ECE 333: Introduction to Communication Networks
Fall 2001

Lecture 2: Network Architectures

- Layering

  Motivation

  Terminology

  Examples

Many issues to address in networks:

> Addressing, connection setup, code conversion, message segmentation, routing, flow control, scheduling, multiplexing, medium access, ordering messages, framing, error control, synchronization, encoding, multiplexing, security, billing, compression, …

⇒ Very complex systems!

How to deal with this complexity?

Modularity

Useful method for dealing with complexity is by using ***functional modularity.***

- Break complex problem into simpler sub-problems.
- Use "black box" abstraction of sub-problems.

Example:

Computer --- Processor, memory, bus,…
Processor --- Control unit, arithmetic unit, I/O unit,…
Arithmetic unit --- Adders, accumulators, …

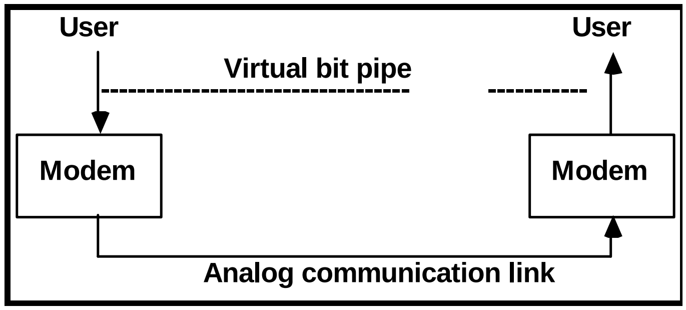
Hierarchical Layering – a type of functional modularity useful in communication networks.

Network functions are viewed as sequence of layers.

Example: Post office

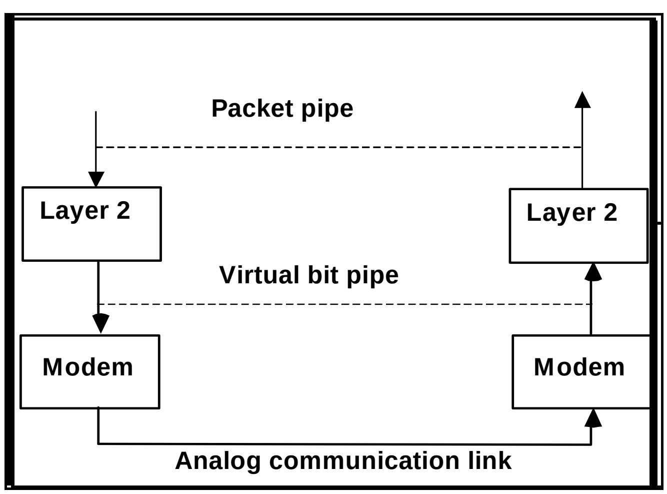
Another Example:

Modem/analog link/modem can be viewed as a "vitrual bit pipe".



The modem/link/modem is **lower layer**; it provides a ***service*** to **higher layer** users.

Higher layers ⟶ more abstract level of service.



Notes:

Slide 1: By "network architecture", we mean a global view of the network that describes how the various operations are organized.

