SE 4C03 Winter 2001

03. The Internet Model and TCP/IP

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The Internetworking Problem

- How can communication be performed across different physical networks, possibly based on different network technologies?
- Possible solutions:
  - Standardization
  - Universal physical network
  - Universal virtual network

The OSI Model

- In 1977 the International Standards Organization (ISO) offered the **Open Systems Interconnection Reference Model (OSI Model)** to facilitate communication between different physical networks
- Seven layer framework:
  1. **Physical layer.** Physical hardware level.
  2. **Data link layer.** Frame delivery in a physical network.
  3. **Network layer.** Packet delivery across physical networks.
  4. **Transport layer.** Message delivery.
  5. **Session layer.** Dialog control.
  6. **Presentation layer.** Data representation control.
  7. **Application layer.** Service level.

Universal Physical Network

- There are many different networks based on different technologies and for different purposes
  - No single network technology is the best for all purposes
- A universal physical network is not possible
  - Different hardware requirements (e.g., short vs. long distance)
  - Legacy networks
  - Multiple political entities involved

Universal Virtual Network

- Need an **virtual network** which allows communication across heterogeneous networks
  - Should provide universal service
  - Should be an **open system** with publicly available specifications
- An **internet** is a virtual network built based on:
  1. The **internet architecture**
  2. The **TCP/IP Internet Protocol Suite**
- The global **Internet** is an internet that serves as a **universal virtual network**

Internet Architecture

- The **internet architecture** consists of:
  - A set of physical networks
  - Routers that connect the networks to each other
- An internet has the structure of a **bipartite graph**:
  - Two kinds of nodes:
    1. **hosts** (including routers)
    2. **single physical networks (SPNs)** (e.g., an Ethernet or ATM network)
  - Edges: **network interfaces**

An SPN is a Fluid Notion

- A router may be considered part of an SPN (i.e., transparent router)
- A collection of serial connections to a router may be considered an SPN
- A collection of SPNs may be considered an SPN

TCP/IP

- The **TCP/IP Internet Protocol Suite** consists of a set of **communication protocols** for communicating across the interconnected physical networks
- TCP/IP enables communication across any set of interconnected networks
  - Hardware independent
  - Universal interconnection
  - End-to-end orientation

Communication Protocols

- A **communication protocol** is a specification of a procedure for transferring information
- Ingredients:
  - Message formats
  - Rules for exchanging, sequencing, and interpreting messages and for detecting and correcting errors
- Different communication protocols can be at different levels of abstraction

Internet Services

- The purpose of an internet is to provide useful services to users on the component networks
- Each service is specified by a communication protocol
- Network-level internet services:
  - Connectionless packet delivery (via IP)
  - Reliable stream transport (via TCP)
- Application-level internet services
  - Electronic mail (via SMTP)
  - File transfer (via FTP or SSH)
  - Remote login (via Telnet or SSH)
  - World Wide Web (via HTTP)

History: ARPA

- The U.S. Department of Defense's **Advanced Research Projects Agency (ARPA)** started funding research in internet technology in the 1970s
  - Lead to the creation of the **ARPANET**
- The global, TCP/IP-based Internet started about 1980 with the ARPANET as the backbone
  - Used mainly to support U.S. military communication and university research

History: Berkeley Unix

ARPA funded a low-cost implementation of TCP/IP built on top of the Berkeley Software Distribution (BSD or Berkeley UNIX)

- Included a set of useful utilities based on TCP/IP in the Unix style
- Offered the abstraction of the **socket** to allow application programs to interface with communication services
- Allowed internet technology to quickly spread across the U.S. research community

History: NSF

- The U.S. National Science Foundation (NSF) started funding research in the mid-1980s to expand the Internet
  - Funded a new backbone for the Internet called the **NSFNET**
- During the late 1980s and 1990s Internet grew at a phenomenal rate in North America and Europe

History: Internet Society

- About 1990 the U.S. government gave up control of the Internet
  - No entity owns TCP/IP
  - The Internet Society (ISOC) promotes the use and guides the development of the Internet
- Technical oversight and standardization for the Internet and TCP/IP are set by ISOC's **Internet Architecture Board (IAB)**
  - Provides Internet and TCP/IP documentation in the form of a series of technical reports called **Requests for Comments (RFCs)**

The Internet Model

- Component physical networks cooperate to form a virtual network called an **internet**
  - All component networks are equal (**Uniformity**)
  - Component networks can be added to existing internets, and smaller internets can be combined to form bigger internets (**Scalability**)
- Any two hosts on an internet can communicate with each other (**Universal Connection**)
- Interconnection is performed at the network level instead of at the application level (**Interconnection Abstraction**)
- Two networks are interconnected via a computer called an **internet gateway** or **internet router** (**Network Interconnection**)

The TCP/IP Internet Layering Model: Application Layer

- Corresponds to the Session, Presentation, and Application Layers of the OSI Model
- Application programs access services across an internet
- Uses application software
- Example protocols: SMTP, Telnet, SSH Shell, FTP, HTTP

The TCP/IP Internet Layering Model: Transport Layer

- Corresponds to the Transport Layer of the OSI Model
- Transmits messages from a client process to a server process
- Messages are converted into streams of **packets**
- Uses operating system software
- Uses **ports** for addressing packets
- Protocols: UDP, TCP

The TCP/IP Internet Layering Model: Internet Layer

- Corresponds to the Network Layer of the OSI Model
- Transmits packets from a source host to a destination host
- Packets are encapsulated in **datagrams**
- Uses operating system software
- Uses **IP addresses** for addressing
- Protocols: IP, ICMP, routing protocols

The TCP/IP Internet Layering Model: Network Interface Layer

- Corresponds to the Data Link Layer of the OSI Model
- Transmits datagrams from a source network interface to a destination network interface
- Datagrams are encapsulated in **frames**
- Uses device driver software
- Uses **physical addresses** for addressing
- Protocols: ARP, RARP

The TCP/IP Internet Layering Model: Hardware Layer

- Corresponds to the Physical Layer of the OSI Model
- Transmits **communication signals** over an SPN
- Uses network hardware

The TCP/IP Internet Layering Model: Notes

1. All the layers except for the hardware layer are conceptual
2. Error detection and recover is performed at the higher layers
3. Intelligence is placed in the hosts, not in the physical networks
4. **Protocol Layering Principle**: The communication object received by layer n at the destination is exactly the same object sent by layer n at the source
5. Advantage of layering: clarity
6. Disadvantage of layering: efficiency