Digital Subscriber Line/Loop Family (*x*DSL)

- Carriers use the term *local loop* or *local subscriber line* to refer to connections between the carrier's *central office* (CO) and a subscriber's location
- *x*DSL is a family of technologies which:

- Operates on top of existing infrastructure of copper wiring
- The same physical wiring originally installed for the analog telephone service!
- Does not in any way affect the phone service; runs simultaneously over the same wires

*x*DSL (1/3)

- Local loops accommodate signals at frequencies higher than those used by the telephone service

 - Complexity: No two local loops have identical electrical characteristics

- Ability to carry signals depends on:

 - Distance

 - Diameter and thickness (gauge) of wiring used

 - Level of electrical interference

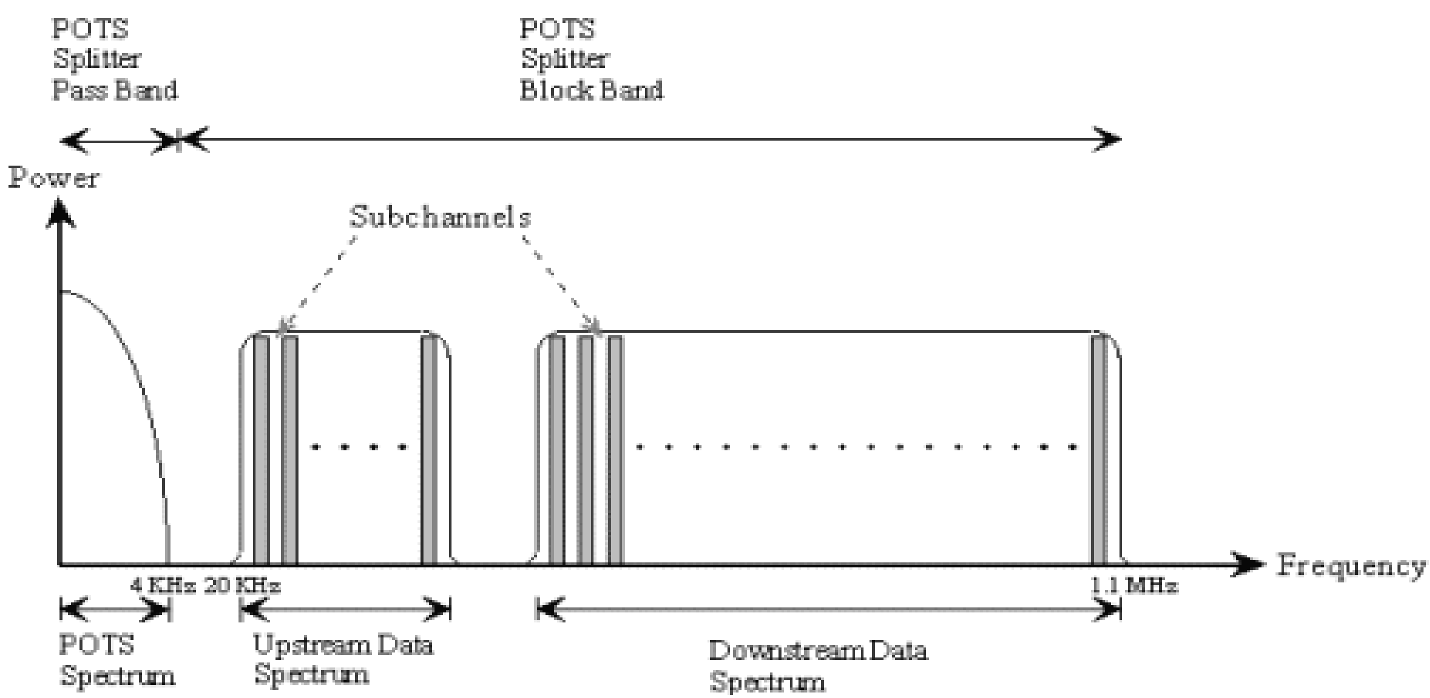
- To accommodate differences *x*DSL is *adaptive*:

 - The *x*DSL modems are powered on and probe the line between them to discover its characteristics

 - Then communicate using techniques that are optimal for the specific line

*x*DSL (2/3)

- The theoretical maximum bandwidth for analog modems over the audible spectrum of frequencies is 56 Kbps
- The audible spectrum consists of only the bottom 4 KHz of the total spectrum available on a copper wire



*x*DSL (3/3)

