

Overview: General Introduction

- **Computation and Communication**
- **Inter-networked Computers**
- **Communication Protocols**
- **OSI Model**
- **Protocol introduction:**
 - IP
 - TCP and UDP
 - FTP and HTTP

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Computation



Abacus



Calculator



Computer



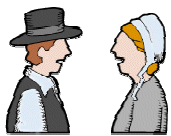
Adding machine



Mainframe



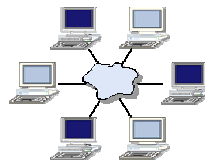
Communication



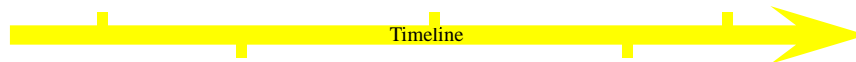
Conversation



Telephone



Network



Mail



Data Transfer



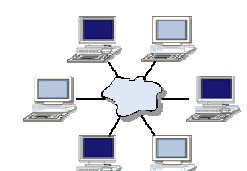
Computation and Communication



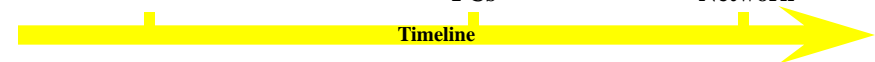
Mainframe



PCs

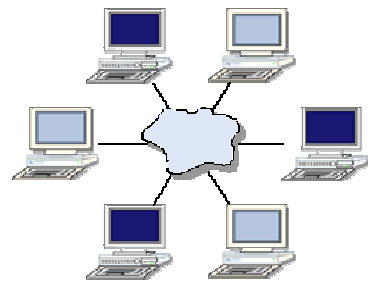


Network



- **Resource Sharing** (equipment, programs, data)
- **Increased Reliability** (alternative sources of supply)
- **Parallelism** (distribution of tasks)
- **Cost Savings** (better price/performance ratio)

Inter-networked Computers

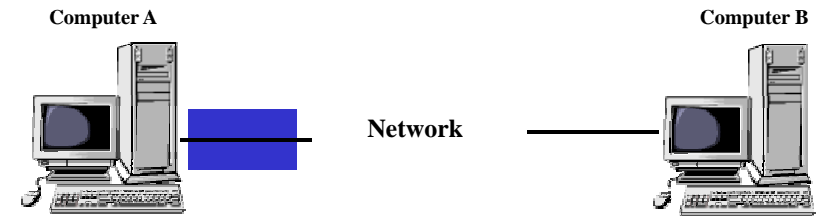


How do the computers inter-communicate?



- Data exchange (main factor)
- Access to remote services (news, banking, etc.)
- Inter-personal communication (e-mail, messaging, etc.)
- Interactive entertainment (radio, TV, etc.)

Computer communications



- There are different types of
 - networks
 - operating systems
 - applications
- Some incompatible with others



Need for a set of rules used when exchanging messages

Communication Protocols

PROTOCOL

(agreement about the format and meaning of the messages exchanged)

- Communication is performed:
 - in diverse forms, and
 - requires significant support
- In order to reduce the complexity, a layered structure was proposed
- Each layer:
 - offers a set of services to the layer above, and
 - uses those services provided by the layer underneath

Who does the standardisation?

- Legal Standards
 - ITU, International Telecommunications Union formerly the (CCITT)
 - ISO, International Standards Organisation
 - FCC, Federal Communications Commission
 - Loads more as well. ETSI, CEPT, CCIR ...
- Informal Standards
 - IEEE, LAN's WAN's
 - ATM Forum, X Consortium
 - Zerox, IBM, Digital, Telecom Eireann, BT, AT&T

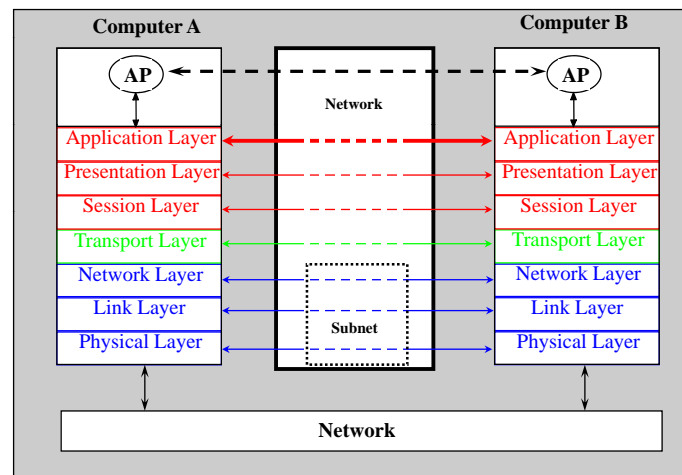
Closed & Open Systems

- The original implementations were not based on any globally accepted standards and the manufacturers produced their own standards.
- Such systems are known as “Closed Systems” since only computers from the same manufacturer can exchange information.
- To overcome this a wide range of network and protocol standards was produced where equipment complying to a particular standard can be used interchangeably. This is an Open System Interconnection Environment (OSIE).

What is the OSI Model?

