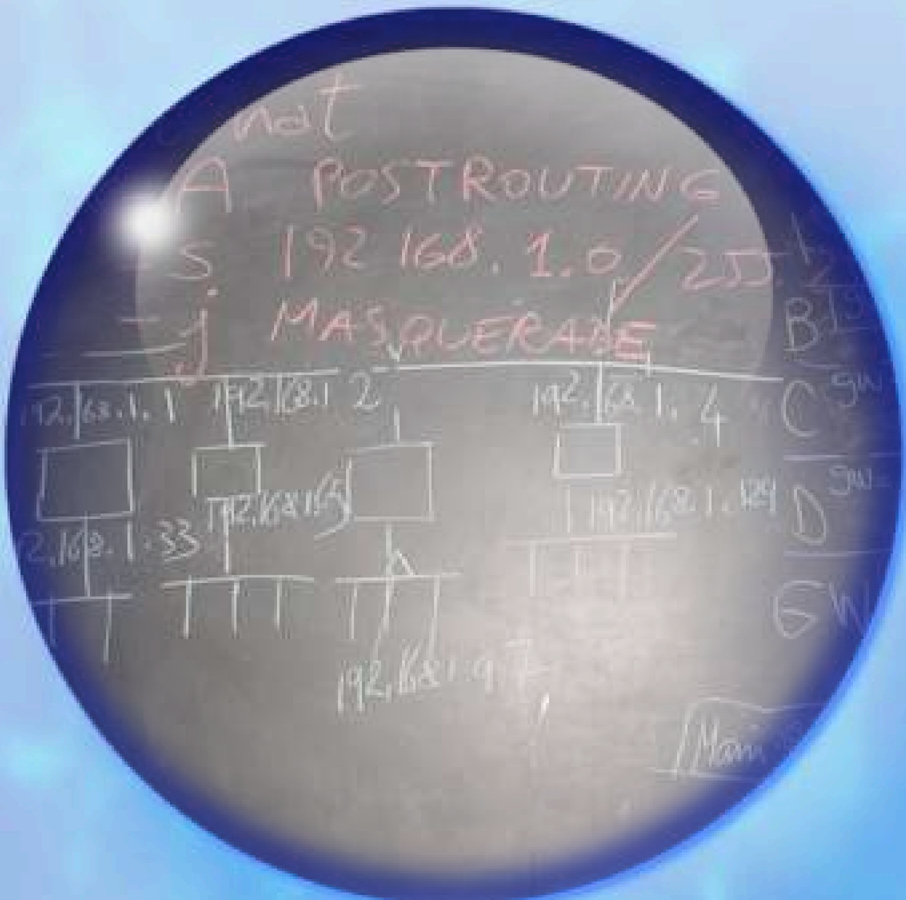
Networking Basics

Aeronomy and RadioPropagation Lab
The Abdus Salam
International Centre of Theoretical Physics



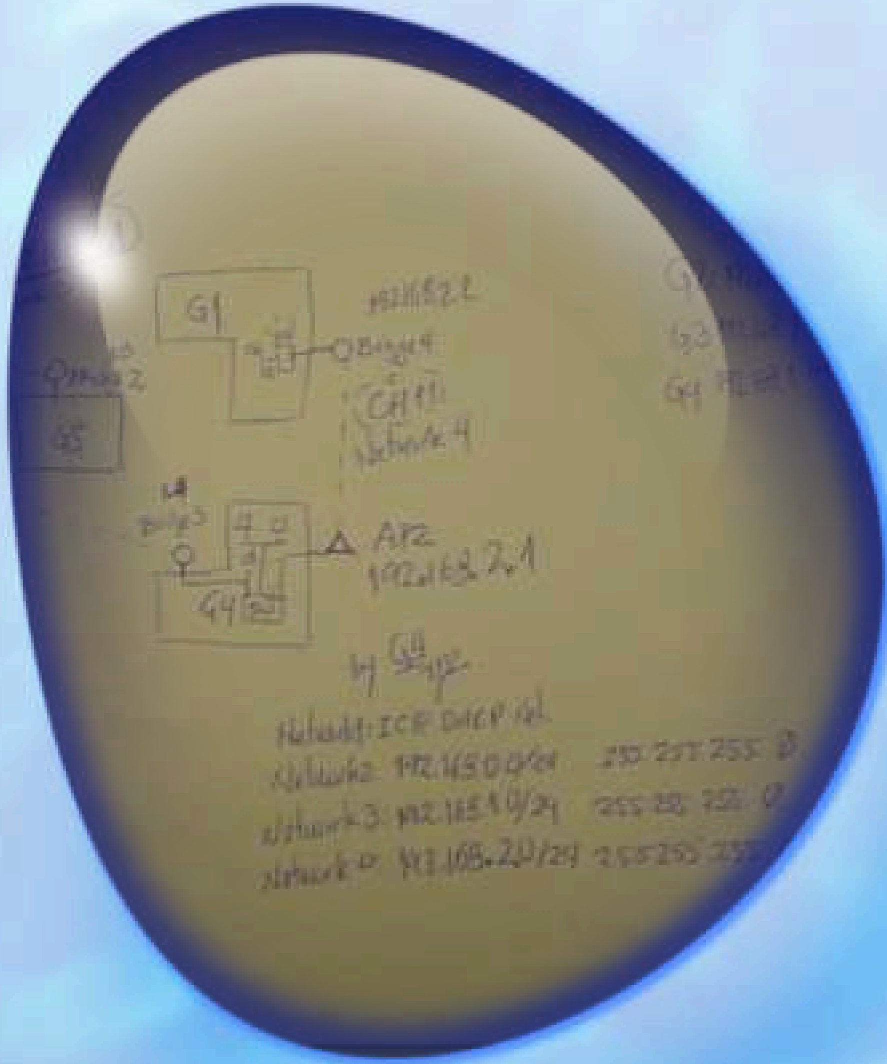
Carlo Fonda
cfonda@ictp.it

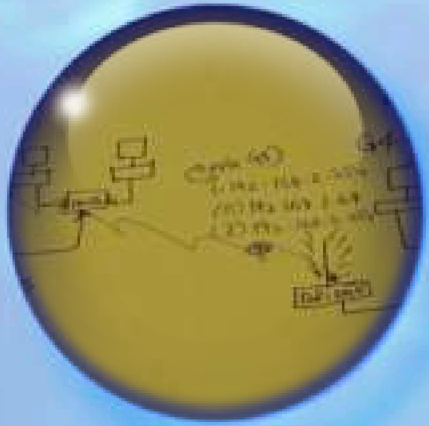
Marco Zennaro
mzennaro@ictp.it

Copyright

Agenda

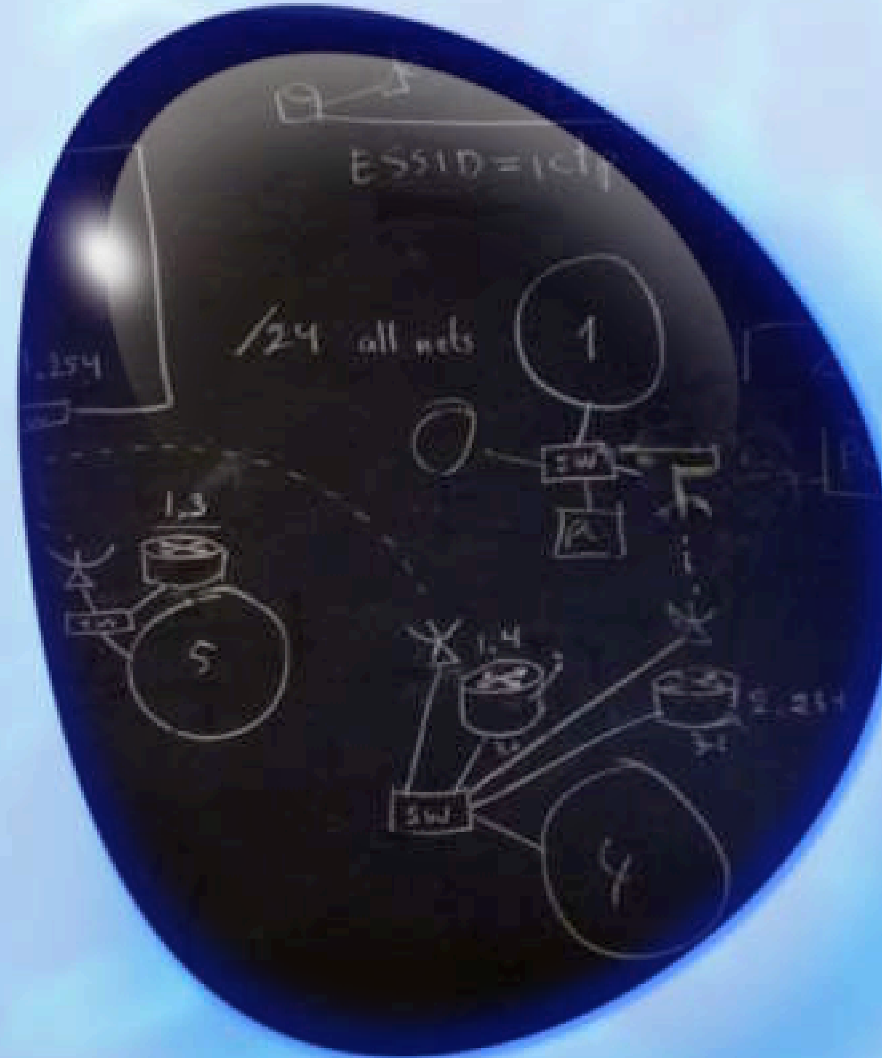
- Why a network?
- Standardisation
- Theory: the OSI Model
- Reality: the Internet
- Network classification

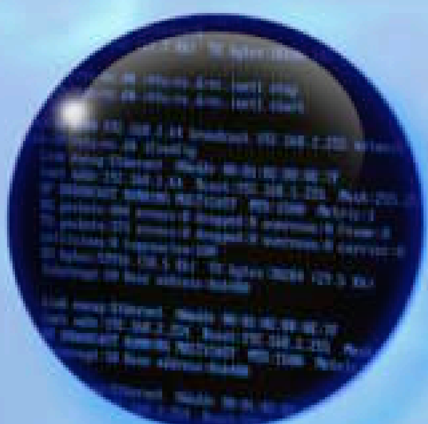




Agenda

- Media and Hardware
- Internet Addressing
- Subnets
- Domain Names System
- Host configuration





Why a computer network?

