Lecture 2
Network Layers and Physical Layer

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Characteristics of Protocols

- A protocol is a set of mutually agreed upon rules that regiment the interactions between the communicating entities.
  - The key elements of a protocol are:
    - Syntax – defines the structure of information communicated, including the data format, the coding, and signal representations.
    - Semantics – defines the meaning of the exchanged signals, including control information for coordination and error handling.
    - Timing – defines the time at which data should be exchanged.

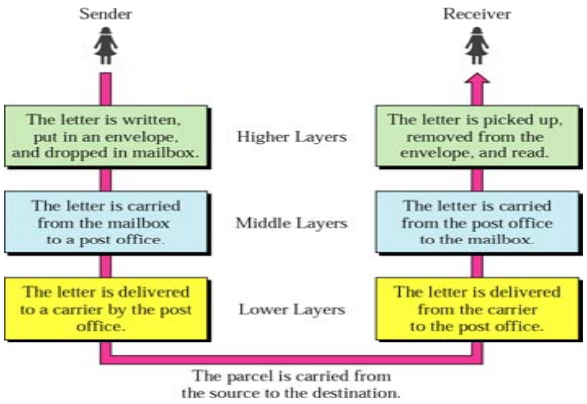
Characteristics of Protocols

- In Summary, the key elements of the protocol define
  - **WHAT** is comunicated,
  - **HOW** it is communicated, and
  - **WHEN** it is communicated.

Standards

- Defined by public organizations (de juro) or by widespread use (de facto)
  - Open standards
    - Avaliable to everyone (but not necessarily for free)
    - Everyone has the possibility to propose, criticize, and influence
- Standards organizations
  - ISO: International Organization for Standardization
  - IETF: Internet Engineering Task Force
  - IEEE: Institute of Electrical and Electronics Engineers
  - ANSI: American National Standards Institute
  - ETSI: European Telecommunications Standard Institute
  - ITU: International Telecommunication Union
    - ITU-T: International Telecommunication Union—Telecommunication Standards Sector
  - EIA: Electronic Industries Association
  - ...

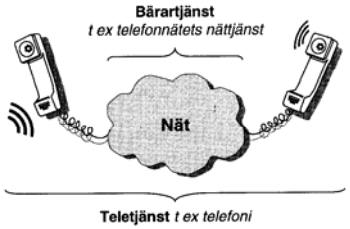
A Layered Model: Sending a Letter



- Layers are independent
  - Modify one without affecting the other

Services and Applications

- Service
  - What a network operator offers to customers (subscribers)
- Application
  - What the customer uses the service for
- Examples
  - Telephone connection
    - Service: voice transmission
    - Application: conversation between two parties
  - Computer communication via modem
    - Service: same as above plus Internet connectivity
    - Application: Web browsing, e-mail, file transfer, chat, etc



Network Architectures

- The task of designing a communication network is too complex to be handled as a monolithic unit.
- An alternative, a structured approach.
  - Divide the communication task into manageable parts.
  - Need to describe the communication functions in terms of an architecture.
    - The architecture defines the relationship and interactions between network services and functions through common interfaces and protocols.

Layered Architecture

- The architecture is divided into multiple layers.
- Each layer performs a related subset of functions required for communication, and adds value to the services provided by lower layers.
  - Layer *N* relies on services of layer *N*-1 to provide a service to layer *N*+1
  - Service required from lower layer is independent of how that service is implemented
    - Information and complexity hiding
    - Changes in layer *N* do not affect other layers

Layered Model Interfaces

- Boundaries between adjacent layers in the same system are called interfaces
  - Interface protocols define the interaction between adjacent layers in the same system

Network Architecture System Design Perpective

- "Best Effort" vs "Reliable" service
- Can the network be totally trusted?
- Where should reliability belong?