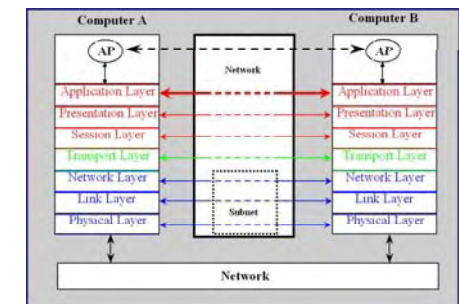
- The *International Standardisation Organisation (ISO)* described a layered model for network protocol architectures called the Reference Model for Open Systems Interconnection (OSI model).
- It is *not* an implementation standard, but partitions the communication functions into layers so they can be individually standardised.
- International Standards Organization has proposed the Open Systems Interconnection (OSI) Reference Model

OSI Model - Principle



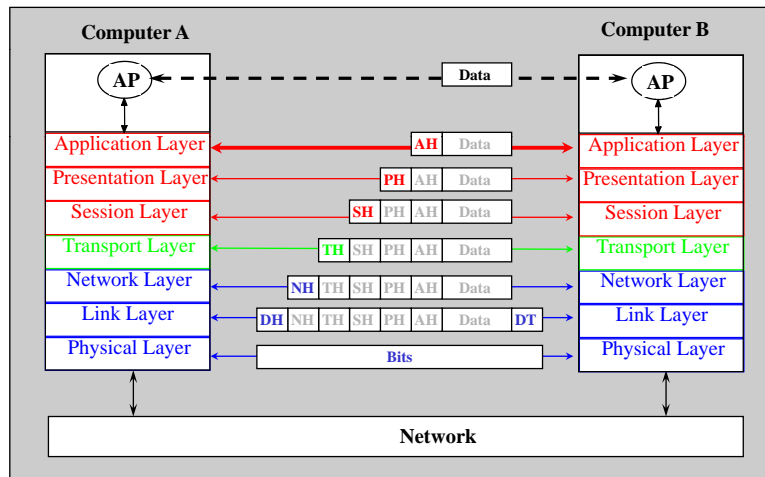
OSI Model - Details

- **Physical Layer** – concerned with the transmission of data bits between two directly inter-connected devices
- **Link Layer** – concerned with ensuring data transmission is free of errors
- **Network Layer** – ensures successful transmission of packets between two nodes of the network
- **Transport Layer** – provides end-to-end sender-destination communication, including correct packetization
- **Session Layer** – supports sessions and synchronization during data exchange



- **Presentation Layer** – concerned with syntax and coding when exchanging data
- **Application Layer** – provides access to extensive network-related services (file transfer, message exchange, etc.)

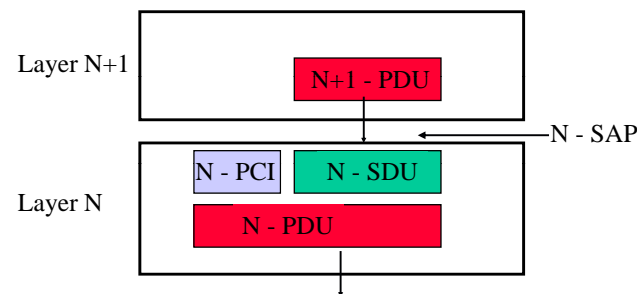
Data Exchange



OSI Terminology

- Service Access Point (SAP) is the point between the layer and the next higher layer
- Service Data Unit (SDU) is the block of data coming down from the next higher layer
- Protocol Control Information (PCI) is the header that is added on to the SDU to make the relevant data block at this layer
- Protocol Data Unit (PDU) is the block of data that is given to the next layer underneath the current layer

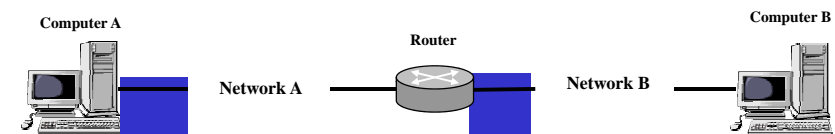
OSI Terminology



Network Layer

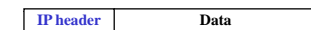
IP – Internet Protocol

Provides support for computer communications in a world of heterogeneous networks



- Exchange of IP datagrams
- Sender & destination addresses
- Best effort delivery, so can have:
 - duplication
 - out-of-order
 - data corruption
 - loss of data
 - delay

- Other issues:
 - IP header format
 - IP addressing
 - IP routing
 - IPv6



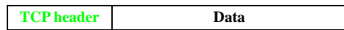
Transport Layer

TCP and UDP

TCP (Transmission Control Protocol)

Supports reliable data exchange

- Connection-based protocol
- Exchange of TCP packets
- Ensures delivery
 - correct
 - no loss
 - in-order



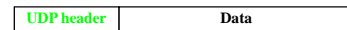
➤ Other issues:

- TCP header format
- Connection management
- Congestion control

UDP (User Data Protocol)

Supports connectionless data exchange

- Connectionless protocol
- Exchange of UDP datagrams
- Ensures encapsulated data delivery
- Less complex, faster than TCP
- Non-reliable



➤ Other issues:

- UDP header format
- Support for real-time applications

Optional: Compare TCP and UDP in details

Application Layer

FTP and HTTP

FTP (File Transfer Protocol)

Supports remote file transfers

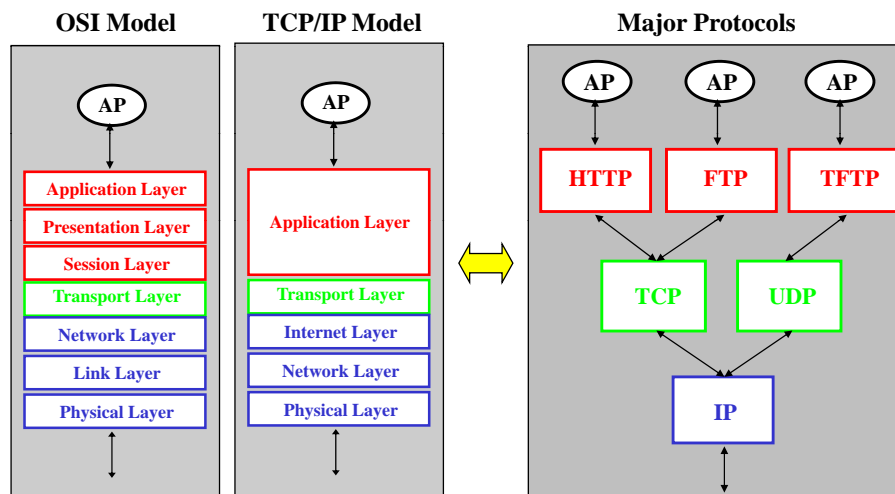
- Relies on services offered by TCP
- Provides a set of primitives that allow remote selection and transfer of files