- *x*DSL technologies achieve their exponential increase over analog modems
  - By exploiting frequencies over 4 KHz
- These frequencies have not been used before
  - Due to the difficulties they cause to normal voice traffic
- Frequencies over 4 KHz transmitted over the same physical wire as the phone service
  - Disrupt POTS by introducing crosstalk
- *x*DSL technologies employ sophisticated techniques to limit crosstalk
  - Allow POTS to continue simultaneously on the same wire on which *x*DSL transmission takes place

ADSL (1/3)

- Asymmetric DSL (ADSL) is the most widely publicized of the *x*DSL schemes
- Asymmetric refers to the fact that it:

 - Allows more bandwidth downstream (384 Kbps to 8 Mbps) from the carrier's central office (CO) to the subscriber

 - Upstream rates range in the region of 16 to 640 Kbps

- The above speeds depend on:

 - Distance from the CO

 - Line quality

 - Wire gauge

ADSL (2/3)

- In ADSL bandwidth is divided into 286 separate frequencies (or subchannels)

  - 255 are used for downstream data transmission
  - 29 for upstream data transmission
  - 2 for control information

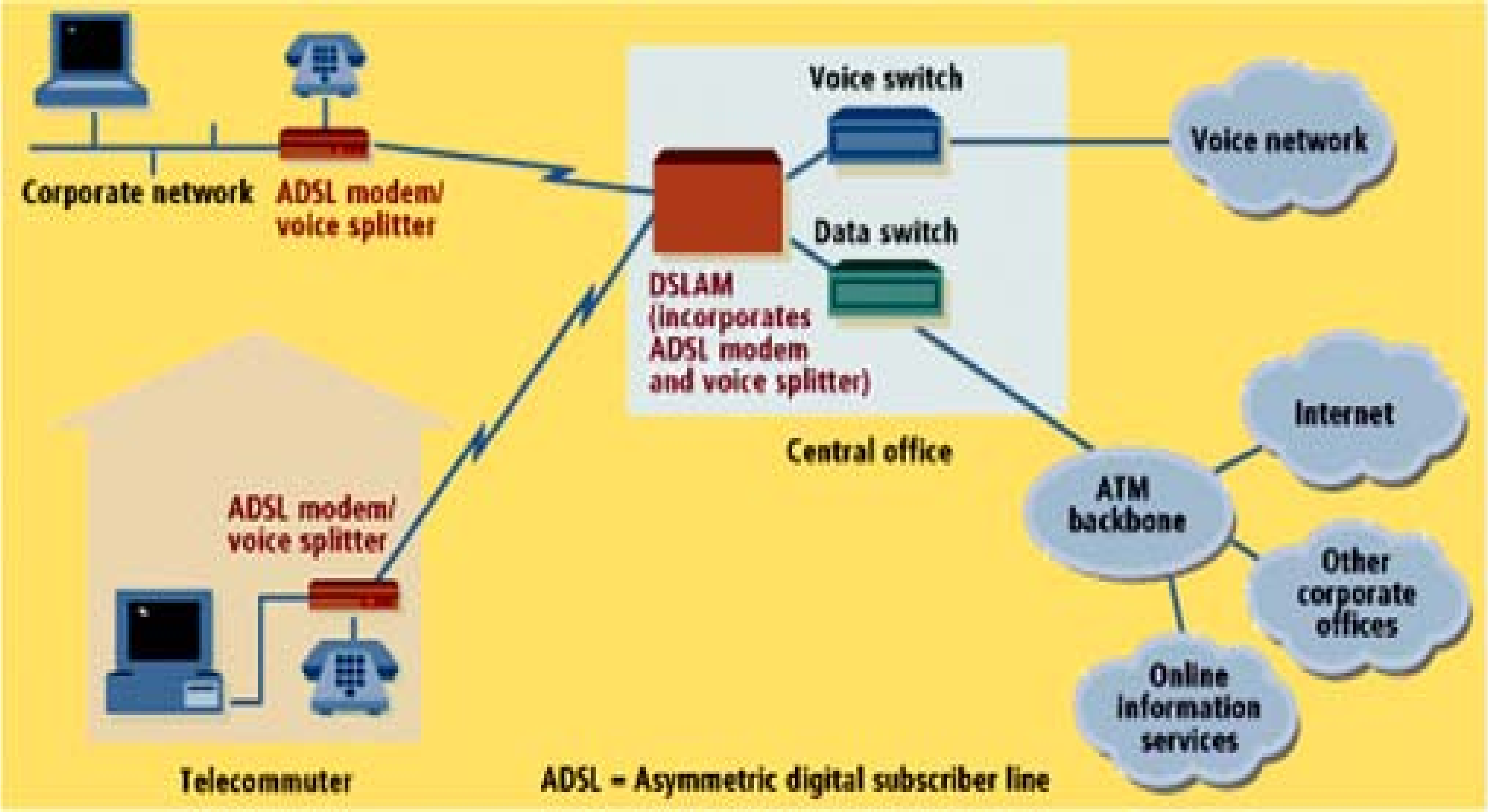
- Conceptually there is a separate ``modem'' running on each subchannel which has its own modulated carrier