- Distribute pieces of computation among computers (nodes)
- Coordination between processes running on different nodes
- Remote I/O Devices
- Remote Data/File Access
- Personal communications (em@il, chat, audio/video conference, messaging)
- World Wide Web

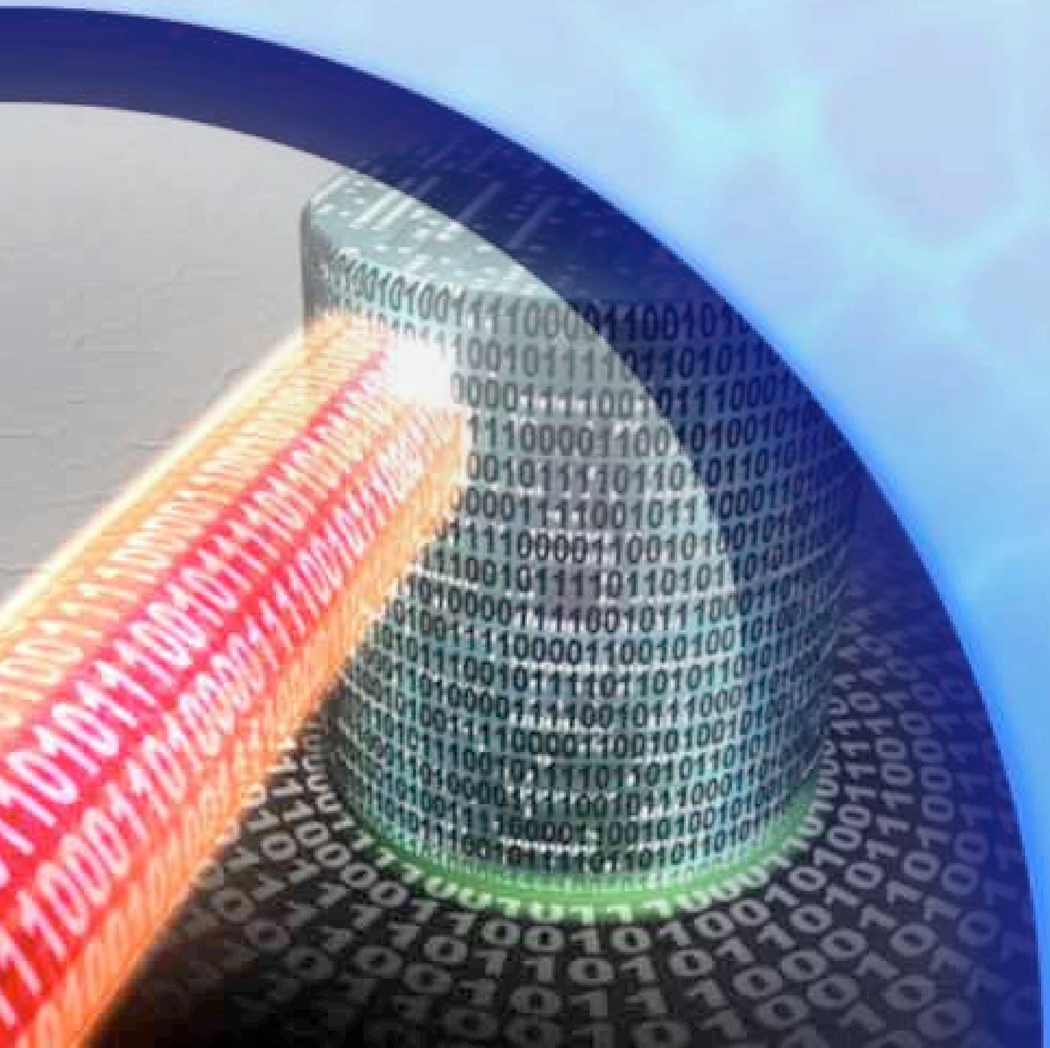
Why standards?

- There are:
  - Many types of connection media : telephone lines, optical fibers, cables, radios, etc...
  - Many different types of machines and operating systems: Macs, PCs, ...
  - Many different network applications: em@il clients, web browsers, ...
  - Many... many :)

Why standards?

- So the need to find a common set of agreements for different aspects of the communication technology.
- This is called standardisation.

What is a “standard”?



- Agreements must be at many levels …
  - How many volts for 0? And for 1?
  - How to determine the end of a message?
  - How to handle lost messages?
  - How many bits for different data types? Integers/Strings, etc.
  - Are characters coded in ASCII ?
  - How machines are identified in a network? Names, numbers ?
  - How to find the way to reach a machine ? How if there are more choices ?
  - How different applications (and OSs) speaks together through the network ?

The ISO Model

- ISO is the International Organization for Standardisation
- ISO developed a standard model for communications, called the OSI (Open Systems Interface) Model

International Organization for Standardization

OSI Model

- Open Systems Interface Model:
  - Model = it means that it's only theory! In fact the OSI model is not yet fully implemented in real networks
  - Open System = It can communicate with any other system that follows the specified standards, formats, and semantics.

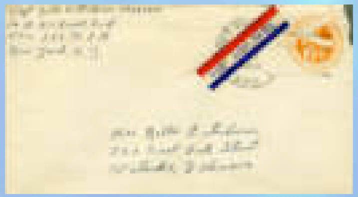
Protocols

- The rules that specify how the parties may communicate are often named PROTOCOLS.
- A standard may be seen as a collection of protocols (and other additional rules).

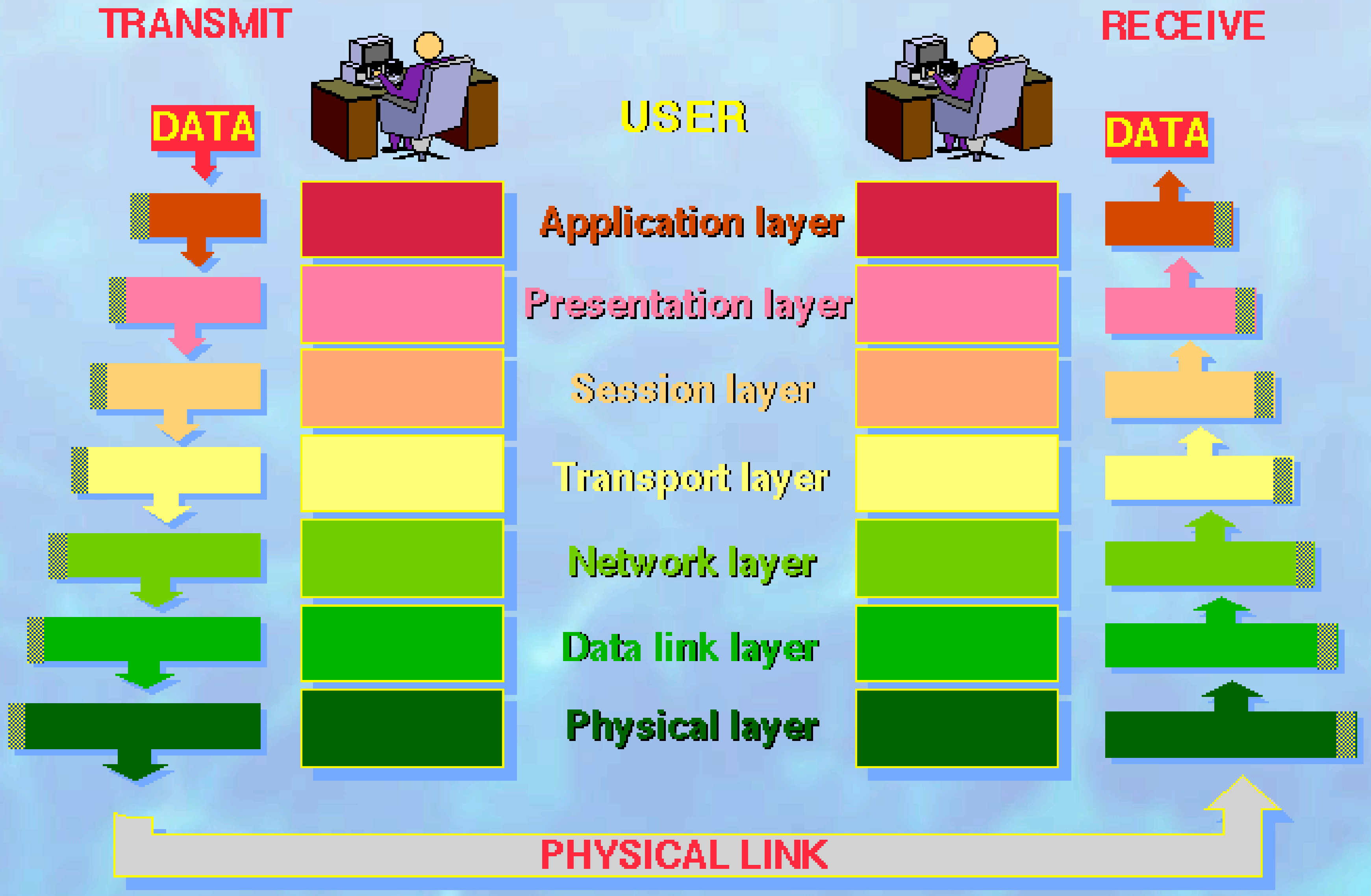
OSI Protocols

- The OSI Model supports two general types of protocols. Both are common:
  - Connection-Oriented
    - 1. Sender and receiver first establish a connection, possibly negotiate on a protocol. ("virtual circuit")
    - 2. Transmit the stream of data.
    - 3. Release the connection when done.
    - E.g. Telephone connection.