HTTP (HyperText Transfer Protocol)

Supports web pages transfer and display

- Built on top of TCP
- Based on client (browser) requests sent to servers
- Each request is followed by the requested page and/or status code
- The browser interprets the document and displays its content, waiting for further interaction with the user

OSI and TCP/IP Models vs. Communication Protocols



Optional: Why TCP/IP Model was more successful?

Summary

- Need for inter-computer communication
- How do the computers inter-communicate
- Need for communication protocols
- OSI Model: application, session, presentation, transport, network, data link and physical layers
- OSI Model and communication protocols
- IP, TCP, UDP, FTP, HTTP

Overview: More Introductory Topics

- **what is a computer network?**
- **digital transmission**
- **components of a computer network**
- **network hardware**
- **network software**

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What is a computer network ?

- “an interconnected collection of autonomous computers”
interconnected = able to exchange information
- “a set of nodes connected by media links”
node = any device capable of sending &/or receiving data to &/or from other nodes in the network
- “a connected collection of hardware and software that permits information exchange and resource sharing”
information = data, text, audio, video, images, ...
resources = printers, memory, link bandwidth, ...

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Computer networks vary in:

- **type:** Ethernet, Cable TV, telephone network, Internet, cellular...
- **size:** from a few computers close together, to a world-wide network of networks containing millions of computers
- **technology:** copper wire, coaxial cable, wireless, fibre optics...
- **technical issues:** services offered, rules for inter-computer communications, how users are charged for network use...

Why all these variations ?

Due to a combination of factors, including:

- different target applications
- different operating environments
- historical reasons
- lack of (sensible) standards
- difficult problems \Rightarrow no “optimal” solutions

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Uses of computer networks

- **companies & organisations:**
 - resource sharing: programs, equipment, data...
 - high reliability: multiple processors/links/file copies/...
 - scalability: gradually improve system performance
 - rapid communications & remote cooperation
 - saving money
- **private individuals:**
 - access to remote & diverse information sources
 - communicating with other people
 - entertainment
 - education, healthcare, access to government...

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Computer networks use digital transmission

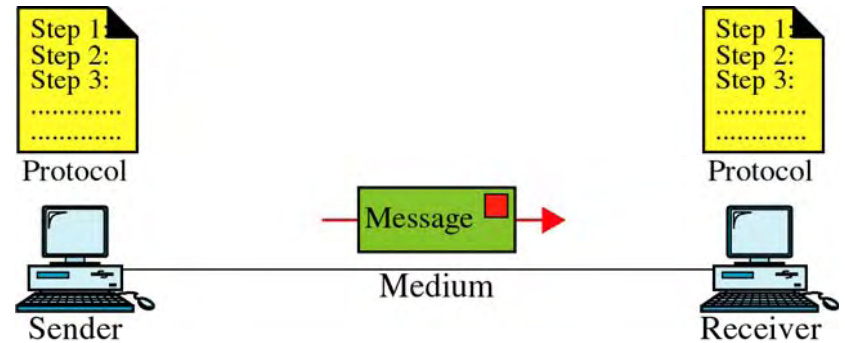
(as opposed to (older) analogue systems)

- all information represented by *bits* (only values are 0 and 1)
- more resistant to *noise*, which unpredictably changes transmitted values
 - basic idea: transmit two **very different** signals for 0 and 1
 - even if these signals are corrupted during transmission, they should still be **distinguishable** – and as long as the destination can distinguish 0 and 1, who cares about noise ?!
 - in addition, extra bits (not part of the information to be transmitted) can be added in order to reduce noise effects
 - e.g. automatically correct bit errors
- may require analogue-to-digital &/or digital-to-analogue conversions (e.g. if input/output information is in analogue form)

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Components of a computer network

- **message**: information to be communicated
- **sender**: device that sends the message
- **receiver**: device that receives the message
- **medium**: physical path from sender to receiver
- **protocol**: set of rules that govern data communications



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Computer network hardware

- *transmission technology*
 - **broadcast networks**: single communication channel **shared** by all network nodes
 - can send to: one node, all nodes, (maybe) group of nodes
 - address field in message specifies receiver(s)
 - **point-to-point networks**: many possible connection paths between any pair of nodes
 - message may have to pass through intermediate nodes on the way from sender to receiver
 - usually, need a **routing algorithm** to decide *if* a path exists from sender to receiver, and -- if multiple such paths exist -- **which one(s)** to use

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Computer network hardware (cont.)

