessor Distance	Location	Example
100 km - 10,000 km	Same country, continent, or planet	Wide Area Network (WAN), The Internet

Personal Area Networks (PANs)

- **Scale**: PANs facilitate communication over a **short range**.

A common application is a wireless network that connects a computer to its peripherals, such as a mouse, keyboard, or printer.

- **Bluetooth** is a popular PAN technology that eliminates the need for cables and simplifies device connection through a master-slave model.
- Other PAN technologies include those used for embedded medical devices and **RFID** in smartcards.

Local Area Networks (LANs)

- **Scale**: A LAN is a **privately owned network** that operates within a **single building** or a **small area** like a home, office, or factory.

LANs are commonly used to connect personal computers and other electronic devices through **wired (Ethernet)** or **wireless (Wi-Fi)** connections.

Metropolitan Area Networks (MANs)

- **Scale**: A MAN is designed to cover an entire **city**.

The most well-known examples of MANs are cable television networks, which are often used in areas with poor over-the-air reception.

Wide Area Networks (WANs)

- **Scale**: A WAN spans a large geographical area, such as a country or a continent.

It consists of:

- **Hosts**: The computers that are connected to the network.
- **Subnet**: The collection of routers and communication lines that carry messages from host to host.
- **Routers**: Devices that forward data packets toward their destination.

Internet

Internet is a **collection of interconnected networks**, it allows communication on different, and often incompatible, networks.

Network Architecture and Models

Layers and Protocols

To reduce design complexity, networks are organized as a **stack of layers**, where each layer offers **services to the one above it** while hiding its own implementation details.

The **interaction** between these adjacent layers is defined by an ***interface***, which specifies the operations the lower layer makes available.

For **communication** to occur between different machines, corresponding layers use a common set of rules known as ***protocols***.

This entire framework, comprising the set of layers and their associated protocols, is known as a ***network architecture***, and the specific list of protocols implemented on a particular system is called its ***protocol stack***.