  - These carriers are spaced at ~4 KHz intervals to keep signals from interfering with one another

- ADSL does not use the bandwidth below 4 KHz

  - To avoid interfering with the analog phone signals

ADSL (3/3)


Voice switch
Voice network
Corporate network
ADSL modem/
voice splitter
Data switch
DSLAM
(incorporates
ADSL modem
and voice splitter)
Central office
Internet
ATM
backbone
ADSL modem/
voice splitter
Other
corporate
offices
Online
information
services
Telecommuter
ADSL = Asymmetric digital subscriber line

Other *x*DSL Technologies

- Rate-Adaptive DSL:

 - RADSL is a subset of ADSL that automatically adjusts the line speed based on a series of initial tests

- Symmetric DSL:

 - SDSL provides the same amount of bandwidth upstream as downstream

 - Results in lower aggregate bandwidth

- High-Bit-Rate DSL:

 - HDSL is the most widely deployed of the *x*DSL technologies

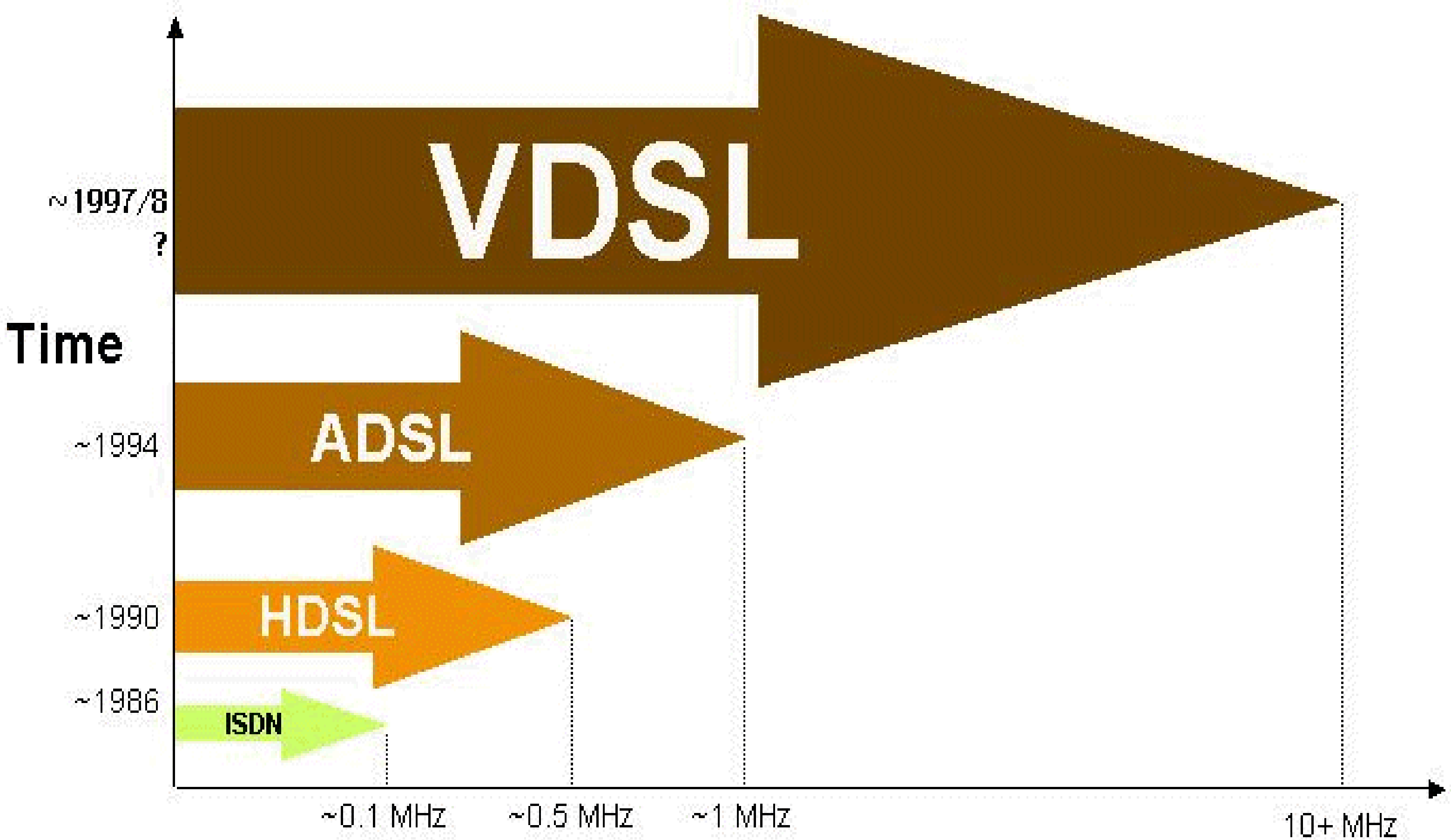
 - Uses two pairs of copper wire; does not carry POTS