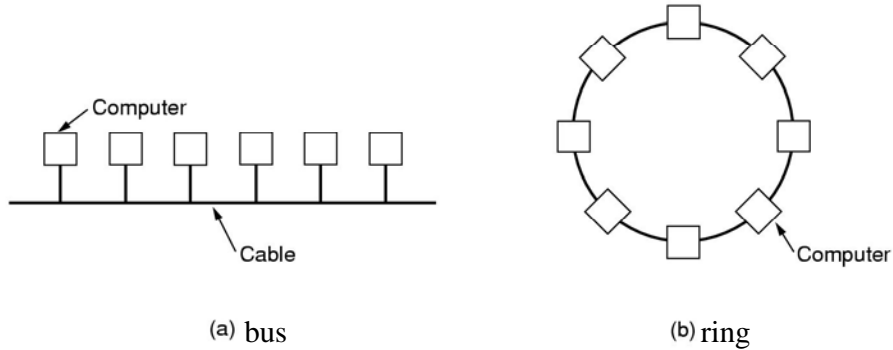
- *network scale*: different techniques are used at different scales

Interprocessor distance	Processors located in same	Example
0.1 m	Circuit board	Data flow machine
1 m	System	Multicomputer
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1,000 km	Continent	
10,000 km	Planet	

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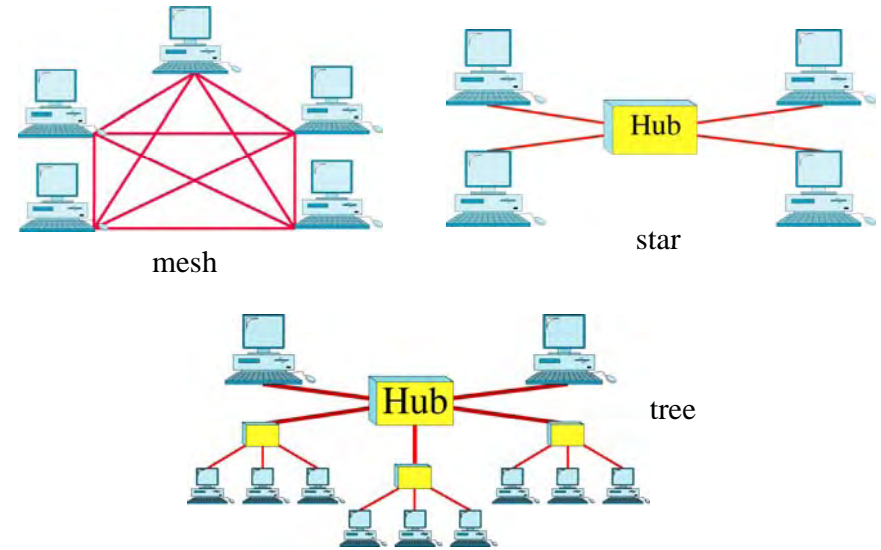
Wired Local Area Networks (LANs)

- *restricted size* \Rightarrow worst-case communication delay is bounded
- *low propagation delay* (e.g. small fractions of a second)
- *high speed* (e.g. 10 Mbps up to 1 Gbps and beyond)
- *low error rate*
- *different possible topologies for broadcast LANs:*



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other possible LAN topologies:

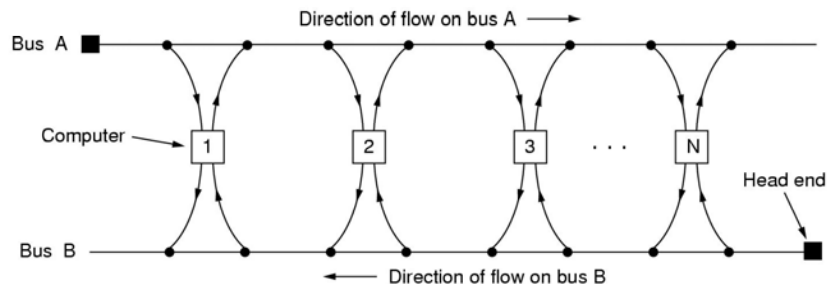


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Metropolitan Area Networks (MANs)

- bigger version of wired broadcast LANs
- may be a means of connecting multiple LANs (“backbone”)

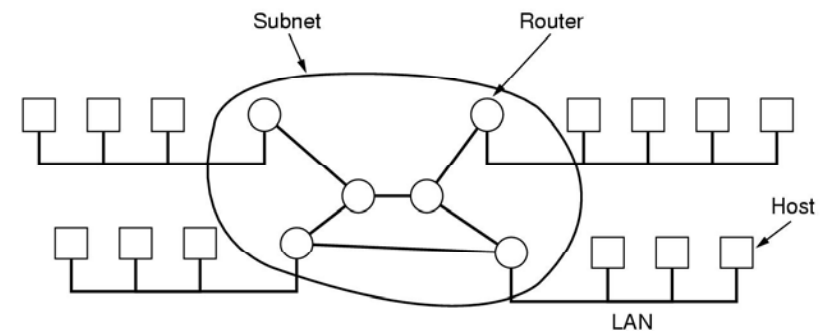
Example of a MAN: Distributed Queue Dual Bus (DQDB)



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Wide Area Networks (WANs)

- nodes which run user applications: **hosts** (or end-systems)
- **subnet** connects the hosts
- nodes within the subnet: **routers**, switches, intermediate systems...
- links within the subnet: **links**, circuits, channels, trunks...



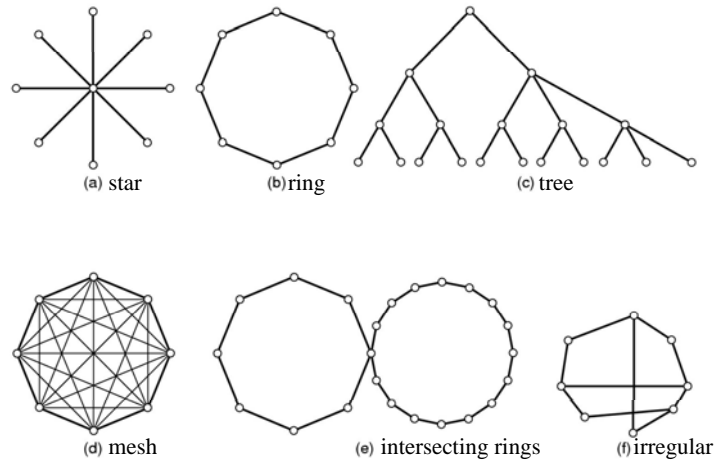
Beware: “subnet” has another (specific) meaning in IP networks!