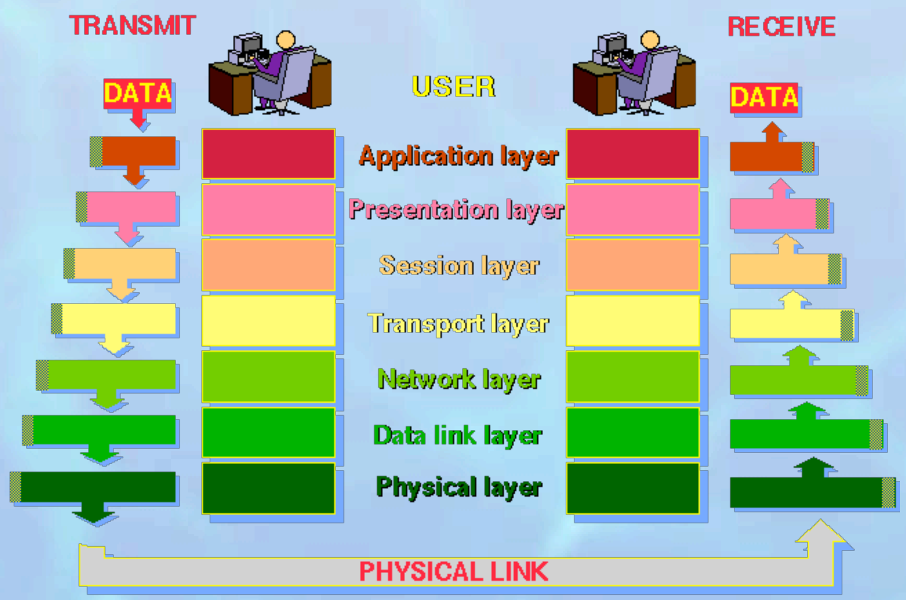
  - Connectionless
    - No advance setup is needed.
    - Transmit the message ("datagrams") when sender is ready.
    - E.g. surface mail.



7 Layers

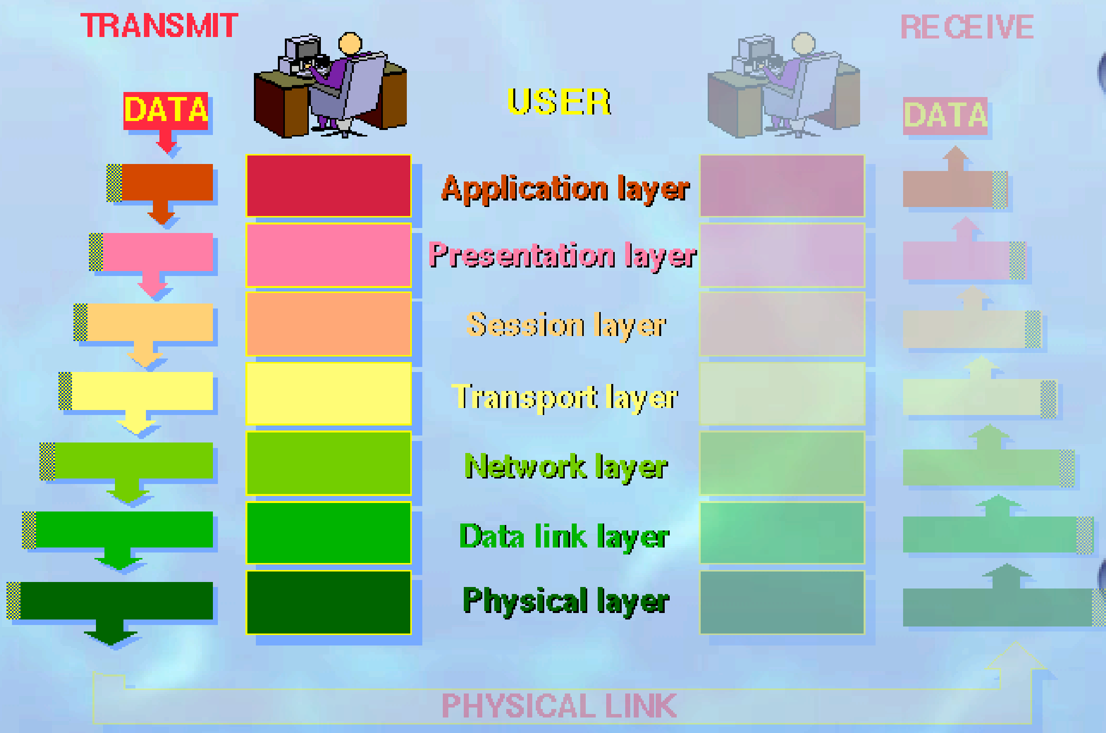

TRANSMIT
RECEIVE
DATA
USER
DATA
Application layer
Presentation layer
Session layer
Transport layer
Network layer
Data link layer
Physical layer
PHYSICAL LINK

7 layers

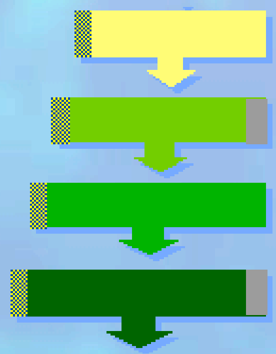


- The OSI model consists of 7 layers.
- Each layer deals with a specific aspect of the communication.
- Each layer provides an interface to the layer above. The set of operations define the service provided by that layer.

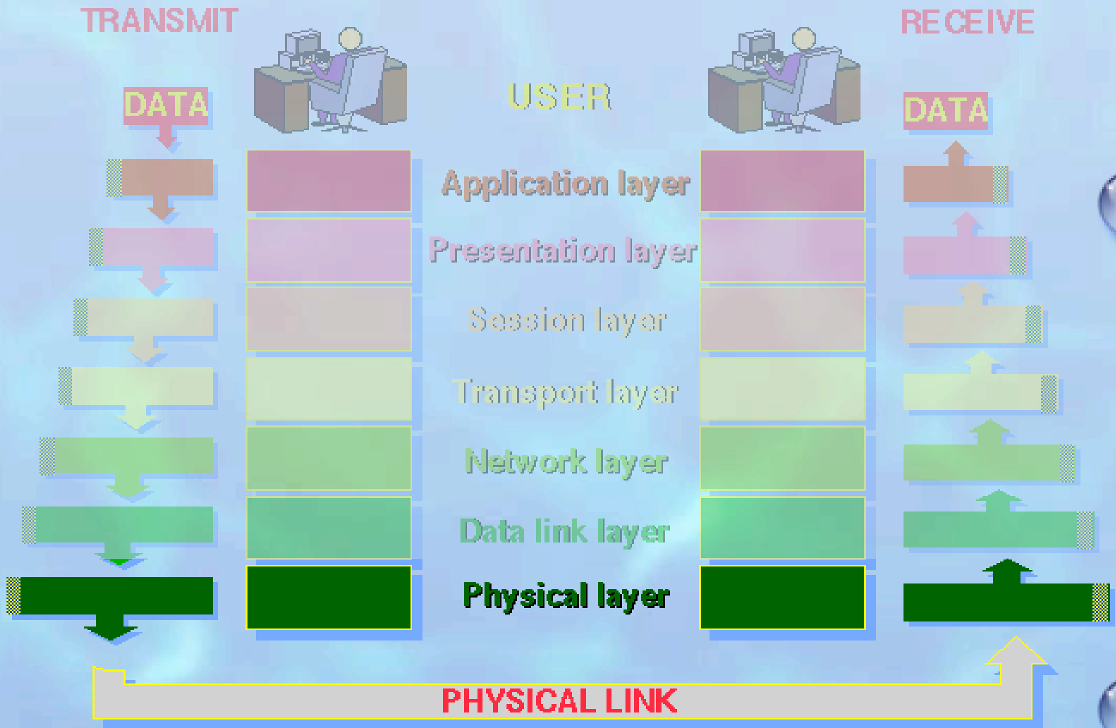
7 layers



- A message sent by the top layer is passed on to the next lower layer until the most bottom one.
- At each level a header may be prepended to the message. Some layers add both a header and a trailer.