 - Provides 1.5 or 2 Mbps of symmetrical bandwidth

Very-High Rate DSL

- VDSL is an asymmetrical transmission scheme
- Designed for much higher transmission rates
  - 13 to 52 Mbps over extremely short distances between 500 to 1000 meters
- Can run over existing copper wiring, however not used since distances are too long
- Requires intermediate concentration points (Optical Network Unit (ONU)) with optical fiber connections to the CO
- Low rates of VDSL (13 to 26 Mbps):
  - Can run over longer distances of copper
  - Require fewer concentration points to reach a subscriber

*x*DSL Summary



The OSI Reference Model (1/2)

- The ISO (International Standards Organization) created a model of how protocols and networking components should be made

 - Open Systems Interconnection (OSI)

- An abstract representation of an ideal network protocol stack; not used in real networks
- Protocol:

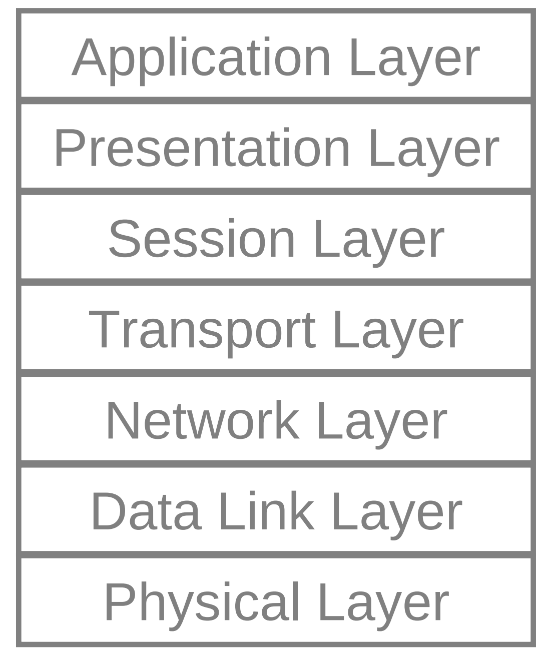
 - A set of rules that control the communication of network devices

- Stack of layers:

 - Represents all the specifications, functions and activities that need to occur in networking

- Modularization:

 - Helps to simplify the design of network software
 - Eases maintenance



The OSI Reference Model (2/2)

- Each layer:
  - Represents a group of related specifications and activities that perform a well-defined function
  - Solves a different problem
  - Builds on top of the functionality of the one below to provide more functionality to the one above it
- Logically layers communicate with their peers on the remote side:
  - In practice they communicate with the layer(s) below them
  - Physical communication takes place at the lowest layer
- ``Open'' means that the specification of each layer is public:
  - Anyone can connect to an OSI ``open system''
  - There can be multiple implementations (from different vendors) of a layer

Protocol Layering (1/4)

- Protocols are stacked vertically as series of ``layers''
- Each layer offers *services* to layer above through an *interface*, shielding implementation details
- Layer *n* on one machine communicates with layer *n* on another machine (they are *peer processes/entities*)
- The entire set of layers is called a *protocol stack*

