COMP 225: Network and System Administration
Notes #6: Internetworking

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Topics

- Networking models and the Internet
- International Standard Organization
- Layered architectures

Some Definitions

- **Computer network**: a collection of computers that are connected in such a way that data can be exchanged among any two computers
- **Intranet**: within an enterprise, a collection of networks that are mostly interconnected by ***switches*** and/or ***routers***
- **Internet**: a world wide internetwork operates with different IP-based (Internet Protocol) technologies, standardized through the Internet Administration Board (IAB), and a multitude of low-level (e.g., hardware level) communication technologies

Why Internetworking?

- Standalone computing devices might have limited usefulness
- Solution: networking and internetworking
  - Interconnecting and collaborating numerous units for communications and offer better service solutions

An Internetwork

- No single networking technology best for all needs:
  - Heterogeneity is inevitable;
  - With heterogeneous network technologies, come different types of physical network designs
  - Create protocol standards to make resulting system ubiquitous
  - With recommended **standards**, the resulting networks created is the ***Internet***

Benefits of Computer Networks

- Resource Sharing: include hardware devices such disk storage and printers and software (data + programs)
- Higher Reliability: obtained by duplicating devices and replicating data
- Incremental and cheaper growth
- Distributed processing: client/server applications (e.g. web browser/web server) and clustering
- Promote communication among network users through resource sharing and e-mail

Design Goals of Networking

- Two computers exchange data with the scenarios such as
- They may be located in the same room or separated by thousands of miles
- They are from different manufacturers and run different operating systems
- They may use different byte/bit ordering in multi-byte data and may use different character encodings for text data
- Design must allow for continuing use of existing technology while embracing new technology

Organizations for the Internet

- **IAB** (Internet Architecture Board) – manages ISOC (Internet Society)
- **IETF** (Internet Engineering Task Force) – standards creation body under ISOC
  - The RFC Editor, IESG (Steering Groups) and IETF Working Groups are responsible for reviewing and publishing new standards
- **ICANN**: Internet Corporation for Assigned Names and Numbers
  - For IP address space allocation, protocol parameter assignment, domain name system management, and root server system management functions
  - **IANA**: Internet Assigned Number Authority - information on domain names and application numbers
- **InterNIC**: Keeps information about domain-name registration

Request for Comments (RFCs) at IETF

- IAB maintains a list of RFCs for different protocol suites
- Possible assigned protocol states: Standard, Draft Standard, Proposed Standard, Experimental, Informational, Historic
- Possible protocol status: Required, Recommended, Elective, Limited Use, Not Recommended
- Freely Available: https://www.ietf.org
- New protocol proposals presented through *Internet Drafts (IDs)*
- A thoroughly reviewed ID can become an RFC, or
  - Update or obsoleted (when a new RFC number issued for it), or
  - Simply disappeared if no updates or failed to become RFC

Some Internet Standards

When a protocol is standardized, it is assigned a *Standard Number (STD)*, with references associated RFCs

Very important Internet standards, e.g.:

- STD 1 -- Internet Official Protocol Standards
  - State and status of each Internet protocol or standard
  - Issued by the IAB approximately quarterly
- STD 2 -- Assigned Internet Numbers
- STD 3 -- Host Requirements
- STD 4 -- Router Requirements
  - Requirements for IPv4 Internet gateway (router) software
  - RFC 1812 -- Requirements for IPv4 Routers

Standards and Protocols

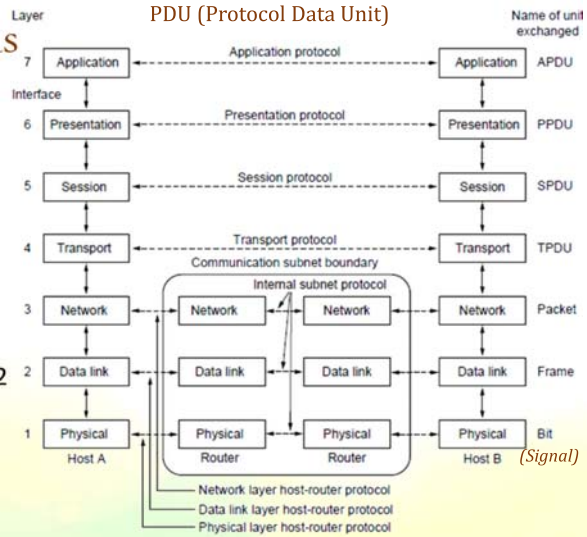
- A standard is an agreed-upon specification for some types of product or service
  - Examples: A4 paper size, 2-feet florescent light, serial (RS-232C) and parallel port interfaces
- A protocol is an agreement (contract) between two (or more) parties to conduct a joint task
  - Examples: two persons handshaking, traffic light