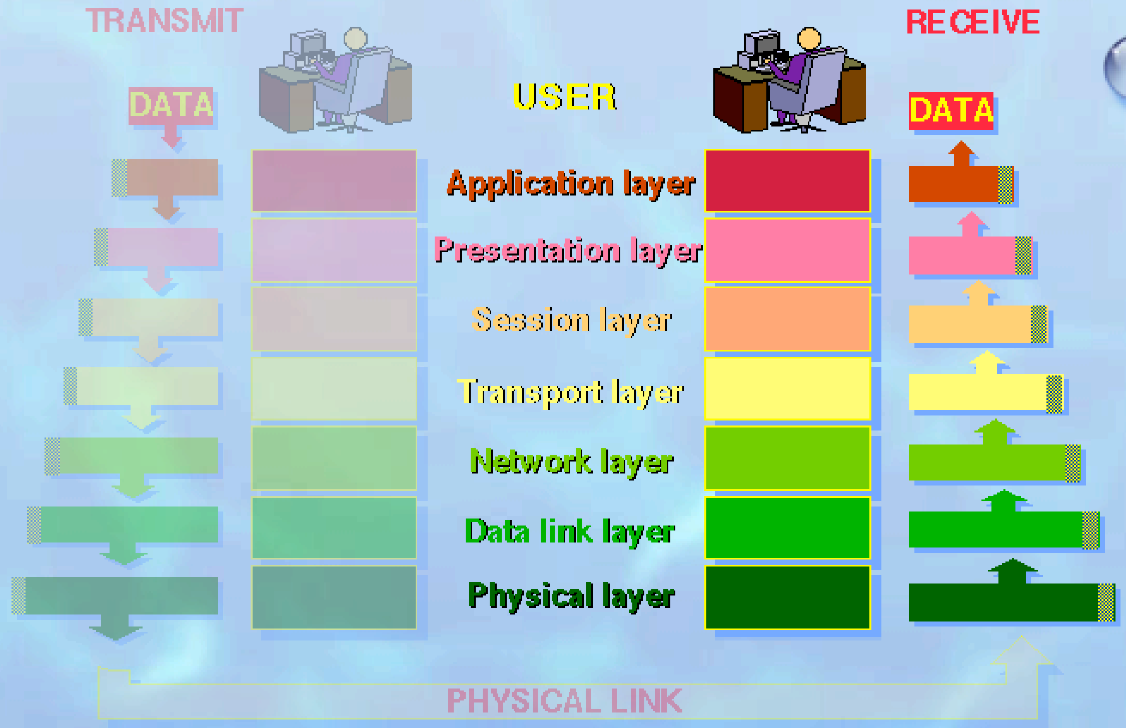


7 layers



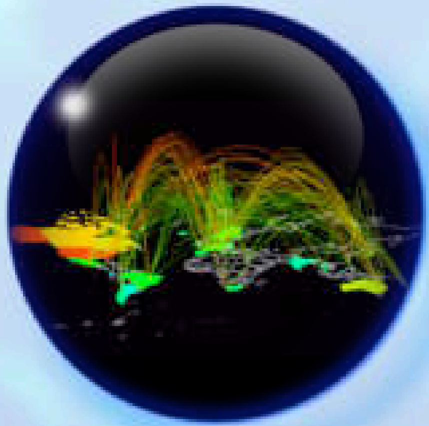
- The lowest layer transmits the message over the network link to the receiving machine.
- It communicates with the most bottom layer of the receiver.

7 layers



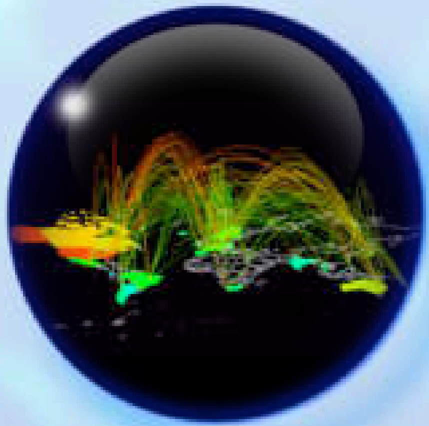
- At the receiving side, each layer strips the header (trailer), handles the message using the protocol provided by the layer and passes it on to the next higher layer.
- Finally the message arrives to the highest layer in the receiver.

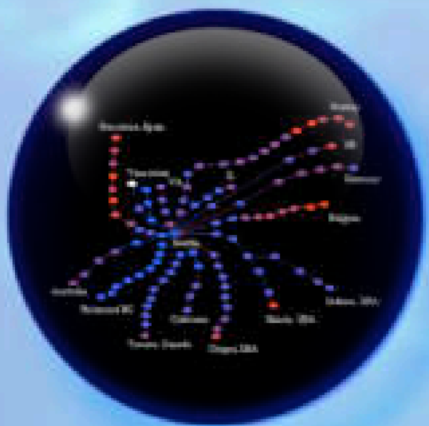
1: Physical



- Concerned with the transmission of bits.
- How many volts for 0, how many for 1?
- Number of bits of second to be transmitted.
- Two way or one-way transmission
- Standardized protocol dealing with electrical, mechanical and signaling interfaces.
- Many standards have been developed,

E.g. RS-232 (for serial communication lines), X.21

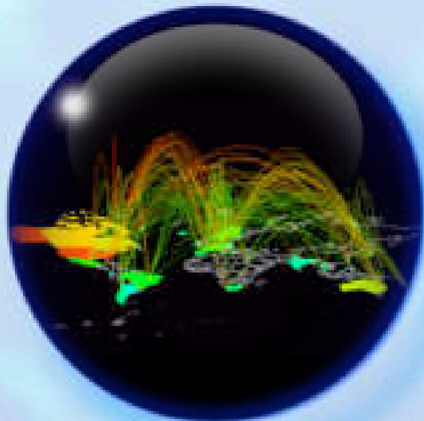




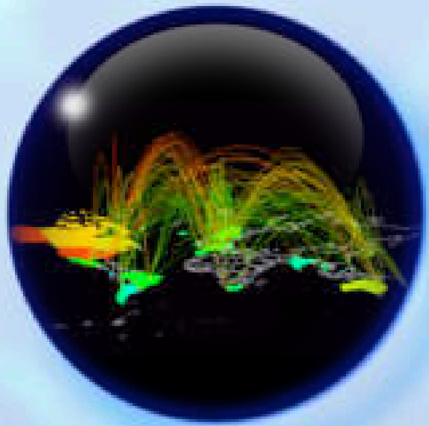
2: Datalink

- Handles errors in the physical layer.
- Groups bits into frames and ensures their correct delivery.
- Adds some bits at the beginning and end of each frame plus the checksum.
- Receiver verifies the checksum.
- If the checksum is not correct, it asks for retransmission. (send a control message).
- Consists of two sublayers:
    - Logical Link Control (LLC) defines how data is transferred over the cable and provides data link service to the higher layers.
    - Medium Access Control (MAC) defines who can use the network when multiple computers are trying to access it simultaneously (i.e. Token passing, Ethernet [CSMA/CD], etc...).

3: Network



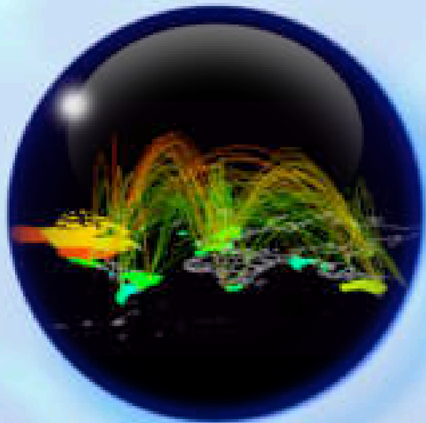
- Concerned with the transmission of packets.
- Choose the best path to send a packet (routing).
- It may be complex in a large network (e.g. Internet).
- Shortest (distance) route vs. route with least delay.
- Static (long term average) vs. dynamic (current load) routing.
- Two protocols are most widely used.
  - X.25
    - Connection Oriented.
    - Public networks, telephone, European PTT.
    - Send a call request at the outset to the destination.
    - If destination accepts the connection, it sends an connection identifier.
  - IP (Internet Protocol)
    - Connectionless.
    - Part of Internet protocol suite.
    - An IP packet can be sent without a connection being established.
    - Each packet is routed to its destination independently.

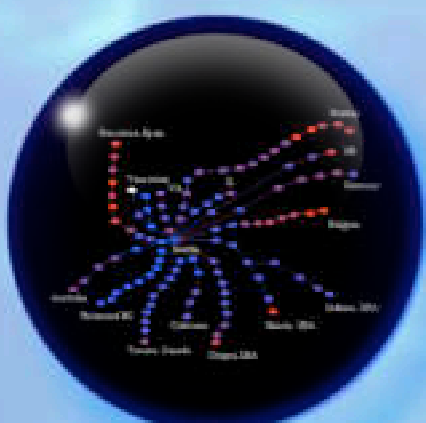


4: Transport

- Network layer does not deal with lost messages.
- Transport layer ensures reliable service.
- Breaks the message (from sessions layer) into smaller packets, assigns sequence number and sends them.
- Reliable transport connections are built on top of X.25 or IP.
- In case IP, lost packets arriving out of order must be reordered.
- Two examples:
  - TCP(Transport Control Protocol): Internet connection–oriented transport protocol.
    - TCP/IP is widely used for network/transport layer.
  - UDP (Universal Datagram Protocol): Internet connectionless transport protocol.
    - Application programs that do not need connection–oriented protocol generally use UDP.

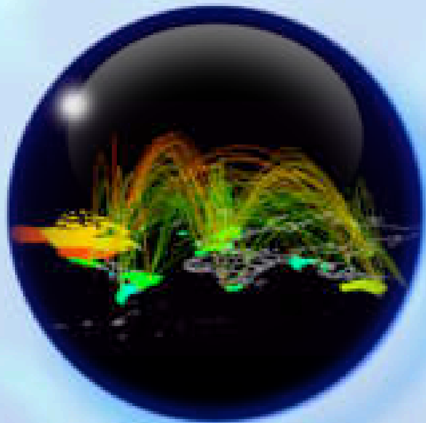
5: Session

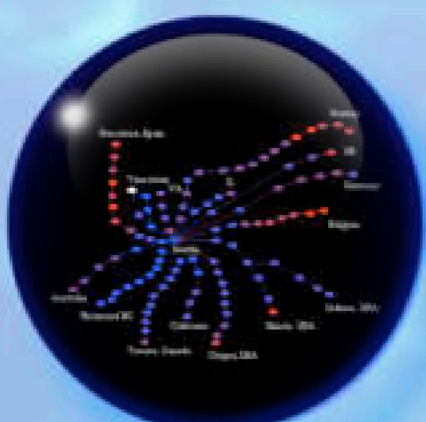




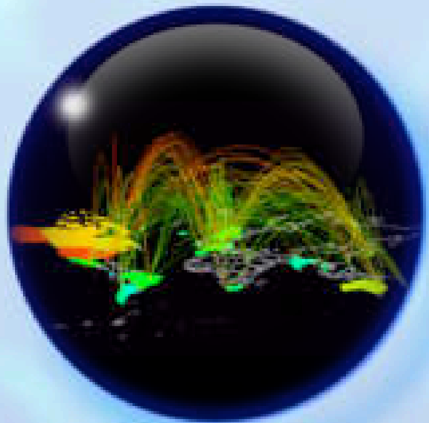
- Just theory! Very few applications use it.
- Enhanced version of transport layer.
- Dialog control, synchronization facilities.
- Rarely supported (Internet suite does not).
- Supposed to be the right place for security and authentication.