- E.g.: The TCP/IP stack we will see

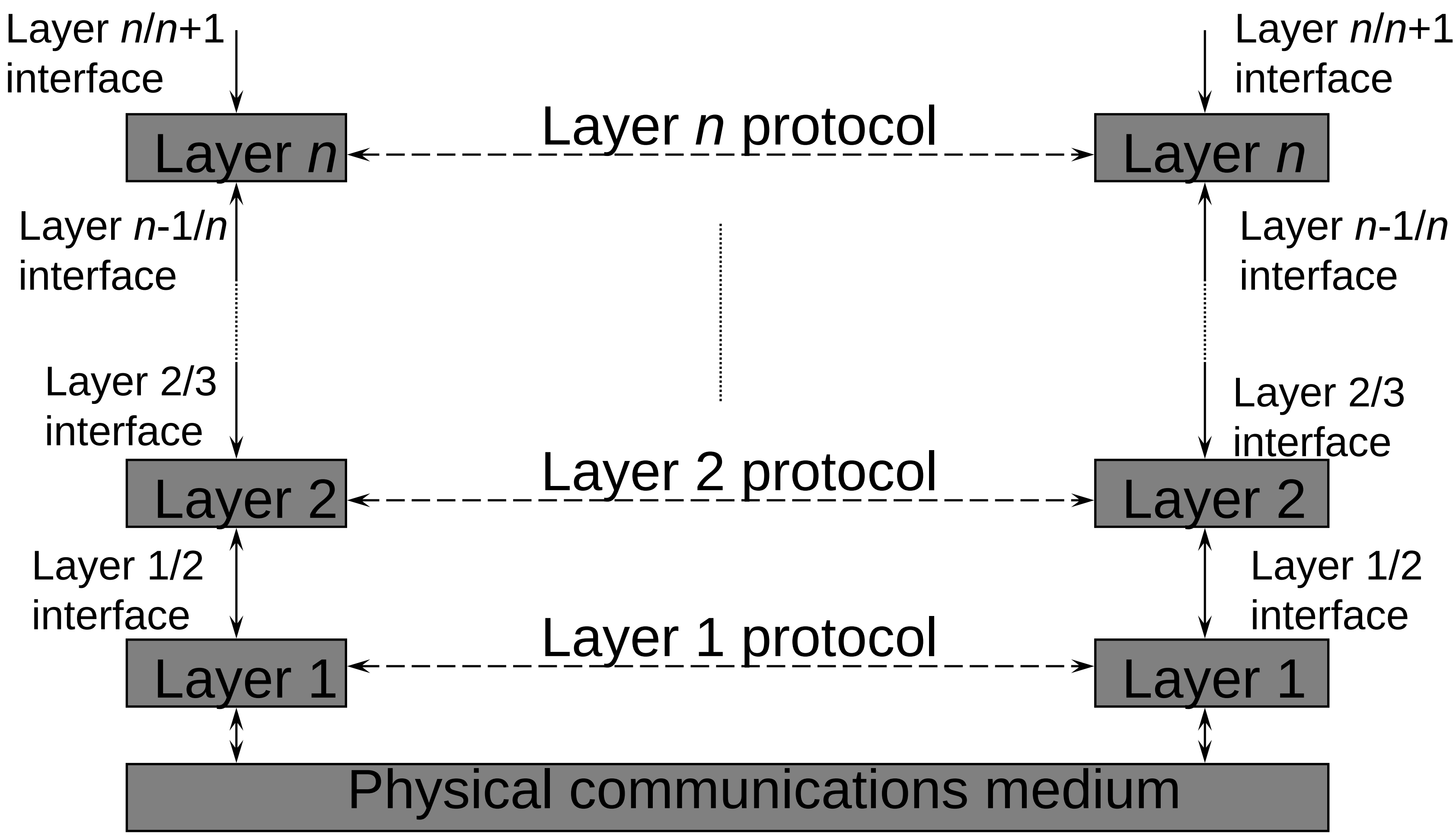
Protocol Layering (2/4)

- Each layer provide *services* to layer above, and ``consumes'' *services* provided by layer below
- Active elements in a layer are called *entities*
- Entities in same layer in different machines are called *peer entities* (or just *peers*)

Protocol Layering (3/4)

- Service:
  - Set of primitives provided by one layer to layer above
  - Service defines what layer can do (but not how it does it)
- Protocol:
  - Set of rules governing data communication between peer entities, i.e. format and meaning of frames/packets
- Service/protocol decoupling is very important

Protocol Layering (4/4)



Layer and Interface Design

- An important design objective is ``clean'' interfaces, having minimal set of well-defined services
- Use of protocol layering and clean-cut interfaces enables:

- Easy replacement of individual layers
- Designers and implementers to focus on solving one sub-problem at a time
- Independent implementations of the same layer to inter-operate
- Minimization of inter-layer communications
- Diagnosis of faults, errors, congestion, etc.