The Beginning of the Internet

- The Advanced Research Projects Agency Network (ARPANET), by the US Department of Defense, was the precursor to today's Internet
- In 1969, ARPANET interconnected the University of California Los Angeles (UCLA), the Augmentation Research Center at Stanford Research Institute (SRI), the University of California Santa Barbara (UCSB), and the University of Utah
  - FYI, Prof. Leonard Kleinrock at UCLA is an associate with School of Applied Sciences at MPI
- The University of California at Berkeley (UCB) incorporated the TCP/IP software protocol in their BSD Unix
- Nowadays, ubiquitous across the Earth planet

International Standards Organization

- ISO – another international standard organization
  - Mainly for telecommunication standards
- OSI (Open System Interconnection) 7-layered model
  - ISO layer 2 can be divided into 2 sublayers
  - LLC (logical link control)
  - MAC (medium access control)



Principles of Layering

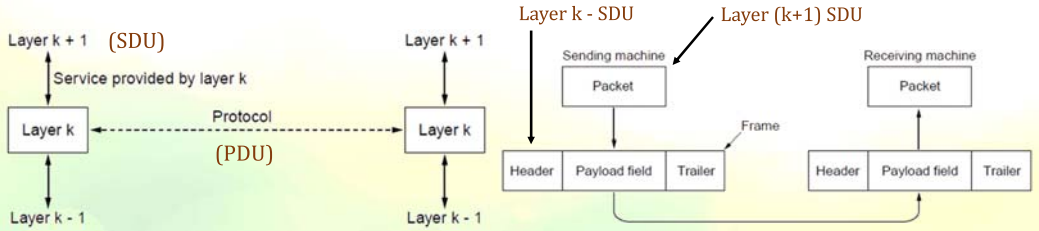
- Each layer should represent a different abstraction level, wherever needed
- Each layer should define well defined functions
- Information flow between layers should be minimum
- Number of layers should be optimum, not too many not too few

Principles of Layering (cont'd)

- Layered Protocols are designed such that the ***layer n at the destination*** receives exactly the same object sent by the ***layer n at the source***
- Protocols are standards that specify how data is represented when being transferred from one machine to another
- Protocols specify how the transfer occurs, how errors are detected, and how acknowledgements are passed

Interface Services between Layers

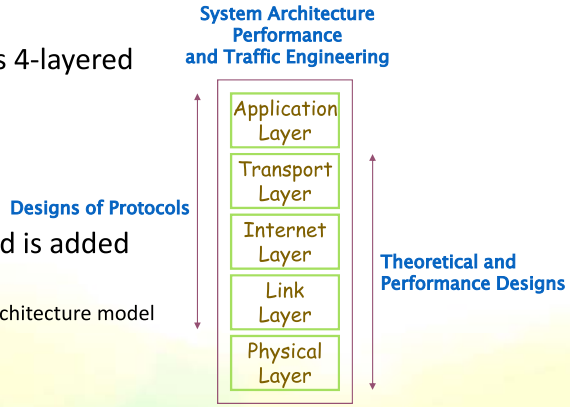
- Encapsulation
  - Data sending down the protocol stack
  - Each layer adds to the data by prepending headers
  - Only the layer 2 SDU, trailer is appended; and layer 2 SDU is generally called "frame"



SDU (Service Data Unit)