End-to-End Argument

- "Making good judgement about where to place functionalities in a complex system is what system design is all about"
- End-to-End argument states that a function, such as reliability or ordered delivery, should not be provided in the lower levels of the system unless it can be completely and correctly implemented at that level
  - Functional redundancy can be allowed if performance optimization is sought
    - Example: error control on a hop-by-hop basis

"Statefull" vs. "Stateless"

- Connection oriented networks require full state management
  - Establishment of a new connection causes a state change in the switch
  - A direct side effect: fate sharing
    - Fate of the end-to-end connection depends on the state of intermediate nodes
- Connectionless network are stateless
  - Simple and more robust
  - Only task required is to maintain end-to-end routing tables

“Statefull” vs. “Stateless”

- Are simplicity and robustness obtained by trading “state” complexity for more routing and processing requirements at intermediate systems?
  - Connectionless networks have to perform address processing on a packet basis
- Not necessarily true, as successive packets usually refer to the same address
  - Caching routing computation greatly reduces processing requirements

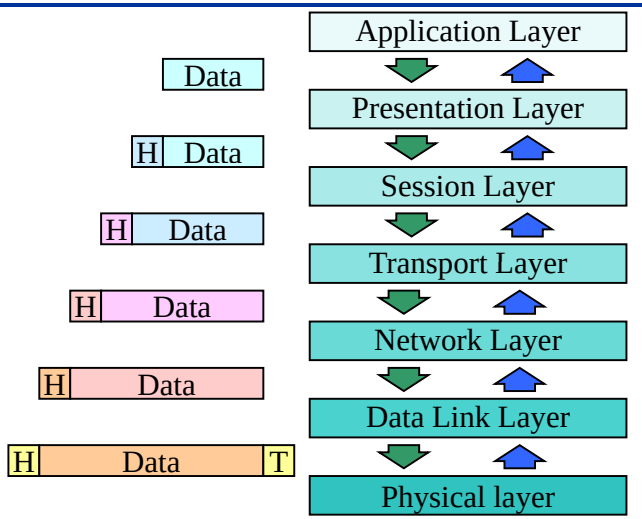
ISO/OSI Communication Model

- The layered architecture viewpoint has been adopted by the International Standard Organization (ISO) in definining its Reference Model.
- The model referred to as the Open System Interconnection (OSI) defines a framework for the specification of protocol standards for connecting heterogenous computers.
  - The model provides the basis for two open systems that conform to the reference model and the associated standards to exchange information.

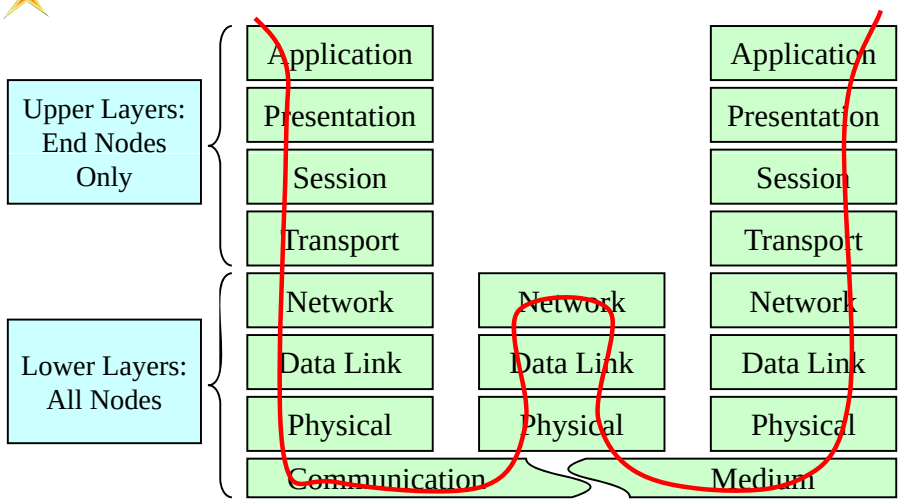
ISO/OSI Communication Model

- The basic goals of the model:
  - Define the rules and conventions for various functions within each layer.
  - Specify the general relations among these functions.
  - Determine the constraints on the types of functions and their relations.