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WANs (cont.)

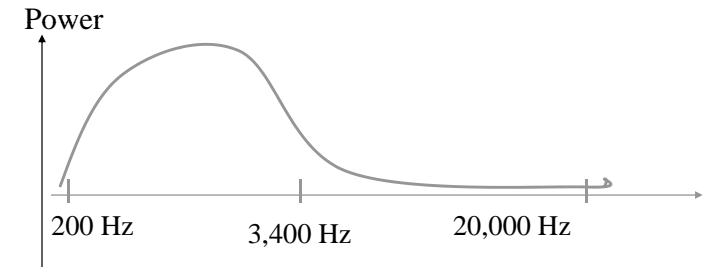
• **point-to-point subnet:** most common type of WAN.

• Examples:



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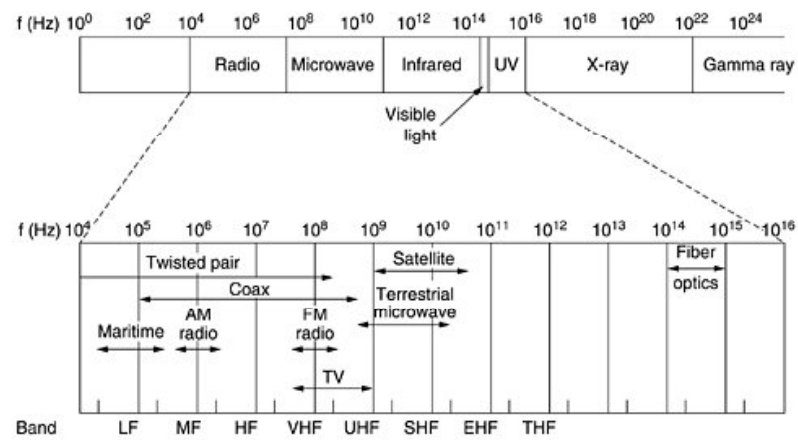
Human Voice Spectrum



Voice Spectrum

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Wireless Networks - Spectrum

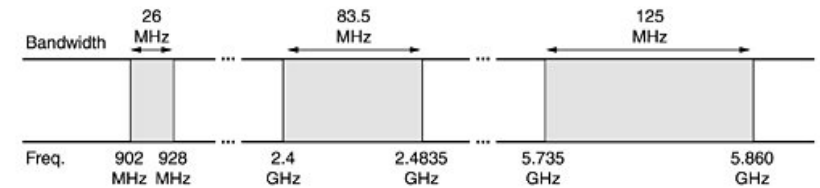


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ISM Band – WiFi

IEEE802.11 – WiFi

802.11b	-	2.4Ghz	-	11Mbps
802.11a	-	5Ghz	-	54Mbps
802.11g	-	2.4Ghz	-	54Mbps
802.11n	-	5 or 2.4Ghz	-	140Mbps



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Wireless and Mobile Networks

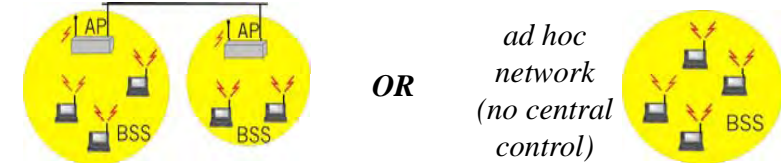
- wireless LANs (as compared to wired LANs):
 - lower speed, higher error rates
- distinction between wireless network and mobile computing:

Wireless	Mobile	Example Application
no	no	stationary wired computers
no	yes	using a (non-wireless) laptop PC
yes	no	wireless LAN in unwired office
yes	yes	rental car return handheld computer

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Wireless and Mobile Networks (cont.)

- several commercial Wireless LAN products
 - e.g. Airport (Apple), WaveLAN (Lucent), AirLAN (Solectek)
- Wireless LAN possibilities:
 - IEEE 802.11b standard** – medium-range, higher-rate
 - uses 2.4 GHz frequencies to send data at 11 Mbps (variations may run at 54 Mbps)
 - wireless devices grouped into “cells” (called BSS):

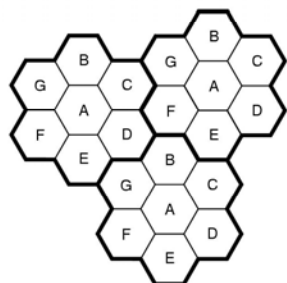


- Bluetooth emerging standard** – connect electronic devices over short distances without needing line-of-sight connections
 - 2.45 GHz band, 10-100 metre range, 721 kbps + three 64 kbps voice channels

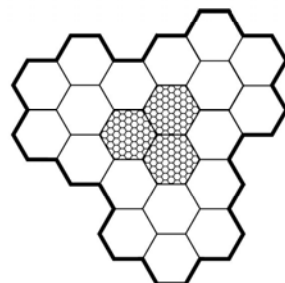
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Wireless and Mobile Networks (cont.)