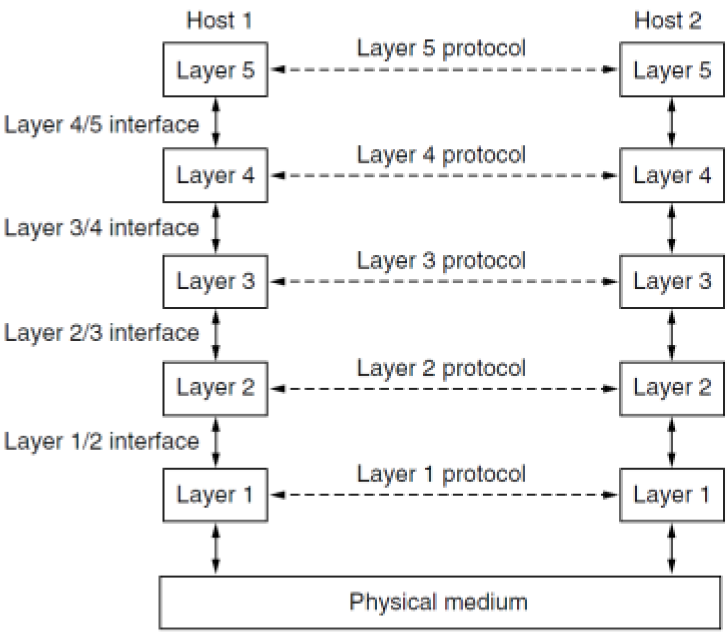


Figure: Example of Layered Network Model

Example of Information Flow

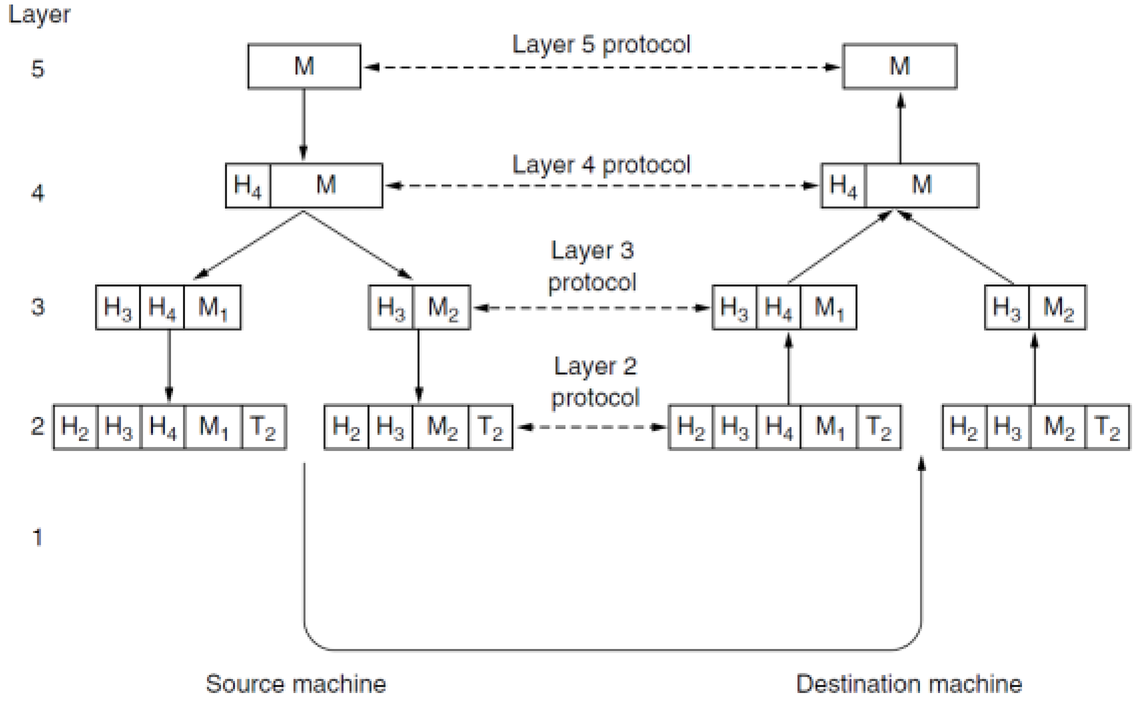


Figure: Example information flow supporting virtual communication in layer 5.

When a message is sent, it travels down the layers of the source machine and up the layers of the destination machine.

1. **Down the source**: At the source, each layer accepts the message from the layer above and adds its own control information.
   - This control information is called a **header**, layer 2 also adds a **trailer**.
   - This process is called **encapsulation**.
2. **Transmission**: The message is then transmitted over the physical medium.
3. **Up the destination**: At the destination, the message moves up the protocol stack. Each layer remove its corresponding header before passing the message to the layer above.

This layered approach, known as the **peer process abstraction**, simplifies network design by breaking the problem into **smaller, manageable parts**.

Design Issues for Layers

Several key design issues must be addressed in layered networks:

- **Reliability**: Ensuring the network operates correctly despite having unreliable components.
  - Often through ***error detection*** and ***correction*** techniques.
- **Routing**: Determining the **best path for data** to travel from source to destination.
- **Addressing/Naming**: A mechanism to **identify senders and receivers**.
- **Resource Allocation**: Managing network resources to prevent interference between users.
  - **flow control**: preventing a fast sender from overwhelming a slow receiver.
  - **congestion control**: managing network overload.

The OSI Reference Model

The **OSI (Open Systems Interconnection) Model** is a conceptual framework that standardizes the functions of a telecommunication or computing system in seven distinct layers.

1. **Physical Layer**: **Transmits** raw bits over a communication channel.

2. **Data Link Layer**: Takes the raw bitstream from the Physical Layer and transforms it into a **free of *undetected* errors** communication line for the Network Layer above it.

    - Key functions:
        - **Framing**: **Grouping bits into frames** with defined start and end points.
        - **Error Control**: Adds **checksums** to detect (and sometimes correct) frames damaged during transmission.
        - **Flow Control**: Prevents a fast sender from overwhelming a slow receiver on the same link.
        - **Medium Access Control (MAC)**: Determines which device gets to use the shared medium at any given time (e.g., who gets to "talk" on the Wi-Fi channel).

3. **Network Layer**: Responsible for the end-to-end delivery of packets across multiple networks or "hops."

    - **Key Functions**:
        - **Logical Addressing**: Assigns **unique addresses** (like IP addresses) to hosts on the network.
        - **Routing**: Determines the **best path** to forward packets from source to destination through a series of routers.

4. **Transport Layer**: Ensures that data pieces arrive **correctly** (in the right order, without error or duplication) at the destination.

    While the Network Layer gets packets to the correct computer, the Transport Layer ensures the data gets to the **correct application** on that computer.