ISO/OSI Communication Model



ISO/OSI Communication Model



ISO/OSI Communication Model Architecture

- The ISO reference model defines seven layers:
  - Application layer,
  - Presentation layer,
  - Session layer,
  - Transport layer,
  - Network layer,
  - Data link layer, and
  - Physical layer.

ISO/OSI Communication Layers

- Application Layer:
  - Process to process communication
  - All layers exist to support this layer
  - Applications include e-mail, teleconferencing, WWW, ftp, distributed databases
- Presentation Layer
  - Conversion of data to conform to a common format (e.g. little endian vs big endian, byte orders, integer and floating point representation)

ISO/OSI Communication Layers

- Session Layer:
  - Bind two communicating entities into a “relationship”,
    - Session setup (authentication), failure recovery (broken session), synchronization services
- Transport Layer:
  - End-to-end data delivery
    - End-host to end-host communication
    - Multiplexing of multiple data streams from higher layers (upward multiplexing)
    - Flow control between sender and receivers

ISO/OSI Communication Layers

- Network Layer:
  - Data transmission and delivery between hosts
    - Controls access to the network
    - Provides routing of packets within the network
    - Manages contention and bottlenecks within the network
- Data Link Layer:
  - Error free communication over a single link between adjacent nodes
  - Speed matching between senders and receivers
  - Framing

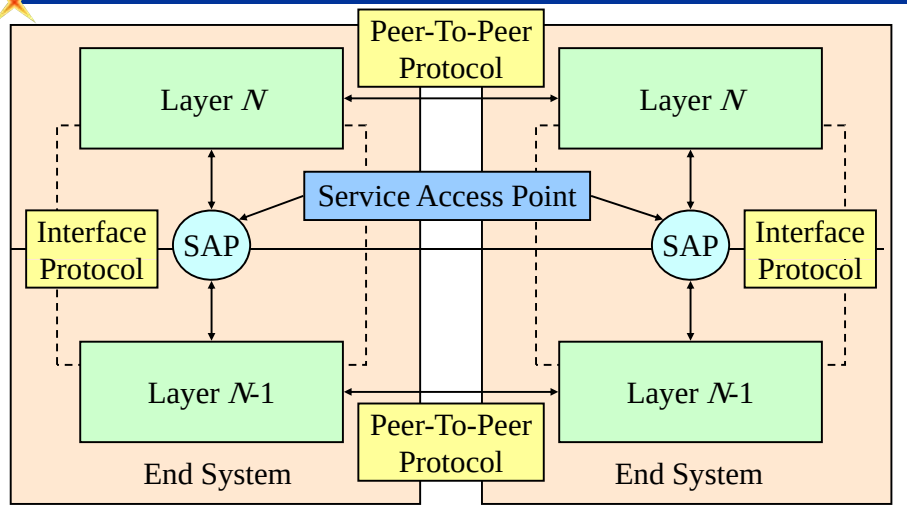
ISO/OSI Communication Layers

- Physical Layer:
  - Transmission of raw bits (0/1) over physical wires
    - Interfacing, data encoding, clock recovery, etc.

ISO/OSI Communication Model

- Direct communication between peer layers in two different machines is only achieved at the physical layer.
- The interlayer interface defines a framework for standards
  - No details of the implementation, no definition of the interlayer interfaces.

ISO/OSI Communication Model Interfaces



Interfaces

- Communicating systems need not implement the same interlayer interfaces, since these are not visible from outside.
- The interfaces is used to access services provided by a lower layer to a higher layer.
- The point at which service is provided is called Service Access Point (SAP)

Model Limitations

- The model is complex
- Focus entirely on listing of details, with no motivation for techniques adopted.
  - Every reasonable suggestion becomes an option.
  - This results in an excessive number of options, for a protocol architecture that is supposed to be an international standard.
- The layering structure of the model is arbitrary
  - Appropriate placement of features in layers is not always obvious.