- mobile telephony uses **cellular** technology
 - coverage area divided into smaller regions called *cells*
 - simultaneous transmissions from neighbouring cells (ideally) don't interfere with each other
 - important issue: *handoff* at cell boundaries
 - originally*: analogue system; *now*: digital (e.g. GSM)



(a) frequency re-use

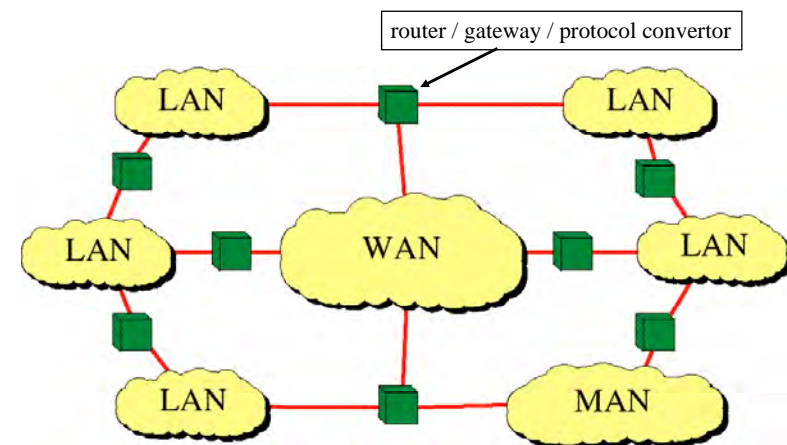


(b) smaller cells in overloaded areas

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Internetwork

- collection of connected networks



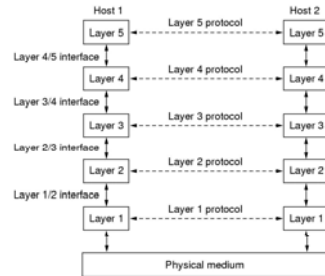
- “an internet” vs. “the Internet”
 - the Internet = connected set of networks which all use IP

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Computer network software

- structured as a hierarchy of **layers**
 - each layer offers certain *services* to the higher layers, while hiding from the higher layers the *details* of how those services are implemented: **hierarchical modularity**
- a particular layer in one network node communicates with the corresponding layer in another network node by using an agreed **protocol** for that layer
 - this communication may be *actual* or *virtual*

Example:



Note: the lower layers are often implemented (at least partly) in hardware

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Computer network software (cont.)

- actual communication is “vertical” except in the physical medium
- peer entities are programmed as if data transmission were “horizontal”
 - together, these peer entities execute *distributed scripts*
- interfaces** between adjacent layers define which operations and services the lower layer offers to the higher layer
 - minimise* amount of information passed between layers
 - allow different *equivalent* implementations of a layer
- encapsulation:**
 - at the sender, layer N may add control information to the data it receives from layer N+1 before passing the (increased) data to layer N-1; at the receiver, layer N-1 passes data to layer N, which can read, act upon, & remove this control information before passing the (reduced) data up to layer N+1
 - layer N should not need to know which portion of layer N+1’s data is control information, or its meaning

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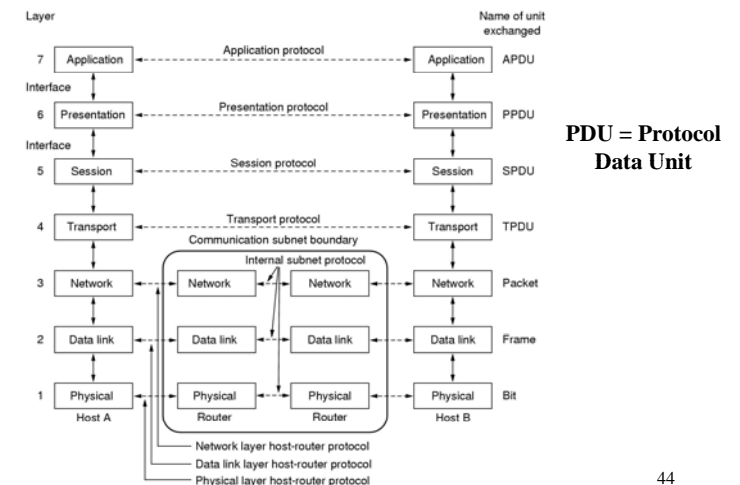
Computer network software (cont.)

- network architecture** = set of layers & protocols
 - doesn’t contain implementation details or interface specifications
- basic principle: each layer should perform a specific set of well-defined functions
- basic question: how many layers are needed ?
 - we’ll see that different network architectures have different numbers of layers and/or different functions within their layers
 - minimum of 2: one focused on (user) application issues, and one focused on network issues
 - more realistically, the following general issues must be addressed:
 - physical signal transmission between directly connected nodes
 - digital transmission of a message between neighbouring entities
 - end-to-end communication between a source and a destination
 - communications needed to run a distributed (user) application

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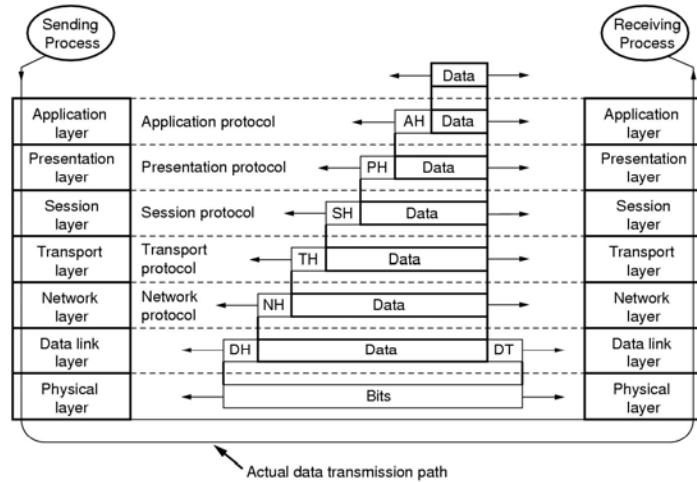
ISO Reference Model for Open System Interconnection (OSI)

- late 70’s: a framework for the structure of open communication systems, not a network architecture (not intended to have a single standard protocol at each layer)



