

Digital Subscriber Line/Loop Family (xDSL)

- 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
- xDSL 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

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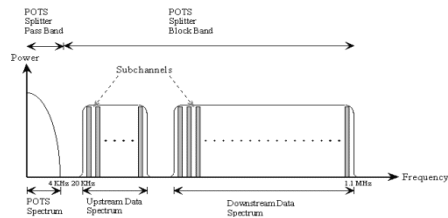
xDSL (1/3)

- 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 xDSL is *adaptive*:
 - The xDSL 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

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xDSL (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



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xDSL (3/3)

- xDSL 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
- xDSL technologies employ sophisticated techniques to limit crosstalk
 - Allow POTS to continue simultaneously on the same wire on which xDSL transmission takes place

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ADSL (1/3)

- Asymmetric DSL (ADSL) is the most widely publicized of the xDSL 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

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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

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ADSL (3/3)



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Other xDSL 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 xDSL technologies
 - Uses two pairs of copper wire; does not carry POTS
 - Provides 1.5 or 2 Mbps of symmetrical bandwidth

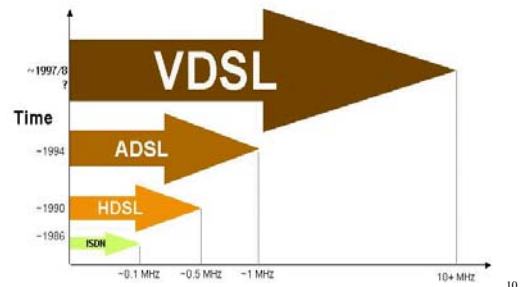
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Very-High Rate DSL

- 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

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xDSL Summary



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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

Application Layer
Presentation Layer
Session Layer
Transport Layer
Network Layer
Data Link Layer
Physical Layer

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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

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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

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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*)

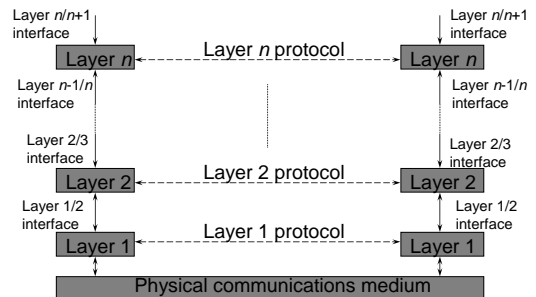
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Protocol Layering (3/4)

- 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

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Protocol Layering (4/4)



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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.

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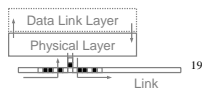
Protocol Layering Disadvantages

- 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

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OSI/RM: Physical (Layer #1)

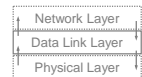
- Performs bit-by-bit transmission of the frames given to it by the data link layer
- Over physical channel
- Provides unreliable bit transmission/reception service
- Its specification includes:
 - How many volts represents a ``1'', how many a ``0''?
 - How long does a bit time last?
 - How many pins does the connector have?
 - How many wires does the transmission media have?
 - Are pulses electrical or optical?



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OSI/RM: Data Link (Layer #2)

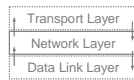
- Provides reliable, error-free service on top of physical layer service
- Corrects errors at the ``bit'' level
- Requires creation of frame boundaries using special bit sequences
- Divided into two sublayers:
 - Media Access Control (MAC)
 - Logical Link Control (LLC)
- Deals with:
 - Address network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



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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



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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



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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



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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 converts it to unicode
 - The presentation layer in the receiver gets the unicode and converts it to ASCII
- Also deals with data compression



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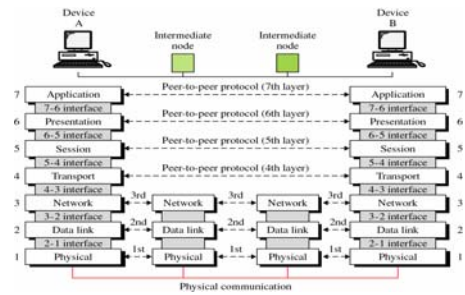
OSI/RM: Application (Layer #7)

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



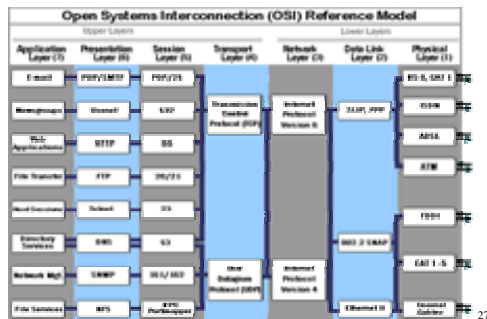
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OSI/RM Revisited



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OSI/RM Example



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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

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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

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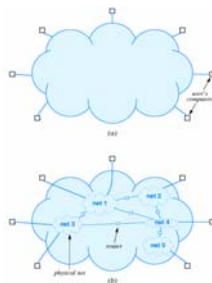
Internetworking

- *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

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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



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