Protocol Layering Disadvantages

- Protocol layering does not solve all networking problems
- Some issues need to be addressed at many layers, e.g.:
  - Need to address data (say who it's for)
  - Possible need for setting up connections
  - Data transfer rules
  - Error management
  - Deal with message component re-ordering
  - Flow control
  - Routing
- Layering can introduce inefficiencies

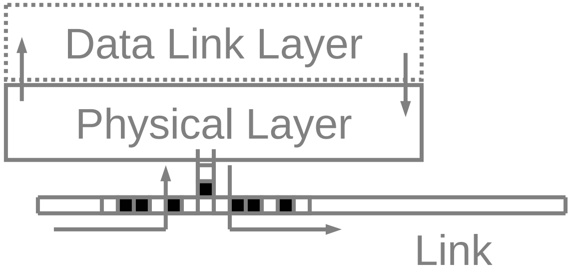
OSI/RM: Physical (Layer #1)

- Performs bit-by-bit transmission of the frames given to it by the data link layer

  - Over physical channel

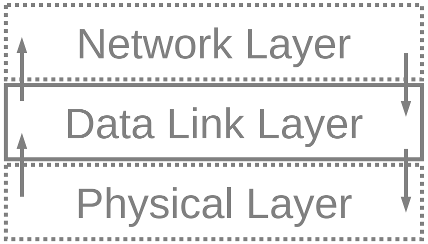
- Provides unreliable bit transmission/reception service
- Its specification includes:

  - How many volts represents a ``1'', how many a ``0''?
  - How long does a bit time last?
  - How many pins does the connector have?
  - How many wires does the transmission media have?
  - Are pulses electrical or optical?



OSI/RM: Data Link (Layer #2)

- Provides reliable, error-free service on top of physical layer service
  - Corrects errors at the ``bit'' level
  - Requires creation of frame boundaries using special bit sequences
- Divided into two sublayers:
  - Media Access Control (MAC)
  - Logical Link Control (LLC)
- Deals with:
  - Address network devices (MAC)
  - Places data into a data frame (MAC)
  - Detect transmission errors (LLC)
  - Adding error checking information to frames (LLC)



OSI/RM: Network (Layer #3)

- Provides uniform addressing scheme for network addresses
- Examines packets given to it by the data link layer to see if they are destined for this host or should be forwarded to another host
- Performs accounting tasks (such as counting the number of packets to determine congestion levels)
- Decides on the best way to route packets destined for other hosts (key responsibility) based on:

- Static tables
- Determined at start of session
- Highly dynamic (varying for each packet depending on network load)

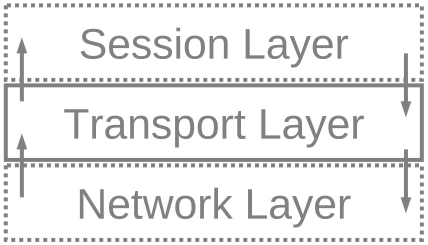
- Performs protocol conversions when packets are routed over different types of networks

OSI/RM: Transport (Layer #4)

- Controls the delivery of data between two hosts
- Fragments data streams from a session into packet sized portions and passes them to the network layer
- Reassembles data streams from data in packets given to it by the network layer
- Ensures delivery of data streams to appropriate sessions

 - Multiple connections per session or multiple sessions per connection

- Performs *host-to-host* flow control to ensure data does not arrive faster than the host can cope with



OSI/RM: Session (Layer #5)

- Allows users on different machines to establish sessions between them and maintains a logical connection between them, for example to:

 - Allow remote logins

 - Provide file transfer

- Responsible for:

 - Dialogue control

   * Who is to transmit data next

 - Token management

   * E.g. control which entity can perform an operation on shared data

 - Synchronization:

   * Inserting checkpoints into data stream so that communication can be resumed from the last checkpoint after a failure

OSI/RM: Presentation (Layer #6)

- Performs data representation and syntax conversions
- Enables cross-platform communication by converting data representations (strings, integers, floating-point numbers etc.) to and from network standard formats
- Example:

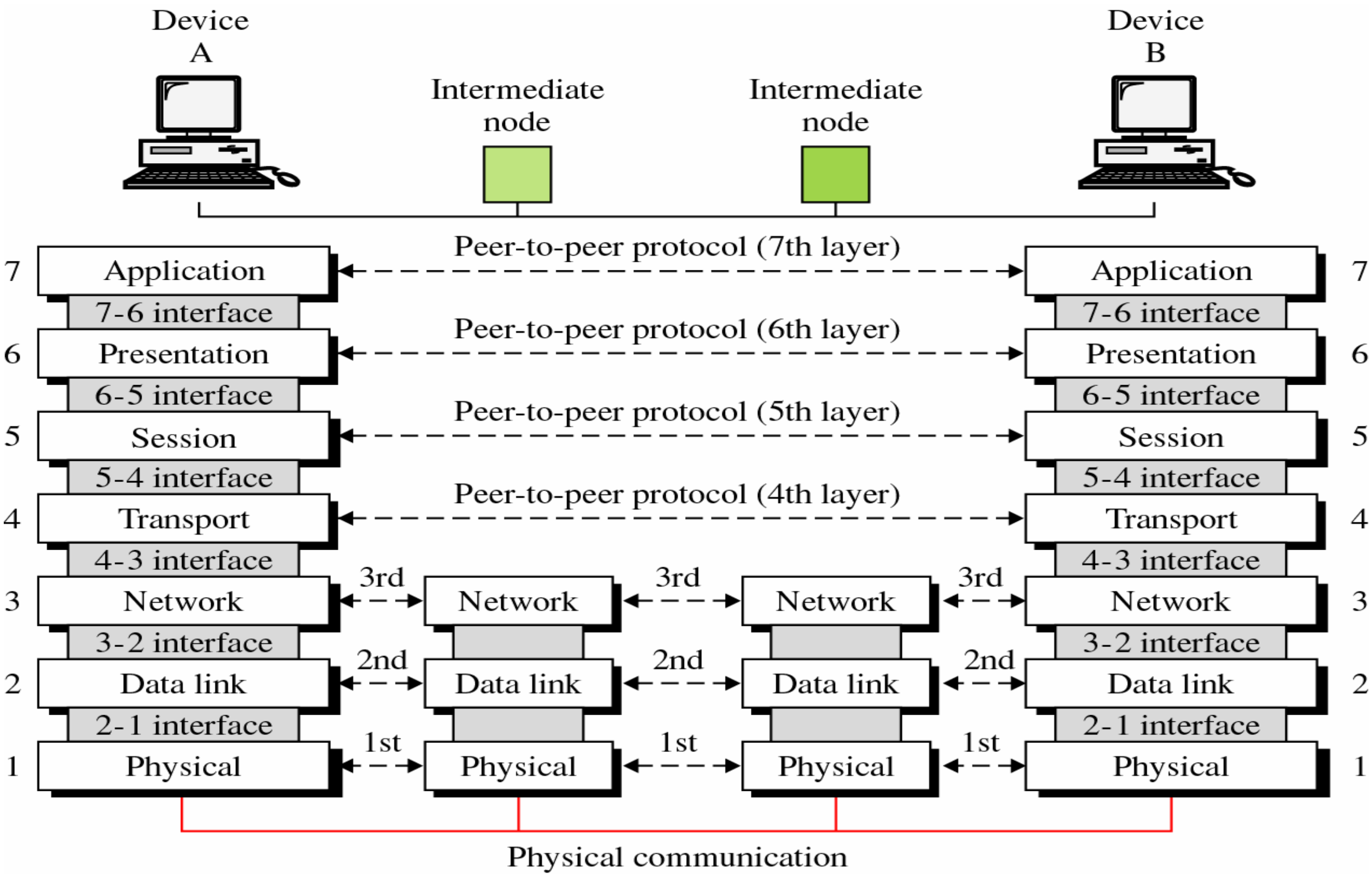
- The sending host uses the EBCDIC encoding
- The receiving host uses ASCII
- The presentation layer in the sender takes the EBCDIC code and coverts it to unicode
- The presentation layer in the receiver gets the unicode and coverts it to ASCII