6: Presentation





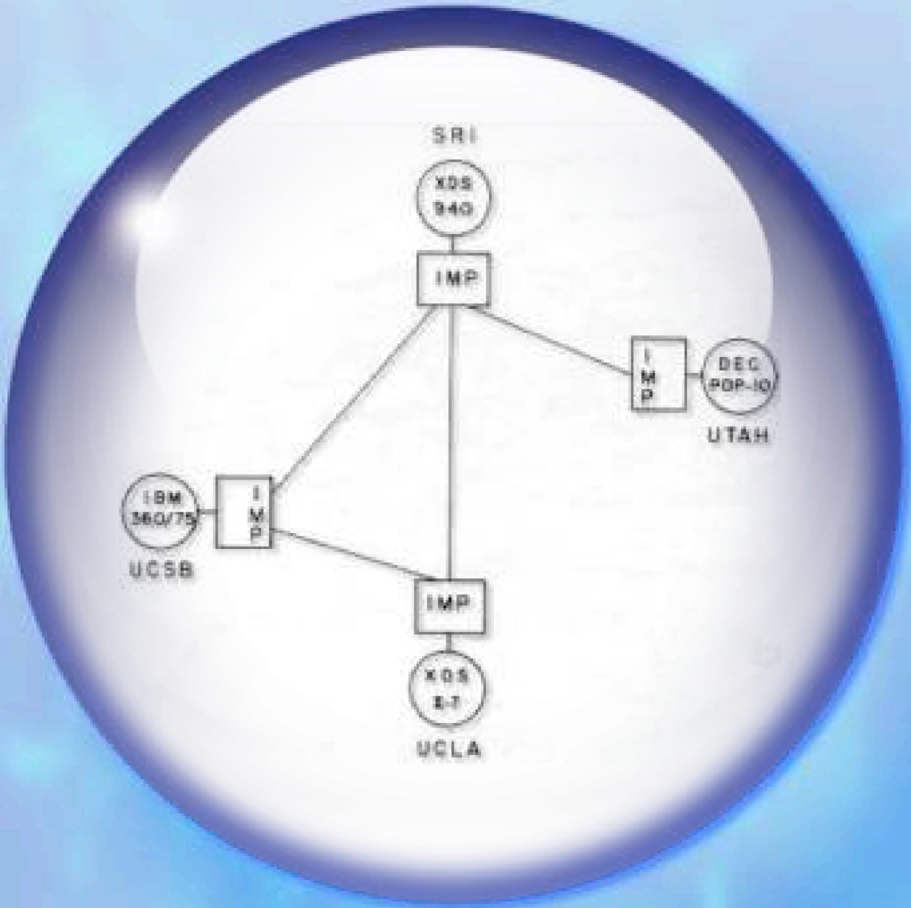
- Just theory! Very few applications use it.
- Concerned with the semantics of the bits.
- Define records and fields in them.
- Sender can tell the receiver of the format.
- Makes machines with different internal representations to communicate.
- If implemented, the best layer for cryptography.



7: Application

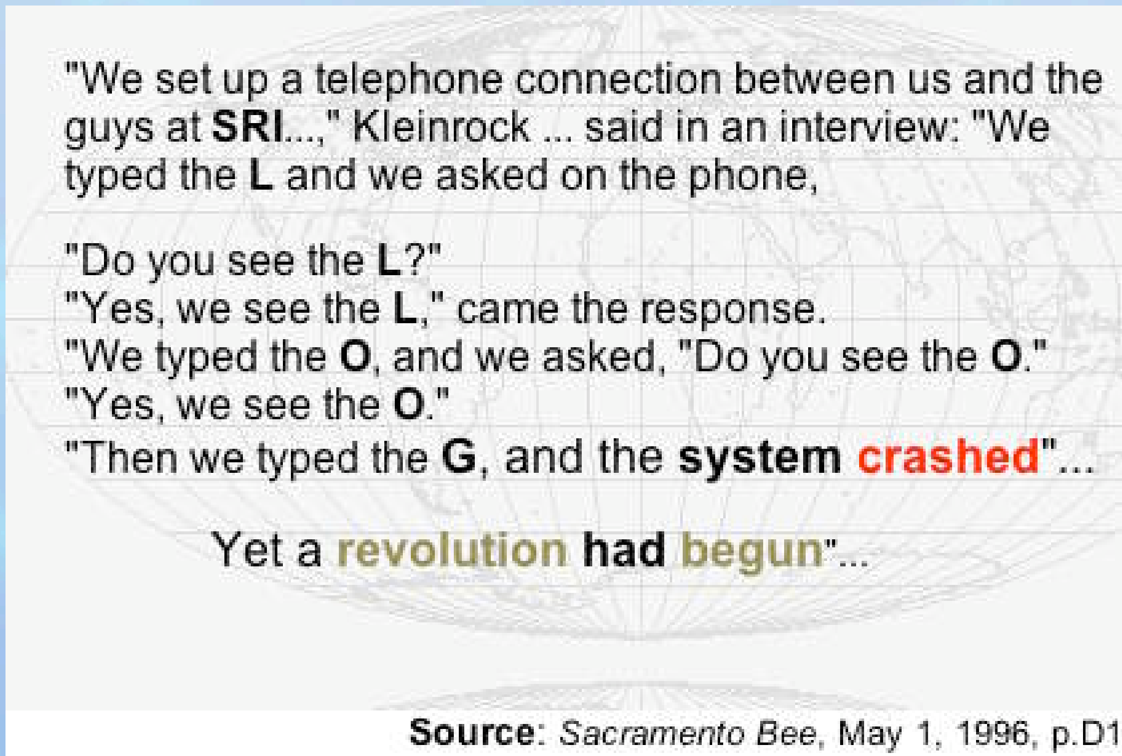
- Collection of miscellaneous protocols for high level applications
- Electronic mail, file transfer, connecting remote terminals, etc.
- E.g. SMTP, POP, IMAP, FTP, Telnet, SSH, HTTP, HTTPS, SNMP, etc…

The real standard



- The Atlantic cable of 1858 was established to carry instantaneous communications across the ocean for the first time. Although the laying of this first cable was seen as a landmark event in society, it was a technical failure. It only remained in service a few days. Subsequent cables laid in 1866 were completely successful and compare to events like the moon landing of a century later... the cable ... remained in use for almost 100 years.
- The Internet was born in 1969