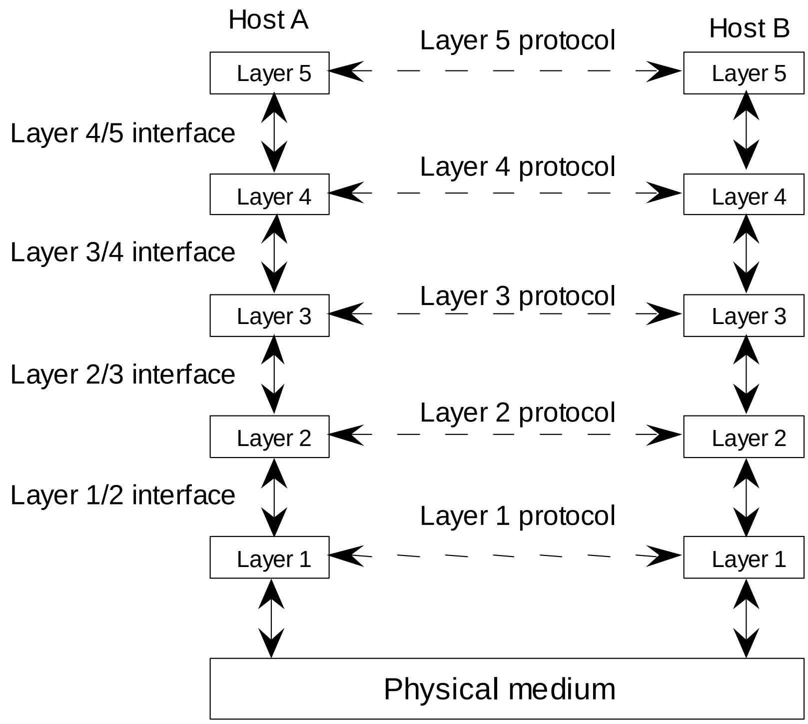
Slide 5: The service offered by the modem-link-modem can be described as a "bit pipe"; more detailed characteristics of this service may include specification of the transmission rate, the error rate, the delay, etc.

Side 6: Two interesting characteristics about layered architectures in data networks are (1) the systems that implement the services at each layer are ***distributed*** and (2) to implement the services, these systems must communicate over unreliable links with delays.

Terminology

- **Peers or peer processes**:
  Members of the same layer at different locations.
- **Protocol:**
  Set of rules for how peers interact.
- **Service:**
  Function performed by layer N for layer N+1.
- **Service Interface:**
  Rules for communicating about services.
- **Protocol Stack:**
  The set of protocols used (one per layer)
- **Network Architecture or Network Reference Model:**
  The set of layers used for a network

Example



Advantages:

Important: separate interface specification from protocols.

1. Rapid evolution

2. Compatibility

Notes

At a given layer, "users" generally only care only about what the underlying system does, not about how it does it. Standardizing what the system does allows the implementation to change while the users get the same service. With this standardization, users can change their systems without worrying about the underlying system. This allows overall systems to evolve very rapidly, while interface standards change slowly. Also allows multiple vendors to offer compatible products.

Standardization of a layer consists of two parts:

1) A standard protocol for the peer processes (entities) at that layer to interact in performing their function. (This assumes the virtual facilities provided by the lower layers).

2) A standard interface (hardware or software) with the next higher layer. This also specifies the input/output behavior. (The interface with the next lower layer is specified by the lower layer.)

The standard interface is critical. This is essential for networks to evolve.