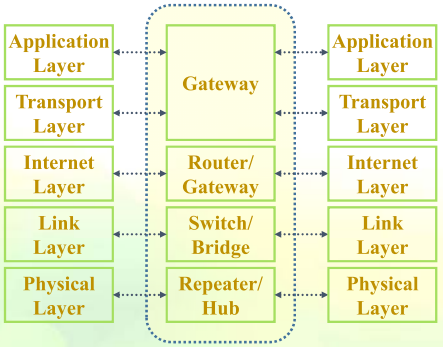
5-Layered TCPIP Model for the Internet

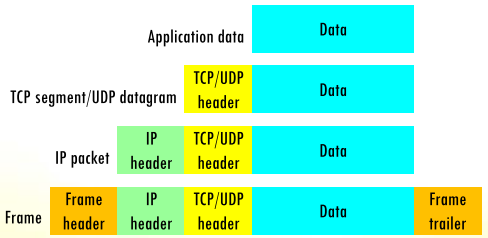
- Originally, the Internet model is 4-layered
  - Application
  - Transport
  - Internet ≡ ISO's Network Layer
  - Link ≡ ISO's Data Link Layer
- For completion, physical layered is added
  - The 5-layered model
    - The generally accepted Internet architecture model



Device Components and Packet Naming

- "Packet" sometime is a generic term used across the layers





Physical Layer

- Interfaces translated upper layered frames into analog signals over the physical medium channel
  - Channel coding – signal streams belong to different users or organizations
  - Different protocols have different channel coding designs, e.g., OFDM (Orthogonal Frequency Division Multiplexing)
  - Channel capacity (bits/second) is associated with the Shannon Theorem
  - Signal modulation and demodulation – specifies bit to signal encoding such as voltage levels and duration for bit 0 and bit 1

Types of Networks

- Body/Personal area networks (BANs/PANs)
- Local-area networks (LANs)
- Metropolitan-area networks (MANs)
- Wide-area networks (WANs)
- The classification could be based on
  - Geographical area?
  - Number of users?
  - Number of computing devices?
  - Equipment cost?
  - Etc.

Typical Classification of Networks by Distance

1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

The TCP/IP Model

- TCP/IP (Transmission Control Protocol/Internet Protocol)
- TCP/IP is the common name of the protocol suite used on the Internet
  - Simpler than ISO-OSI Model
  - Provides an elegant solution to world wide data communication
  - The TCP flow control designs were successful disregard the amount of traffic jamming a connection (started by Van Jacobson)
  - Majority of the wireline protocols used TCP and IP protocols
  - Applications interface with TCP layer to communicate with other peer applications

The TCP/IP Model (cont'd)

- Some newer wireless technologies for IoT less likely adopt TCP today
- IETF are open standards, freely available, and independent of any hardware platforms

TCP/IP Features

- Work independent of any network hardware
  - TCP/IP works on many types of networks (Ethernet, Token Ring, X.25, dial-up)
  - TCP/IP works independent of the scales of the networks: LANs, WANs, etc.
- A common IP addressing scheme
  - Every host on the Internet has a unique address
- Standardized high-level protocols for world wide available network services

Network Communication Protocols

- Generally, a **network communication protocol** (at the application or lower layers) specifies the format and meaning of messages that are exchanged between two peer entities at the same layer
- A network protocol specifies the control header and its interpretation
- Examples:
  - **Application Layer Protocol**: HTTP is used between web browser and server
  - **Network Layer Protocol**: Internet Protocol (IP)
  - **Data Link Layer Protocol**: Point-to-Point Protocol (PPP) - used between two routers connected by phone lines

Link Layer

- Through the network address to frame address mapping, this layer encapsulates an incoming **packet** into a new **frame**, and sends it through a specific outgoing port/link
- A transmitted frame is
  - Usually appended with a trailer which contains checksum for quick error detection
  - Delimited with start and end markers (block of bits)
- Channel access control and frame retransmissions may be carried out due to corruption or frame loss, especially, over shared media or broadcast channels

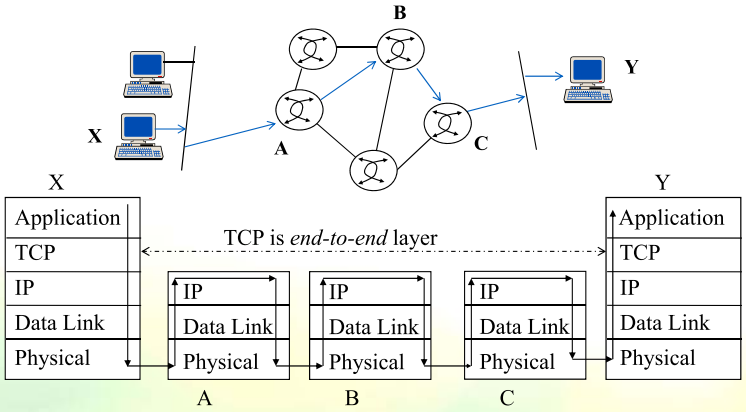
Link Layer – MAC Standards and Technologies