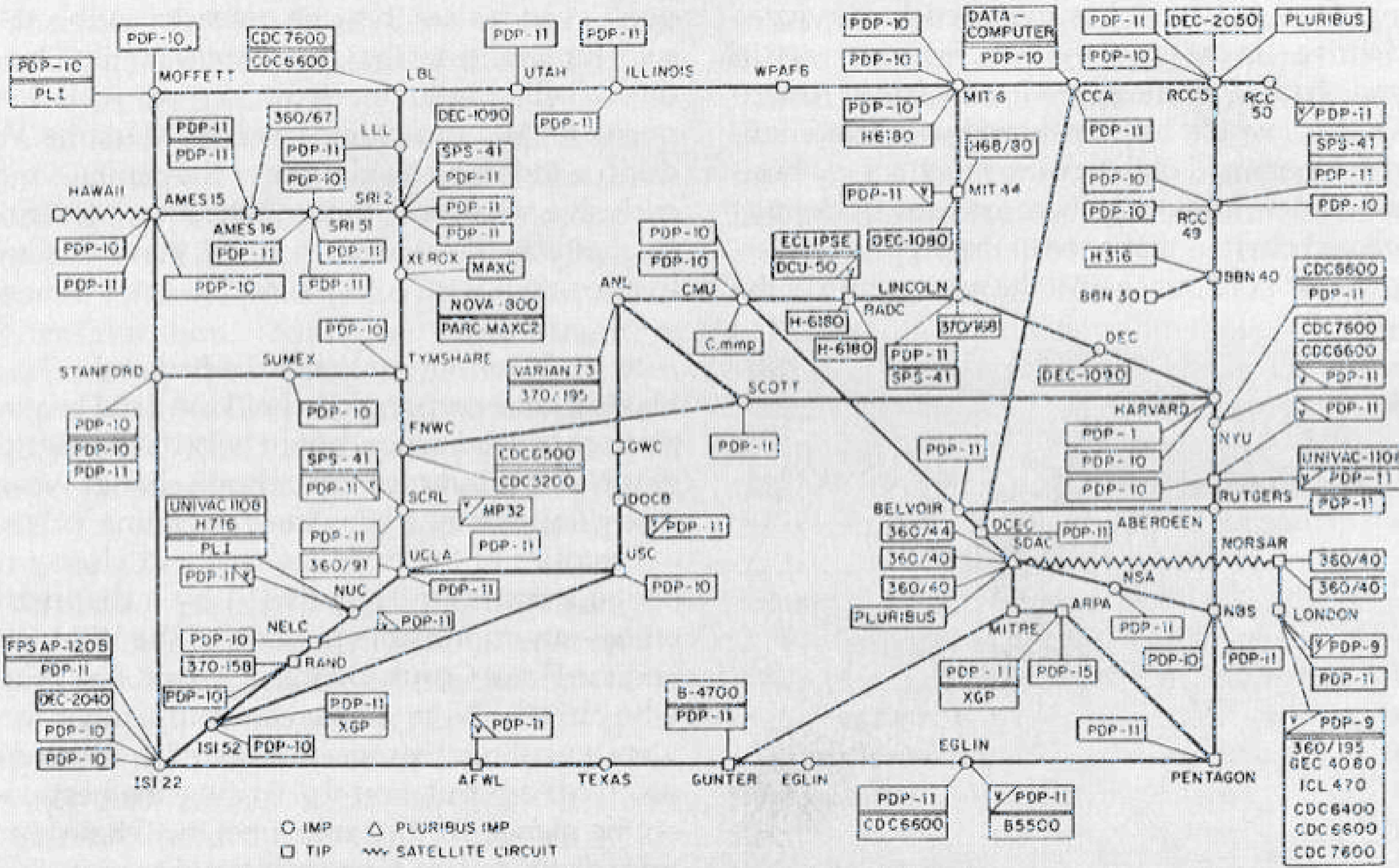
The real standard



The first LOG: UCLA–Stanford

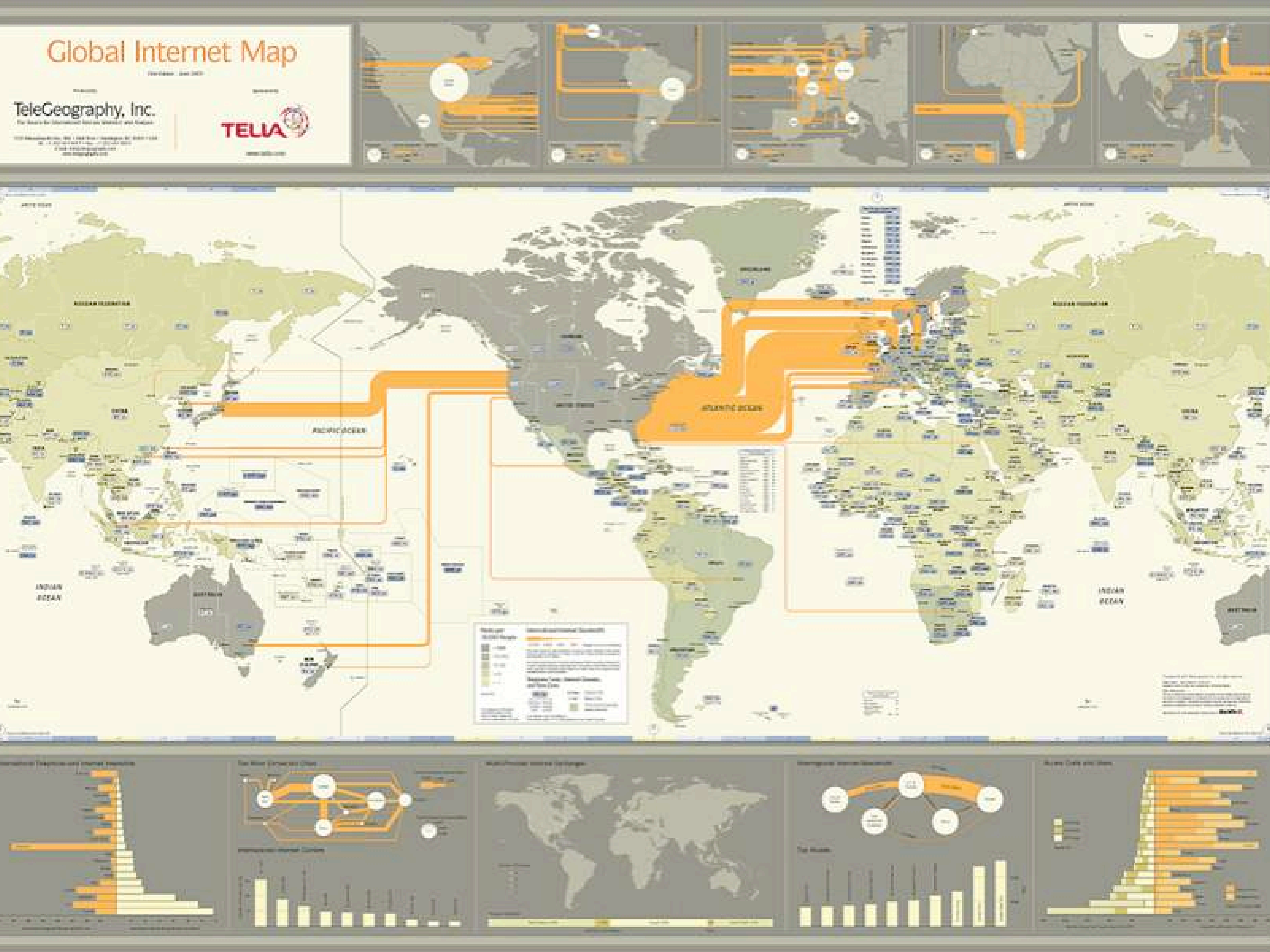
- Around Labor Day in 1969, BBN delivered an Interface Message Processor (IMP) to UCLA that was based on a Honeywell DDP 516, and when they turned it on, it just started running. It was hooked by 50 Kbps circuits to two other sites (SRI and UCSB) in the four–node network: UCLA, Stanford Research Institute (SRI), UC Santa Barbara (UCSB), and the University of Utah in Salt Lake City.

ARPANET LOGICAL MAP, MARCH 1977



(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

NAMES SHOWN ARE IMP NAMES, NOT (NECESSARILY) HOST NAMES


Global Internet Map
TeleGeography, Inc.
TELIA
PACIFIC OCEAN
ATLANTIC OCEAN
INDIAN OCEAN
INDIAN OCEAN

The Internet Model

- The INTERNET and TCP/IP Reference model (aka "the Internet suite")
- Is the standard de facto for the majority of networks
- It is simpler than the OSI Model. It has only four layers:
  - OSI Presentation and Session layers are missing
  - The Internet layer (OSI: Network) handles packets
  - The Host-To-Network layer (OSI: Datalink + Physical) handles frames and bits

The Internet Model

OSI	Internet Suite
7. Application	Application
6. Presentation	
5. Session	
4. Transport	Transport
3. Network	Internet
2. Data link	Host-to-network
1. Physical	

Measuring a Network

Measuring the “speed”

- Performance parameters:
  - Latency
  - Data transfer rate
  - Bandwidth

Measuring the "speed"

- Latency
  - It's the time required to transfer an empty message between relevant computers.
  - Sum total of
    - 1. delay introduced by the sender software.
    - 2. delay introduced by the receiver software.
    - 3. delay in accessing the network.
    - 4. delay introduced by the network.
  - Typical values:
    - Local Ethernet: 0.2–1 msec
    - Wireless link: 1.5–3 msec
    - Long distance (many hops): 10–100 msec
    - Intercontinental/Satellite: 100–500 msec
    - Multiple Satellite hops: 500–1500 msec

Measuring the “speed”

- Data transfer rate
  - It’s the speed at which data can be transferred between sender and receiver in a network, once transmission has begun.
  - bit/sec (bps)
  - bytes/sec (Bps)
  - Typical values:
    - 100baseT Ethernet: 100 Mbps
    - 10base2, 10base5 and 10baseT Ethernet: 10 Mbps
    - Wireless 802.11: 1–54 Mbps
    - Telephone modem: 56 Kbps
    - Packet Radio AX25: 1200–19200 bps

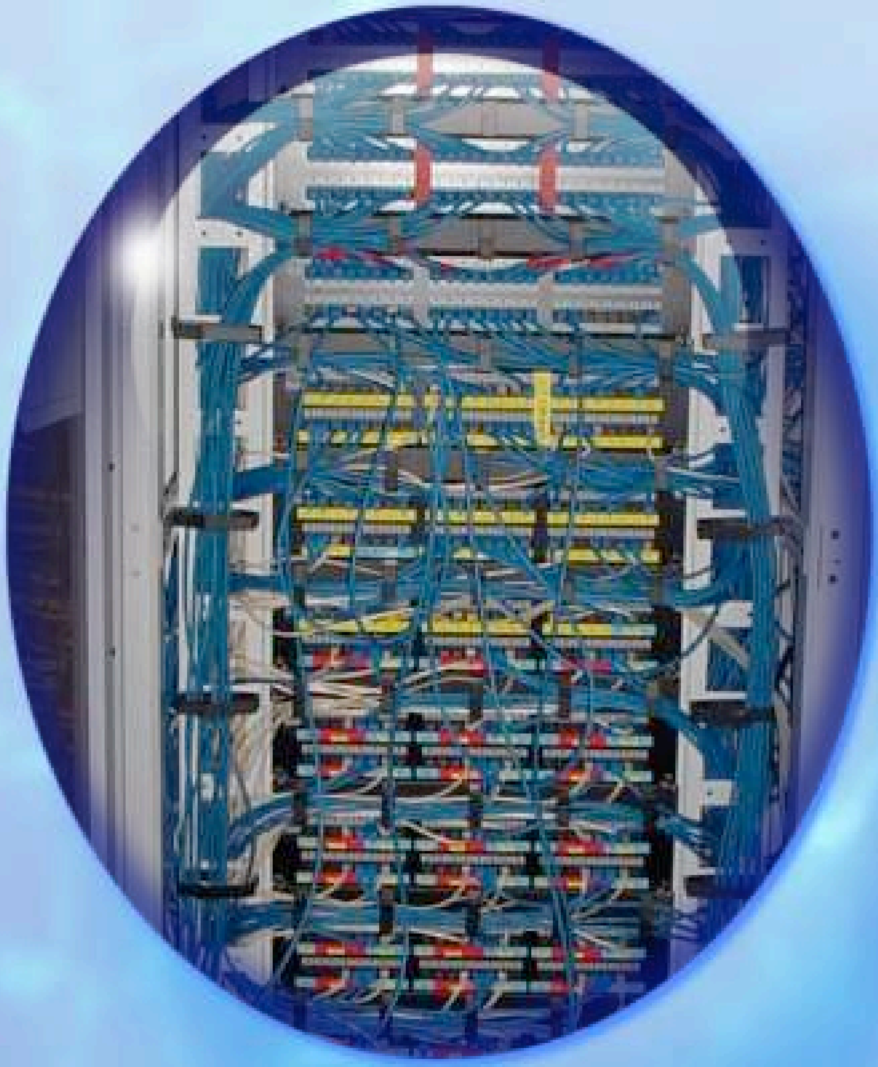
Measuring the "speed"

- Message transfer time

  = latency + (length of message) / (Data transfer rate)

- Bandwidth: is the total volume of traffic that can be transferred across the network
- High/low bandwidth
- The real value may be much lower than the theoretical one (i.e. due to collisions, congestion, protocol overhead, etc...)