Model Limitations

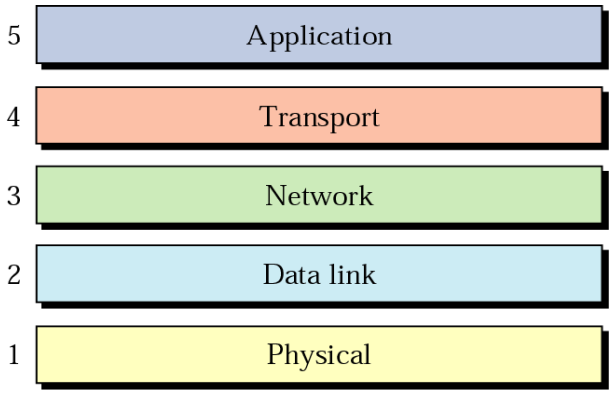
- The development of the model has been dominated by a communication mentality.
  - Techniques from communication fields have been sometimes inappropriate.
    - Use of interrupts, when implementation calls for use of a procedure call.
    - Initial focus entirely on connection-oriented, rather than connectionless service.
    - Connectionless service is currently being provided, but as an afterthought.

Model Limitations

- The model does not allow explicit bypassing of adjacent layers when not needed.
  - May lead to redundancy of functionalities.
  - May result in inefficiency.
- In general, layering has many conceptual advantages, but may be “harmful or difficult”.
  - Fanatical ahderence to layering as a religion may be problematic.
    - Layer N may duplicate lower layer functionality,
    - Different layers may need the same information,
    - Layer N may need to know layer N-2 information.

Internet Model

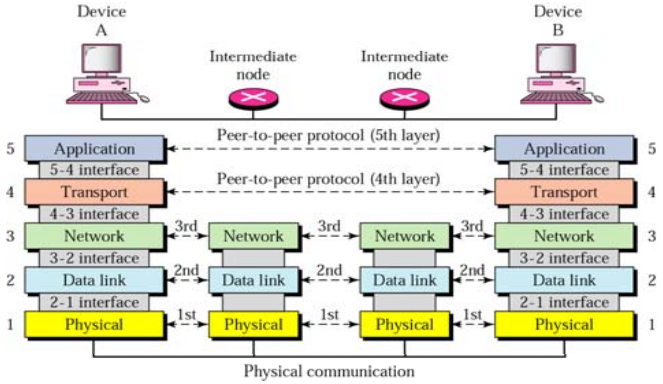
- Also known as TCP/IP protocol suite



Communication Between Layers

- Peer-to-peer processes
  - Betwen protocols at the same layer in different devices
  - Logical connection
- Interfaces between layers
  - Between adjacent layers in the same device
  - Data is transfered by passing data and network information through layers
    - down (sending) or up (receiving)
  - Communication takes place over well-defined interfaces

Communication Between Layers

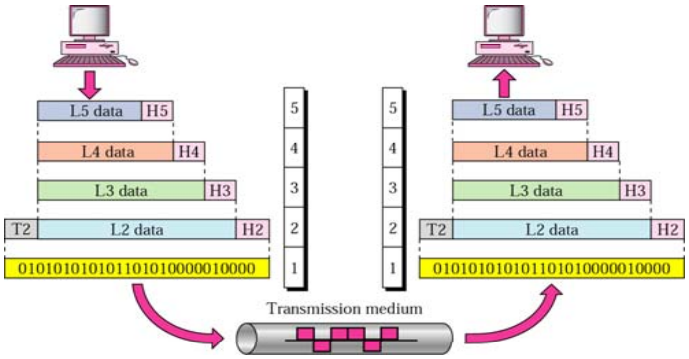


- Two types of communication between layers
  - Peer-to-peer communication—same layer, different devices
  - Communication over interfaces between layers—different layers, same device