    - **Key Functions**:
        - **Segmentation and Reassembly**: Breaks large messages into smaller segments for transmission and reassembles them at the destination.
        - **Service-Point Addressing (Ports)**: Manages port numbers to deliver data to the correct application.
        - **Connection Control**: Can provide connection-oriented (like TCP) or connectionless (like UDP) services.
        - **Reliability**: Can ensure data arrives in order, without errors, and with no loss or duplication.

5. **Session Layer**: Allows users on different machines to establish sessions between them.

6. **Presentation Layer**: Concerned with the syntax and semantics of the information being transmitted.

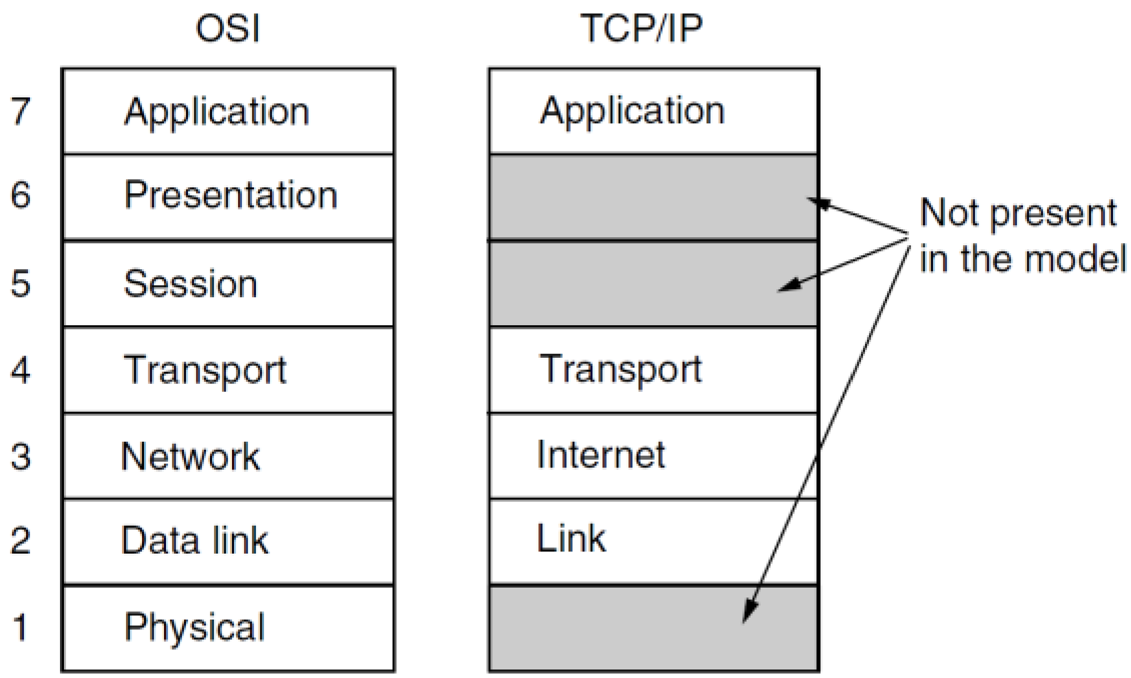
7. **Application Layer**: This layer ensures that data sent by one system is readable by the destination system and to the end user.

The TCP/IP Reference Model

The TCP/IP model is another layered framework that is more practical and widely implemented than the OSI model. Its strength lies in its protocols. It consists of four layers:

1. **Link Layer**: Describes what happens on the physical link (e.g., Ethernet, 802.11).
2. **Internet Layer**: This layer's job is to permit hosts to inject packets into any network and have them travel independently to the destination. It uses the **Internet Protocol (IP)**.
3. **Transport Layer**: Provides end-to-end communication, using protocols like **TCP (Transmission Control Protocol)** and **UDP (User Datagram Protocol)**.
4. **Application Layer**: Contains all the higher-level protocols (e.g., HTTP, SMTP).

The Session and Presentation layers from the OSI model are not present in the TCP/IP model.



Our Reference Model

For the purpose of this course, a hybrid 5-layer model is used, which combines aspects of the OSI and TCP/IP models:

1. **Physical Layer**: Transmits bits as signals over a medium.
2. **Link Layer**: Handles messaging between directly connected computers (e.g., Ethernet).
3. **Network Layer**: Manages packet delivery between distant computers across multiple links (IP).
4. **Transport Layer**: Provides delivery abstractions for applications (e.g., TCP, UDP).
5. **Application Layer**: Includes the network programs themselves.