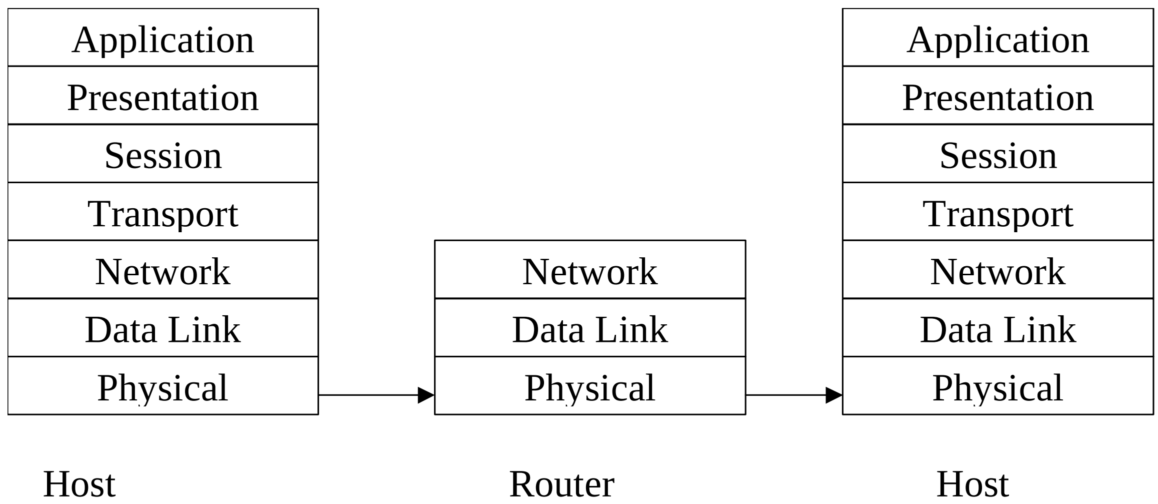
OSI Reference Model

OSI (Open Systems Interconnect) model -
developed by the ISO. (1977-1984)

Application
Presentation
Session
Transport
Network
Data Link
Physical

Several protocols based on these standards – X.21, X.25, Tymnet.

OSI protocols



Physical Layer

Service: "Virtual bit pipe"

Design issues:

- Specifications of connectors
- Modulation/coding
- Protection switching, link restoration
- Bit level synchronization

Data Link Layer

Service: "virtual link for reliable packets".

Design issues

- Framing
- Error Control
- Medium access (sub-layer)

Network Layer

Service: "(virtual) link for end-to-end packets"

Design Issues:

- Addressing
- Routing
- Congestion Control

Each node contains a network layer peer and one DLL peer per port.

All network layer peers in the network must work together.

Transport Layer

Service: "end-to-end message service."

Issues:

- Connection management
- Service class
- Message fragmentation and reassembly
- Multiplexing
- Error Control
- Congestion Control

Session Layer

Service: "end-to end sessions"

- "Directory assistance", Access rights

Presentation Layer

Service: "data representation".

- Code conversion, Data compression, Encryption

Application Layer

Service: "End-to-end applications"

- Ex's: e-mail, file transfer, remote login.

The OSI reference model only specifies the services at various layers and the interfaces, not the protocols that implement these services.

The data link and physical layers are usually implemented in network interface cards, the higher layers are implemented in software, the network and transport layers are often part of the operating system

Standardization has not proceeded well at the Session and Presentation layers. The modern view is to view these functions as “middleware”, i.e. standard functions that an operating system can provide as an aid to applications.

Protocols based on OSI have not been widely used and it has certainly not become the universal network architecture that is creators envisioned. The importance of these protocols lies in that it was one of the first efforts at formally considering network architecture. The general idea of a layered architecture has been universally accepted, and the idea of distinguishing the interface specification from the protocol is also widely accepted - these concepts are due in part to the ISO effort.

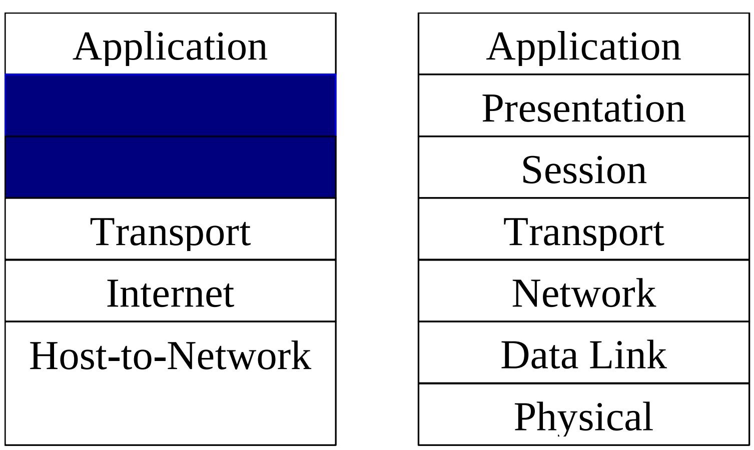
Some reasons for OSI’s failure include:

The growth of LANs and internets was not foreseen.
The complexity of the standards was not foreseen.
The short lifetime of standards was not appreciated.
TCP/IP

TPC/IP REFERENCE MODEL

Used in the Internet and many intranets.