Network dimension



- Networks can be divided into three types based on geographical areas covered:
  - LANs
  - MANs
  - WANs

Network dimension

- LAN
  - Local Area Network.
  - Typically it connects computers in a single building or campus.
  - E.g. Ethernet, WiFi (WLAN).

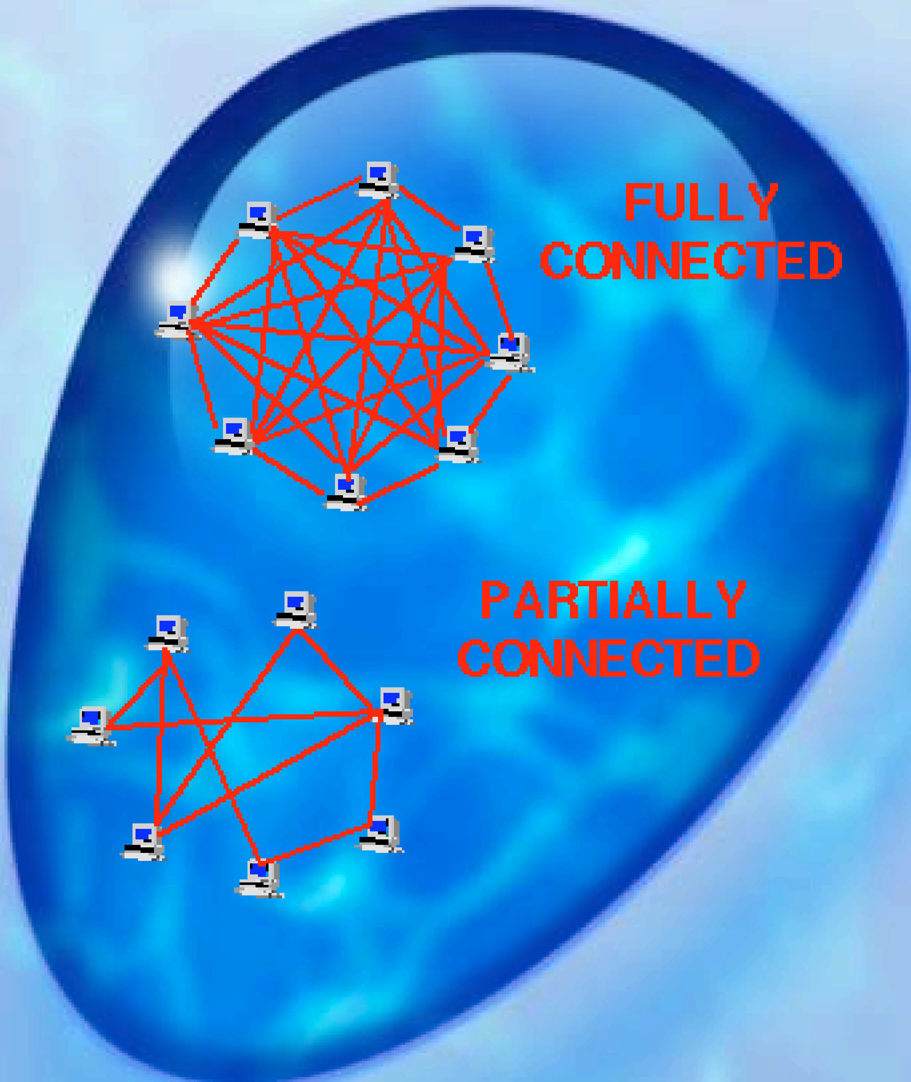
Network dimension

- MAN
  - Metropolitan Area Network.
  - It covers towns and cities (50 km).
  - Optical fibers, microwave links, often operated by Telecoms.

Network dimension

- WAN
  - Wide Area Network.
  - It covers large distances (regions, countries, continents).
  - Satellites, optical fibers, microwave links. Very expensive.

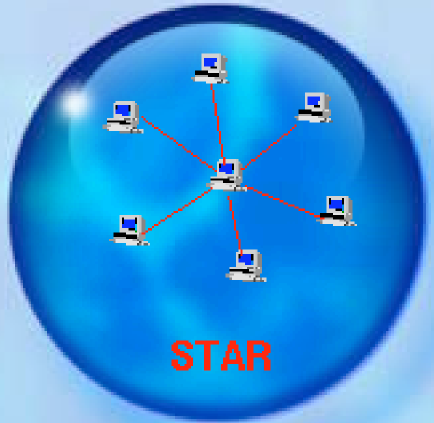
Topology

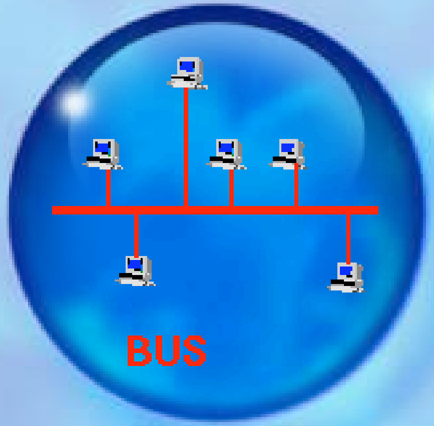


- Networks may be structured according to various topologies:
  - fully connected
  - partially connected

Topology

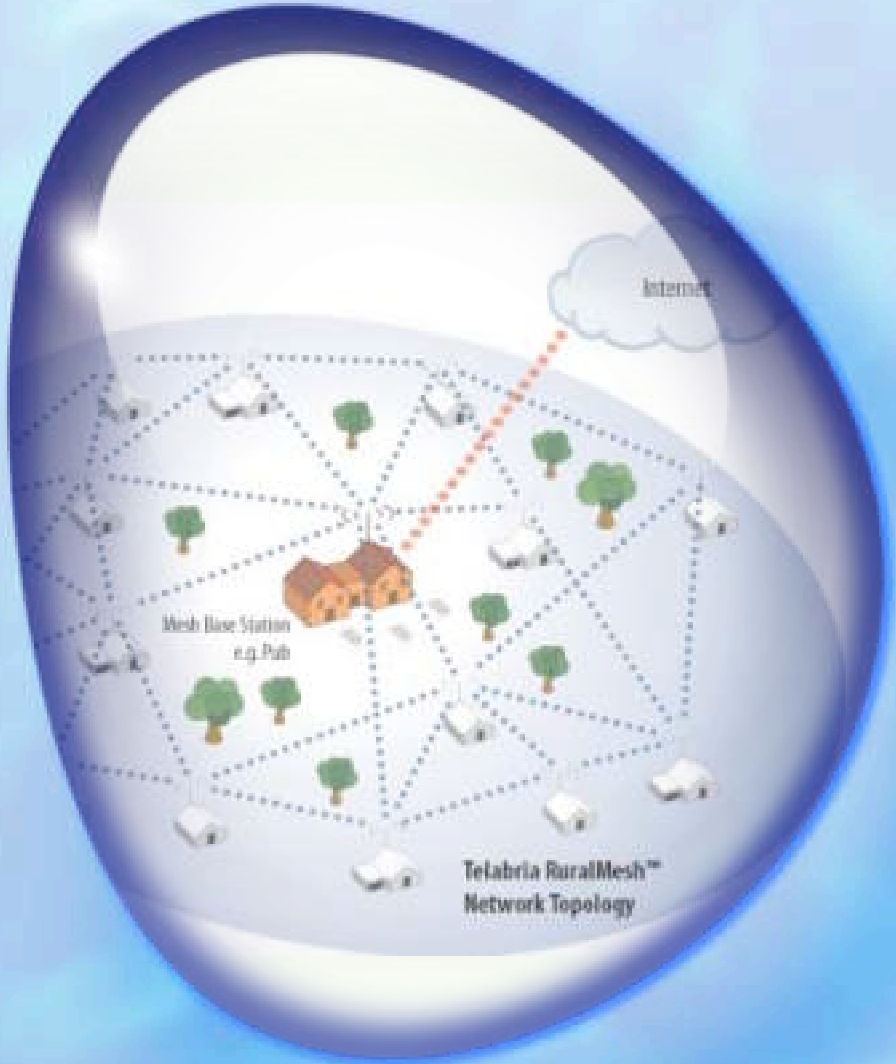
- Examples of simple network topologies are:
  - Ring
    - E.g. Token Ring by IBM
  - Star
    - Used in the past, with many terminals connected to one server
  - Bus
    - The bus is a shared media

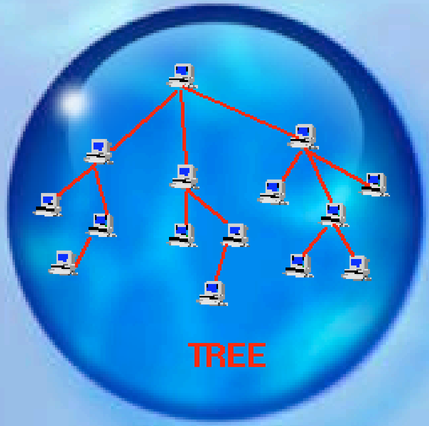




Topology

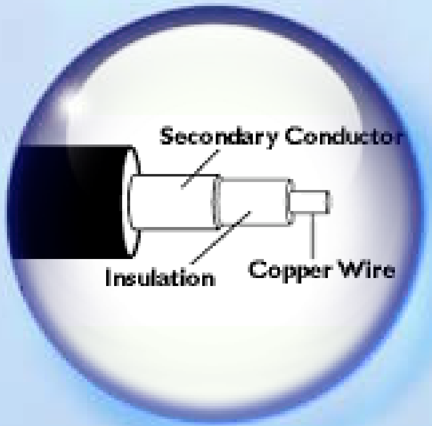
- More realistic and complex network are usually structured as
  - Tree
    - Hierarchical structure with many branches
  - Mesh
    - A mixture of all previous kinds of topology