- Ethernet is the most widely used wired hardware
  - 802.3 standard: CSMA/CD (Collision Sense Multiple Access/ Collision Detect)
  - Ethernet was a shared wire technology developed originally as 1 or 10 Mbps by Digital, Intel and Xerox
  - 100 Mbps, 1 Gbps, 10 Gbps Ethernet cards widely available
  - 60 Gbps card is being developed today
- WiFi is the most widely used wireless interface
  - Modelled on Ethernet, WiFi is IEEE 802.11 standard: CSMA/CA (CA: Collision Avoidance)
  - Bandwidth for wireless links expands rapidly recently

Internet Layer

- All hosts (are supposed) to have unique Internet Protocol (IP) addresses on Earth
- IP enables end-to-end connections from sources to destinations through IP routing
- Routing of packets over the Internet
- The layer encapsulates incoming TCP segments into a new IP packet
- Provides software abstraction independent of communication hardware (addresses at link layer are usually permanently fixed in hardware, network layer address are dynamically configured through software)

IP-Layer Packet Routing



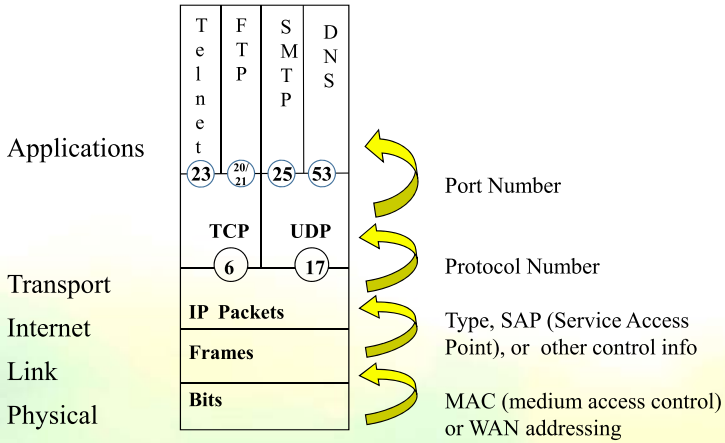
IP Layer – Summary

- Heart of TCP/IP
  - Provides basic packet delivery service on which TCP/IP networks are built
  - All IP packets are also called datagrams because of its original connectionless designs – i.e., packets are accepted to arrive out of order or using different network paths
- Main functions
  - Defines packet format, basic unit of transmission on the Internet
  - Provides Internet addressing
  - Routing of packets/datagrams

Transport Layer

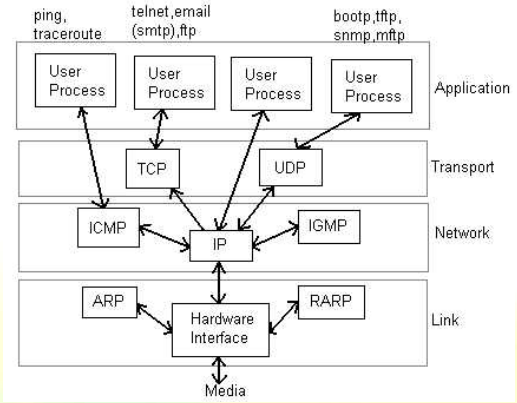
- IP for end-to-end device connection
- Transport layer permits application-to-application communications
- Two popular protocols:
  - TCP (Transmission Control Protocol) uses flow control mechanisms, and sophisticated state machines for connections for re-ordering out-of-order packet arrivals before forwarding to higher layer
  - UDP (User Datagram Protocol) – no flow control, a simple application-oriented connectionless technology

Layer Decapsulation: Examples



Application Layer

- Software programs use the Transport Layer protocols for delivering data messages
- Examples (text-based – unsecured applications)
  - Telnet: Network Terminal Protocol
  - FTP: File Transfer Protocol
  - SMTP: Simple Mail Transfer Protocol
  - DNS: Domain Name Service
  - HTTP: World Wide Web



Remarks

- Covered the concept of layered architecture
- Popular 5-layered TCPIP model