- Also deals with data compression

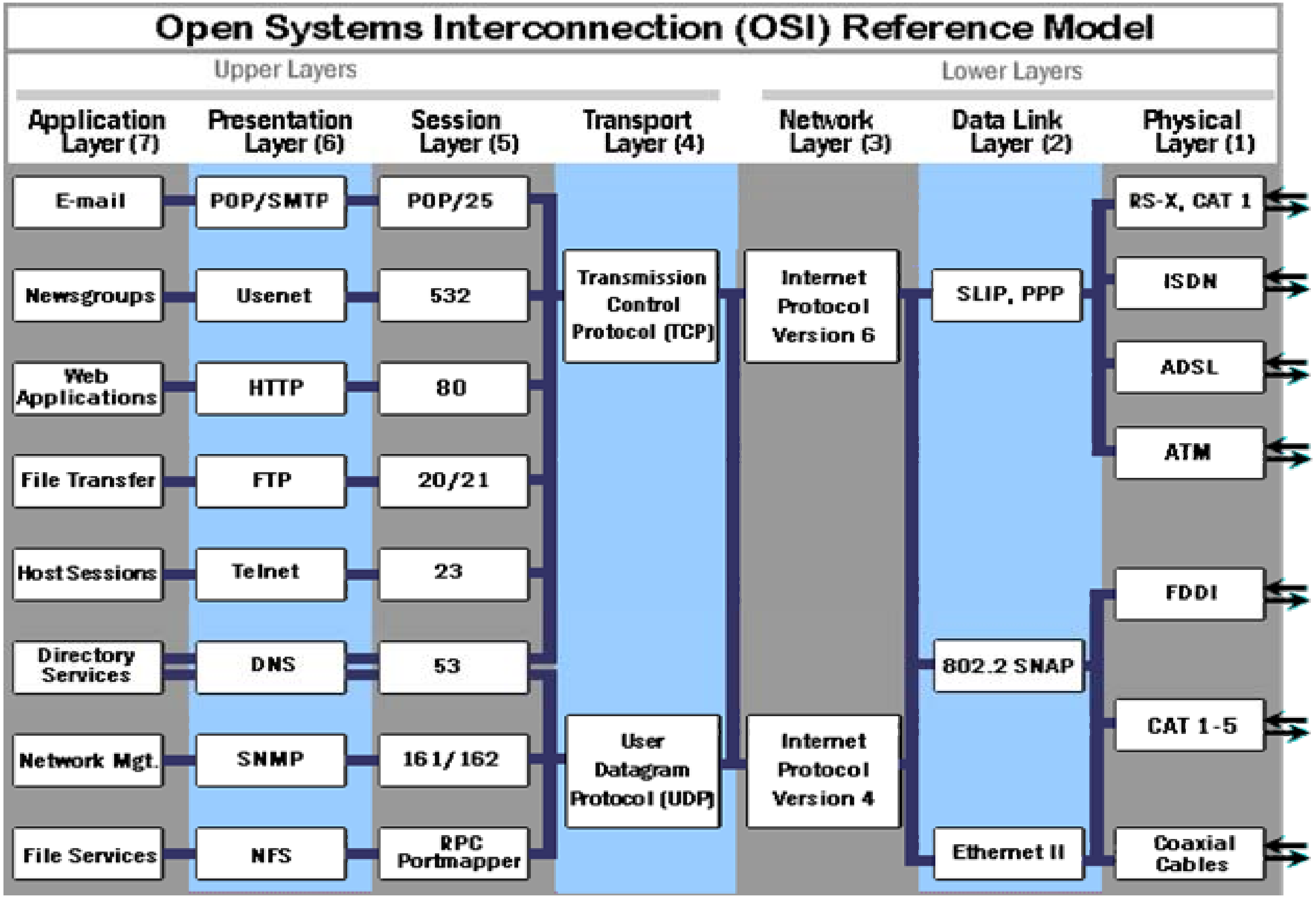
OSI/RM: Application (Layer #7)

- Home to wide variety of application protocols for specific user needs, e.g.:
  - File transfer
  - Electronic mail
  - Directory services

OSI/RM Revisited



OSI/RM Example



Internetworking: Motivation

- There are many different LAN and WAN technologies
  - LANs: Low cost, limited distance
  - WANs: High cost, unlimited distance
- Computers are connected by many different technologies
- Incompatibilities among networks:
  - Electrical properties
  - Signaling and data encoding
  - Packet formats
  - Addresses
- A system that spans a large organization must accommodate multiple technologies

Internetworking: Universal Service

- Telephones are useful because any telephone can reach any other telephone
- *Universal service* among computers greatly increases the usefulness of each computer
- Providing universal service requires interconnecting networks employing different technologies

Internetworking

- *Internetworking* is a scheme for interconnecting multiple networks of dissimilar technologies
- Uses both hardware and software
- Extra hardware positioned between networks
- Software on each attached computer
- System of interconnected networks is called an *internetwork* or an *internet*

 - *Internet* is what the global internet called

- Router:

 - The hardware component used to interconnect networks
 - A router has interfaces on multiple networks
 - Networks can use different technologies
 - Router forwards packets between networks
 - Transforms packets to meet standards for each network

Virtual Network

- Internetworking software builds a single, seamless *virtual network* out of multiple physical networks
- Universal addressing and naming scheme
- Universal service
- All details of physical networks hidden from users and application programs
- Note: protocol software needed on both hosts and routers