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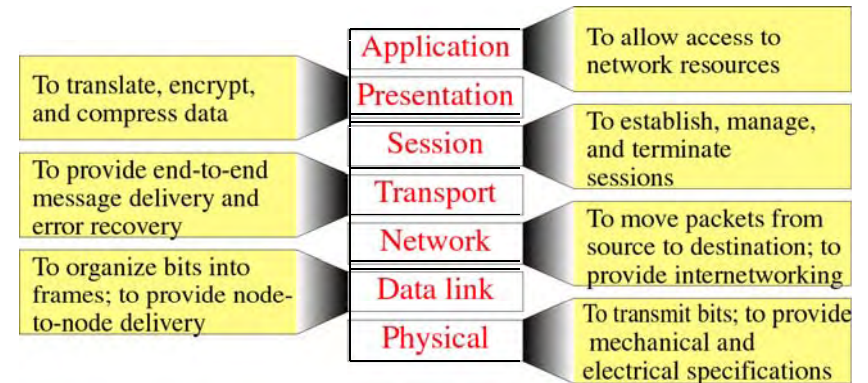
Data Transmission in the OSI model



Ideally, each layer is independent of the other layers and interacts with AT MOST 2 other layers

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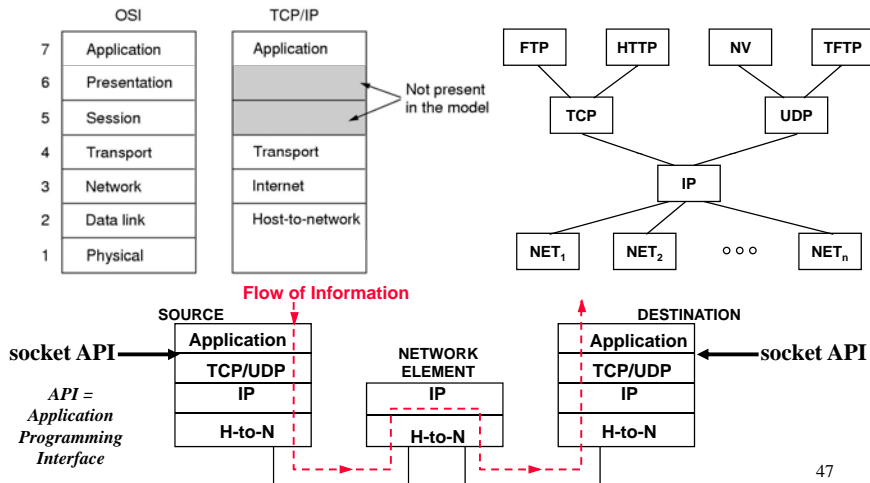
Summary of layer functions in the OSI model



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The TCP/IP Reference Model (or "Internet Protocols")

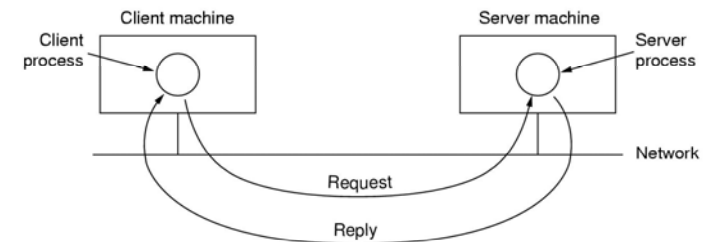
- OSI model dominated by a telecommunications mentality
- mid 70's onwards: data communications protocols implemented
 - widespread use, public domain specs, computer industry support



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The TCP/IP Reference Model (cont.)

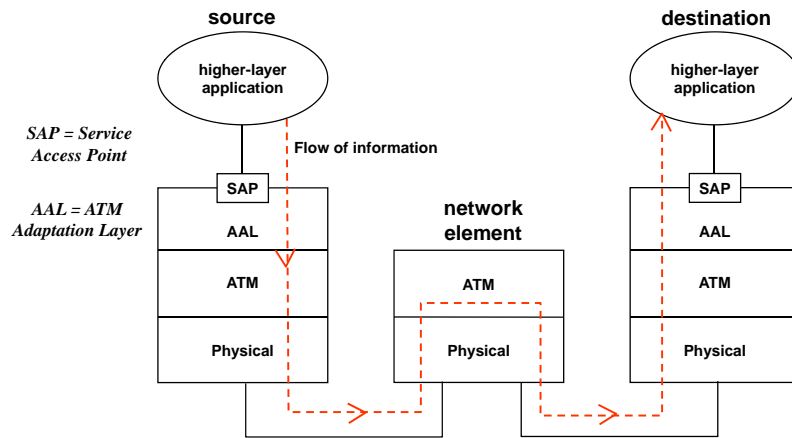
- based on the **client-server** model of communications
 - server = a process which provides a service when requested
 - client – a process which requests a service
- in general, a client program is run only when it is needed, and is *finite* (started by the user/application, terminates when service received)
- a server program should run all the time, and is *infinite* (when started, it runs infinitely, waiting for incoming requests and responding to them)



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The Broadband ISDN Reference Model

- ISDN = Integrated Services Digital Network
- based on Asynchronous Transfer Mode (ATM) technology
- late 80's onwards: developed by telecomms & datacomms groups



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Why is the OSI model not the dominant one ?