Interfaces Between Layers

- The interface of a layer defines how the layer above it can access it
- Each layer has its own format for the Protocol Data Unit (PDU)
- A layer in the sending device may add more protocol information to the data unit from the layer above
  - Headers and trailers
- A layer in the receiving device may strip off protocol information

Data Exchange



- A layer in the sender adds protocol information to the data
  - Headers and trailers
- A layer in the receiver strips off protocol information

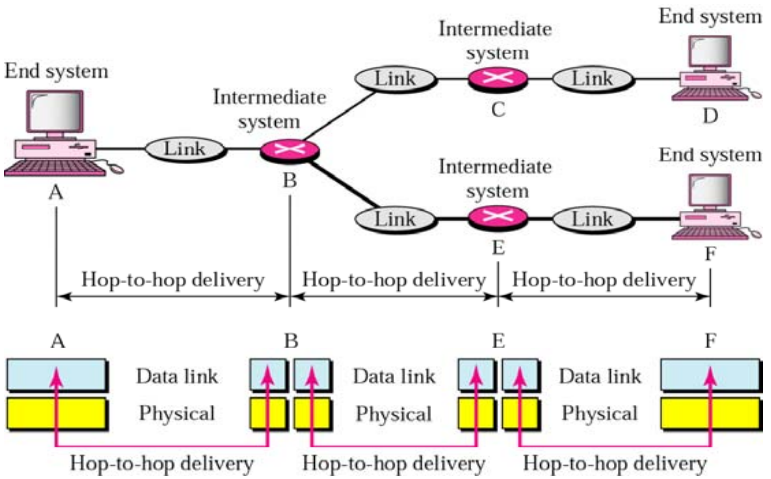
Function of Layers

- Physical Layer
- Data Link Layer
- Network Layer
- Transport Layer
- Application Layer

Physical Layer

- Transmission of bits between nodes
  - Wave guides (cables) for electrical and optical signals
  - Unguided medium (free space) for radio and optical signals
- Protocols
  - Physical connection between device and medium
    - Mechanical and electrical interfaces
      - Connectors, cables, voltage levels
    - Transmission and reception of signals
      - digital modulation, line coding
    - Bit synchronization
      - Synchronous and asynchronous transmission
- Standards, for example EIA RS-232, ITU-T SDH (ANSI SONET)

Data Link Layer—Hop-to-Hop



Data Link Layer

- Transmission of frames between nodes
- Framing
  - Divides bit stream into larger data units, frames
    - Ethernet frame up to 12,144 bits (1518 bytes), including control information
- Flow control
  - Prevent receiver from being overrun
- Error control
  - Detect and (perhaps) retransmit damaged frames
- Access control
  - Which device may send on a shared link
- Addressing

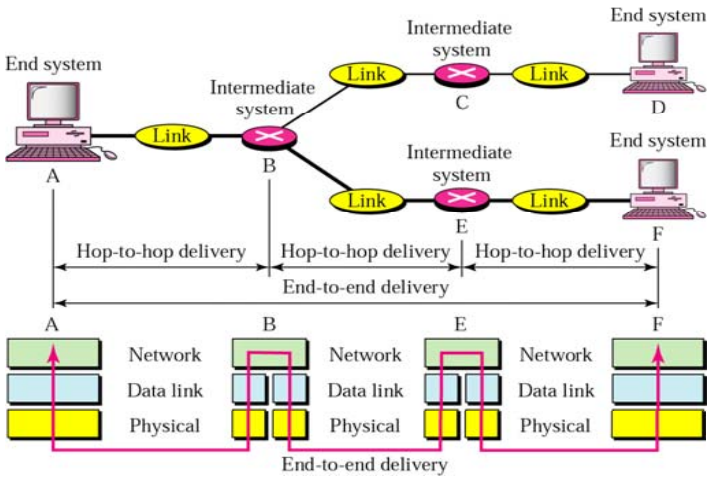
Data Link Layer Frame Example

- Flags
  - Bit sequence for frame synchronization
- Addresses
  - Source and destination
- Control
  - Sequence number
    - Transmitted and expected
  - Link connect and disconnect
  - acknowledgements
- Trailer
  - Bit sequence for detecting bit errors