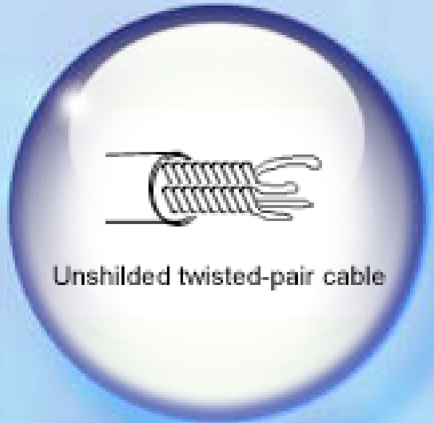


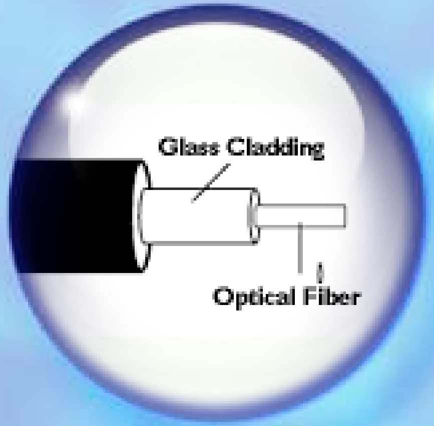


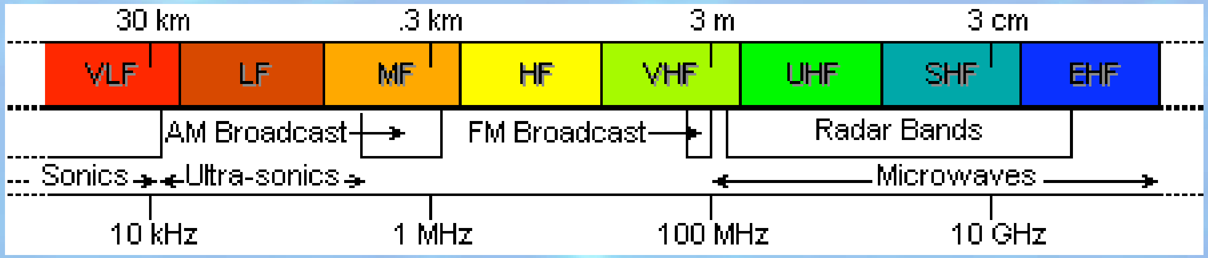
Which medium?

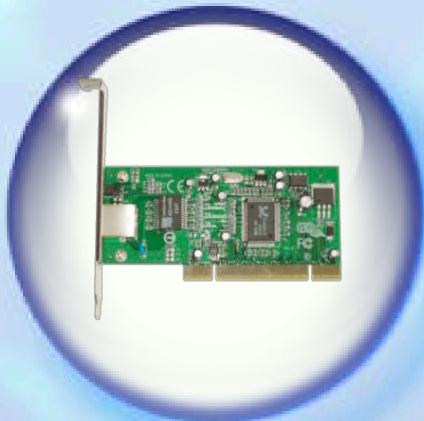
- There are four principal media for network communications:
  - Coaxial cable (now obsolete)
  - Twisted pair cable
  - Optical fiber
  - Wireless











Network hardware

- Common requirements are:
  - To connect networks of different types, different vendors.
  - To provide common communication facilities and hide different hardware implementations and protocols of constituent networks.
  - Standard network hardware is needed for extensible open distributed systems.

NIC

- Network Interface Card, or Network Adapter.
- It interfaces a computer board with the network medium.

Repeater

- It’s a two-ports electronic device that just repeats what receives from one port to the other.
- A multi-port repeater is called hub.

8-ports ethernet hub

Bridge

- It's a more sophisticated repeater with logic capabilities.
- A multi-port bridge is called switch.
- Both can filter packets. (OSI level 2).

Router

- It links two or more networks, passing messages with appropriate routing information.
- It operates at OSI level 3.
- It must have extensive knowledge of the internetwork (routing tables).

Gateway

- Similar to routers, it links two networks.
- It can also operate at OSI levels higher than 3.
- When used for network security purposes, it is called firewall.

Internet addressing

Internet (IP) address

- It's a 32 bits, 4-part, period delimited decimal number called IP number or IP address:

  www . xxx . yyy . zzz

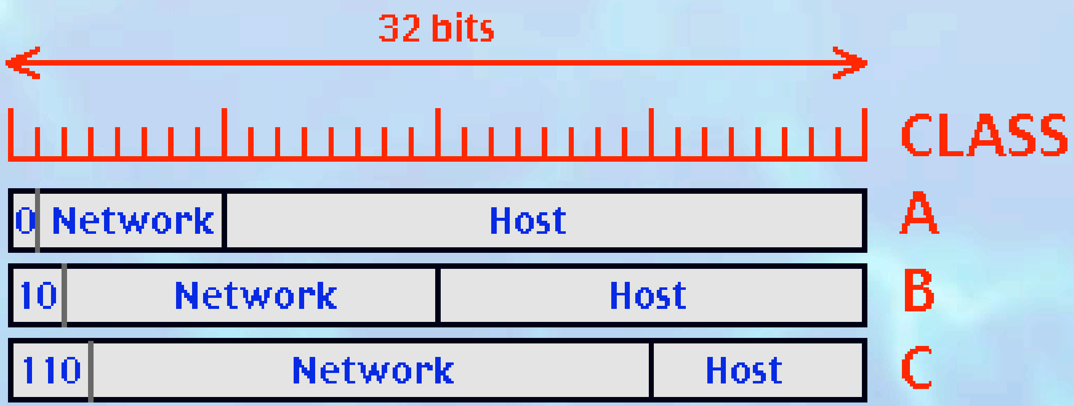
- each part can vary from 0 to 255 (but the last 0 and 255 may be reserved for network and broadcast address).
- each network interface card attached to the Internet mast have an unique IP address.

Internet (IP) address

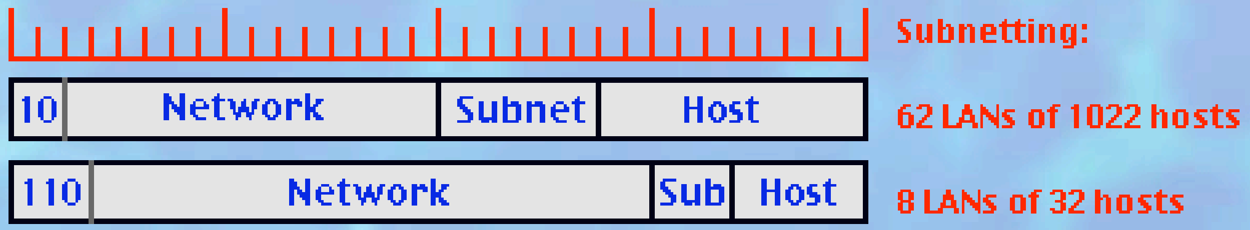
- The IP address can be separated in two parts:
  - network address (part)
  - host address (part)

CLASSES:	class A net: NNN.hhh.hhh.hhh	NNN: 1 to 127
	class B net: NNN.nnn.hhh.hhh	NNN: 128 to 191
	class C net: NNN.nnn.nnn.hhh	NNN: 192 to 223

Subnets



- Subnetting allows a network to be split into several parts for internal use but still act like a single one to the outside world.



How many IPs around?

XML Powered

Whois Source

sponsored in part by

DOMAIN ROUNDTABLE

CONFERENCE • MAY 25-27, 2005

IP Counts by Country

Data was last updated on January 28th 2005.

Domain Counts
Country IPs
World IPs
DMOZ Listings
Registrar Stats

Countries: **229**
Total IPs: **2,196,116,743**

Total IPs	Country
16,899	ANDORRA
606,638	UNITED ARAB EMIRATES
19,072	AFGHANISTAN
23,928	ANTIGUA AND BARBUDA
2,368	ANGUILLA
21,320	ALBANIA
88,976	ARMENIA
36,923	NETHERLANDS ANTILLES

Domain Names System

Domain Names System

- For convenience a domain name is normally assigned to each machine (for humans is easier to remember names than numbers).
- The name is assigned meaning with the most general part on the right (opposite to IP addresses):

host.subdomain.organization.country

pc22.netlab.ictp.it

Domain Names System

- This allows the IP number to be changed while the user using the name sees no change.
- To convert names into numbers an host need to query the Domain Name System (DNS), a hierarchical domain–based naming scheme with a distributed database system.
- DNS Servers for each domain.

How many names?

XML Powered

Whois Source

sponsored in part by ValueWeb AWARD WINNING HOSTING

Detailed Domain Counts and Internet Statistic

Domain Counts
Country IPs
World IPs
DMOZ Listings
Registrar Stats

Welcome to Whois Source's daily domain statistics page. Our stats show how many domains are currently registered and how many domains used to be registered but are now deleted.

Domain Counts

			Daily Changes (last 24hrs)			
Active	Deleted	On-Hold	New	Deleted	Transfered	TLD
34,282,760	18,019,289	346,746	157,961	24,069	36,464	.COM
5,423,923	3,457,907	63,376	8,552	3,423	4,566	.NET
3,386,013	1,007,523	1,274	2,109	588	1,728	.INFO
3,367,443	2,106,339	33,401	4,556	2,589	4,538	.ORG
1,098,749	445,308	1,021	1,814	581	2,642	.BIZ
904,803	523,916	490	1,028	343	1,130	.US
48,463,691	25,413,067	446,308	176,020	31,593	51,068	Total

Last Updated 2/11/2005

Network configuration

TCP/IP stack config

- The information you should provide to configure the TCP/IP stack for your host are:
  - IP address (e.g. 140.105.28.51)
  - Domain name (not always needed)
  - Broadcast address (e.g. 140.105.28.255)
  - Network mask (aka netmask, e.g. 255.255.255.0)
  - Default gateway (e.g. 140.105.28.1)
  - DNS server(s) (e.g. 140.105.16.50 and 16.62)

Thank you!