- unclear what layers 5,6, & 7 should do
- layers 1, 2, & 3 have had to be split into sublayers, so the original layering was unrealistic
- several functions (e.g. error control, flow control) can occur in more than one layer
- with 7 layers, long processing delays are possible
- de facto standards (such as the Internet protocols, which were already widely used) don't fit very well with the OSI model
- the OSI model was devised before the protocols were invented
- associated OSI service definitions and protocols are complex, difficult to implement, and relatively inefficient in operation
- **However:** unlike the Internet protocols, the OSI model distinguishes between *services*, *interfaces*, and *protocols*, and has proved to be a useful "textbook" introduction to layered networking
 - OSI terminology is widely used in describing other models

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Web & Internet Names

- Most of the Internet sites have easy names like yahoo.com, u2.com or ucd.ie
- Sometimes you have to put in the www. in front of it to make it work, sometimes the computer does it
- Once you have a name like this you can then make up others as long as they end in the name e.g.:
www.yahoo.com, docs.yahoo.com, mail.yahoo.com
or even www.mail.yahoo.com

More than .com

.com	mtv.com
.org	un.org, nationalacademies.org
.net	hea.net, eircom.net, esat.net
.edu	berkeley.edu, upenn.edu
.gov	fbi.gov, cia.gov, nasa.gov
.mil	navy.mil, army.mil, af.mil
.tv	Tuvalu Pacific Island
.cc	Cocos Indian Ocean Island
.ws	Samoa now Web Site
.ie	Ireland

Web & Internet Names

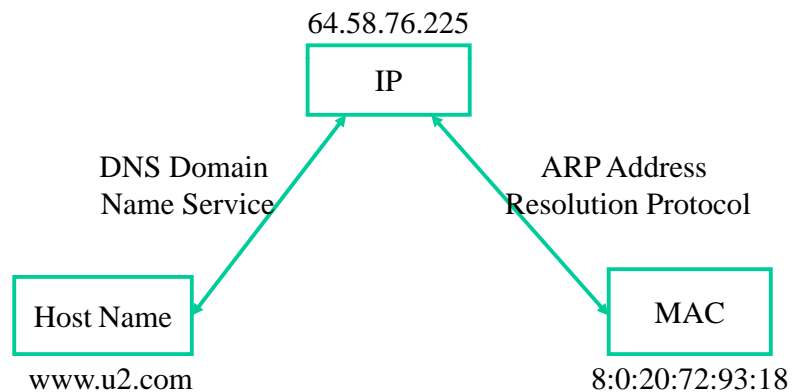
- This name that we have been talking about is the domain name of the site, or the host name
- Some big sites want to have many different computers serving that site
- Some smaller sites might want to have many different domain names on the one computer

The Internet & Internet Protocols

- How does your computer find web addresses?
- All Internet devices (computers, internet enabled mobile phones, laptops, computer servers and network equipment) have a unique address
- This is called the IP address of the device and is usually given in a dotted decimal format:

64 . 58 . 76 . 225
each number is between 0 and 255

Name Translation



IP Addresses

- The Internet address does not have to remain the same all the time, for example when you dial in you get assigned an address
- You can find the IP address on your computer by typing at the DOS prompt

`ipconfig`

IP Address Classes

- There are different addresses for different places on the Internet
- By looking at the first number you can see which class of address is being used

Class	1 st Byte	hosts	nets	used
A	<128	16,777,216	128	95
B	128... 191	65,534	16,384	5,892
C	192... 223	254	2,097,152	128,378
D	224... 239		268 million	dynamic
E	240... 255		134 million	reserved

- Which class of IP addresses are you using here?

Name to IP

- One way to find out which IP address is being used by a site would be to try the following command

`nslookup www.u2.com`

- This will give you information on which IP address might be for this site, or sometimes which set of IP addresses can be used

How to get there!

- Does the computer that you are using have a direct link to the site that you want to look at?
- Well to find out you can look at the route that that is usually taken by using the command

`tracert www.manutd.com`

- This will show you all the pieces of network equipment that are used, the time taken between them and the IP address of all of them

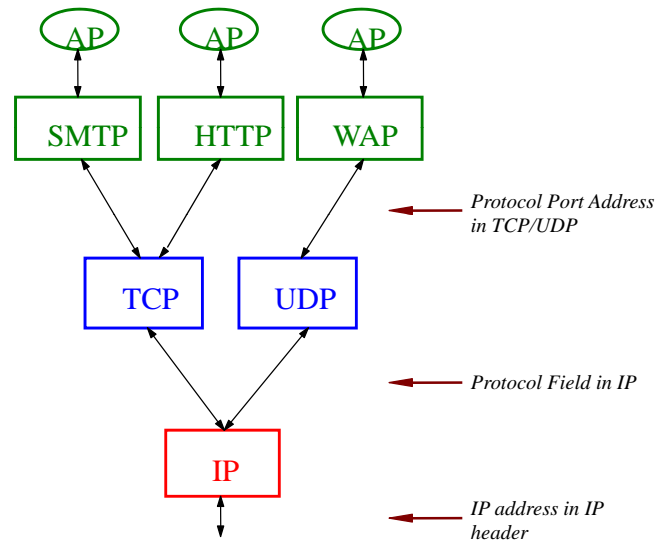
Network in Ireland

- So what can we see about the network from UCD to the outside world
- Well to find out you can look at all the topology of the network by the following site

www.heanet.net

The Internet

TCP/IP Protocol Suite



Two Modes of Operation

- IP provides a best-try service for the transfer of individually-addressed data pieces
- To enable applications avail of this a connectionless transport protocol known as the “User Datagram Protocol” (UDP) can be used
- Applications that require a reliable transfer service the IP service is converted into a reliable connection-oriented service by the “Transmission Control Protocol” (TCP)

Port Address

- When you are on the computer, you will probably want more than one application running at a time
- For this to happen we need another address, called the port address so that UDP/TCP can give the application the correct data
- The total address in TCP/IP the composite address of the internet-wide IP address of the host plus the additional protocol Port Address

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