Data Link Layer Standards

- Ethernet
  - Family of protocols
  - ”Ethernet” (10 Mb/s), ”Fast Ethernet” (100 Mb/s), ”Gigabit Ethernet” (1 Gb/s)
- IEEE 802.11 Wireless LAN
- IETF: Point-to-Point Protocol (PPP)
- IETF: Multi-protocol Label Switching (MPLS)
- ISO: High-level Data Link Control (HDLC)
  - Link Access Procedure Balanced (LAP-B), ITU-T X.25
  - Normal Response Mode (NRM), SDLC

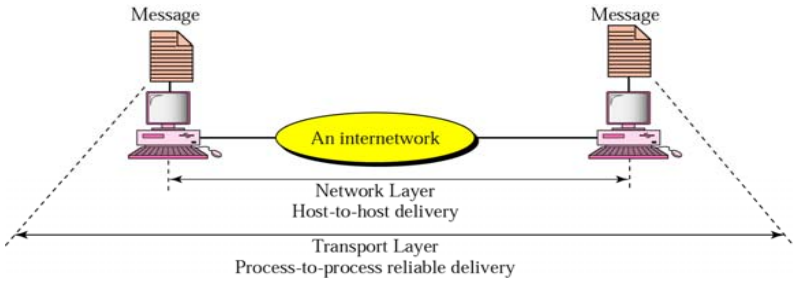
Network Layer—Source-to-Destination



Network Layer

- Delivery of packets from source to destination
  - possibly across multiple links
- Addressing
  - ”Logical” addresses
  - Unique within the network
- Routing
  - Calculation of paths between pairs of nodes
- IETF: Internet Protocol (IP)

Transport Layer—Process-to-Process

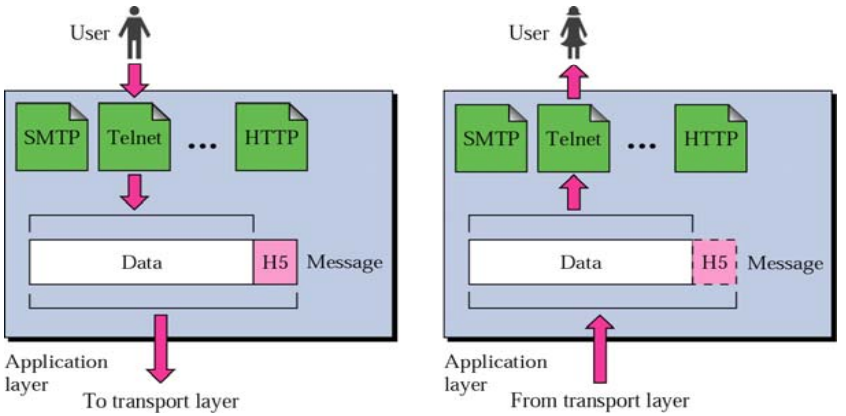


Transport Layer

- Delivery between end users (processes)
  - Addressed by ports
  - Reliable (connections) or non-reliable (datagrams)
  - Flow control
  - Reactive traffic control (prevent congestion)
  - Error handling
  - Connection set-up and tear-down
- Segmentation and reassembly
- IETF: Transport Control Protocol (TCP), User Datagram Protocol (UDP)
- ISO: Transport Protocol Class 0 – 4

Application Layer

- Provides services to the end user



Future Trends of Communication Networks

- In recent years, a large technological progress occurred both in the field of electronics and the field of optics
- Technological progress has opened the door to a new class of applications: **Real-Time Applications**
  - These applications create the need for:
    - Greater flexibility in the transfer mode,
    - Transport of services other than pure data,
    - Transport of high bit rate services,
    - Development of higher speed systems.