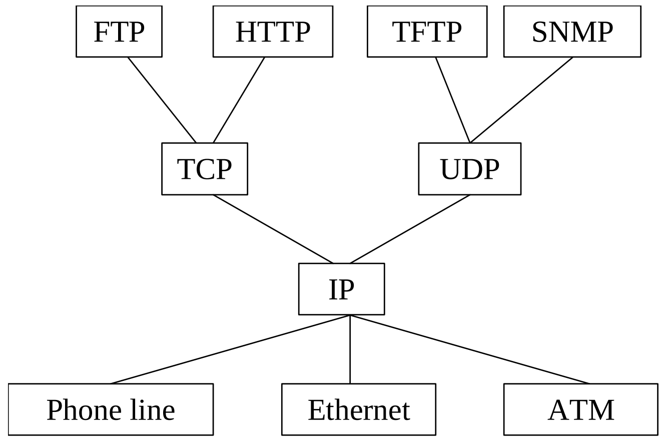
Originally developed for the ARPANET in mid-1960s.



TCP/IP OSI

- Architecture evolved with implementation.

Common TCP/IP protocols:



Notes:

The transport and Internet layers of TCP/IP have similar functions to those in the OSI model. The principle function of the transport layer is establishing host-to-host communication. There are two main transport layer protocols, TCP and UDP, these offer different services to the application layer. TCP offers a "reliable" service and implements flow control, UDP is a bare-bones transport service.

The Internet layer is similar to the OSI network layer. Addressing and routing are addressed here. There is one main Internet layer protocol, IP. This layer provides unreliable packet delivery to the transport layer.

The host-to-network layer is not really specified in the TCP-IP reference model. The only requirement on this layer is that it be able to carry IP packets. This is essentially the functionality of the OSI data link layer. These services may be provided by a point-to-point direct link or by a dial up line through the telephone network or by a connection through an ATM network or by a series of Ethernet LANs.

In modern networks, layers often no longer run in consecutive order - Multiple layers in one network can telescope down and appear as a lower layer to higher network.

For example, the telephone network uses physical lines (L1), multiplexers (L2) and cross connects (switches (L3)) to provide physical lines to connect ATM switches. ATM switches uses these leased lines as L1 services, adds framing (L2), switching (L3), fragmentation and reassembly (L4) to provide a variable bit rate data link to connect routers. IP Routers use these data links as the basis for its packet routing (L3)

Standards

"*The nice thing about standards is that there are so many to choose from*."

Types of standards:

de facto - from the fact

de jure - by law

Organizations:

§ ITU-T
§ ISO
§ IEEE
§ Internet Society
§ ATM Forum

Notes:

The ITU-T (International Telecommunication Union - Telecomm sector) is an agency of the UN. Voting members of the ITU-T are government representatives of member nations of the UN. These representatives are often associated with national telecommunication authorities, such as nationalized telephone companies, in countries where such bodies exist. In the US, the representative comes from the State Department. ITU-T was previously known as CCITT. Notable ITU standards include X.25, ISDN and ATM. ITU recommendations must have unanimous approval.

ISO (International Standards Organization) is a voluntary organization of national standards bodies; the US member is ANSI (American National Standards Institute). ISO was responsible for the OSI architecture.

IEEE (Institute of Electrical and Electronic Engineers) is a professional organization. It was responsible for developing the 802 standards for LANs. See http://standards.ieee.org/

The Internet Society is also a professional society of researchers that oversees a number of boards responsible for the development of the Internet, including the IETF (Internet Engineering Task Force) and the IAB (Internet Architecture Board). See http://www.isoc.org/.

The ATM forum is an international non-profit organization, funded by corporations interested in accelerating the development of ATM technology.