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ICTP - URSI - ITU/BDT WORKSHOP ON THE USE OF RADIO FOR DIGITAL COMMUNICATIONS IN DEVELOPING COUNTRIES

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Introduction to Computer Network Technology

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Introduction to Computer Network Technology

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Presented by:

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Introduction

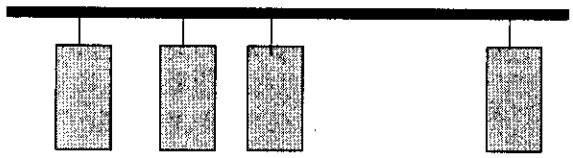
Interprocessor distance	Processors located in same	Example
0.1 m	Circuit board	Data flow machine
1 m	System	Multicomputer
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1,000 km	Continent	
10,000 km	Planet	The internet

Summary of Course

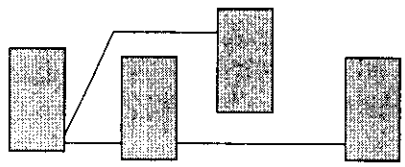
- Networking computers: networks and protocols
- Ethernet: the traditional Ethernet network: coaxial cables, repeaters
- The modern variants of Ethernet: twisted pair, fiber optics
- Bridging, switching, Ethernet-based backbones
- Recent developments

Basic topologies

- Broadcast networks



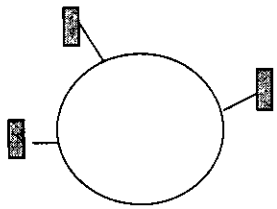
- Point-to-point networks



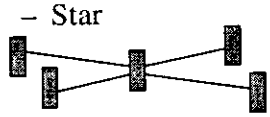
Basic Topologies

- Broadcast
  - Typical of LAN
  - Bus

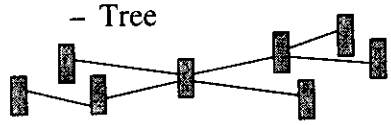
  - Ring



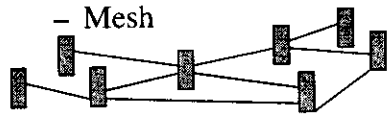
- Point-to-point
  - typical of WAN
  - Star



  - Tree



  - Mesh



LAN's protocols

- Each host has a unique address
- Every message contains addresses of sender and of destination
- Every host listens for messages addressed to himself

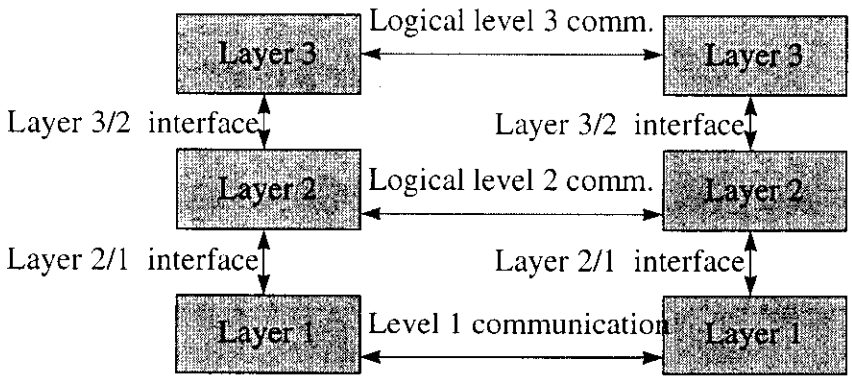
- Problems:
  - crowding
    - » break messages in small packets
    - » segment network
  - contention
    - » MAC protocols
  - inter-networking
    - » beyond broadcast

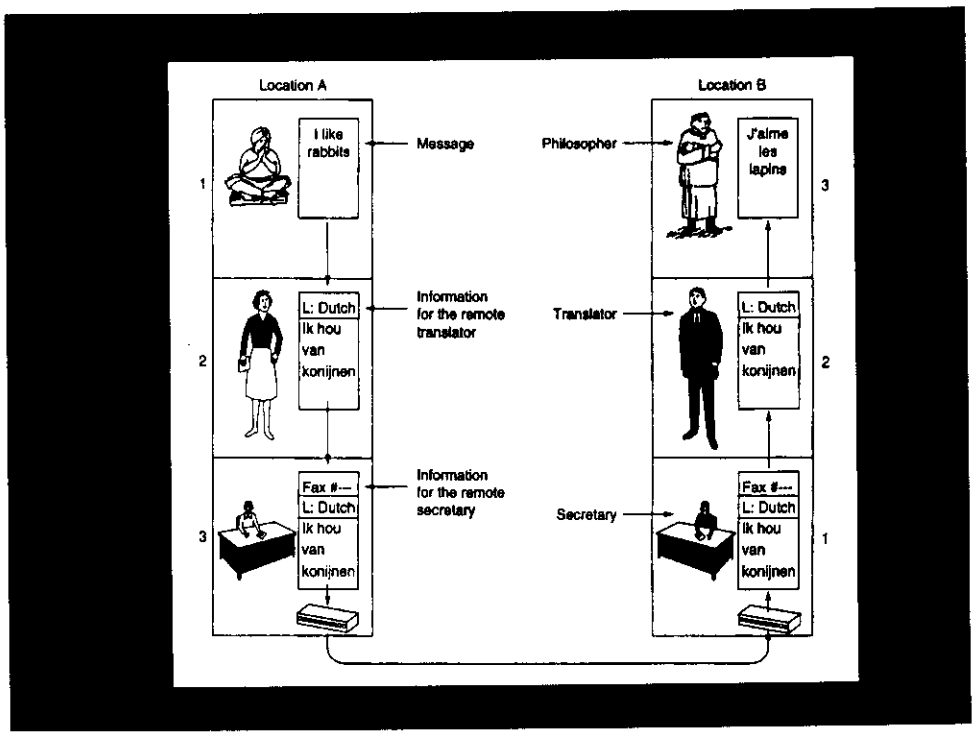
COMPLEXITY !

An answer to complexity: layering

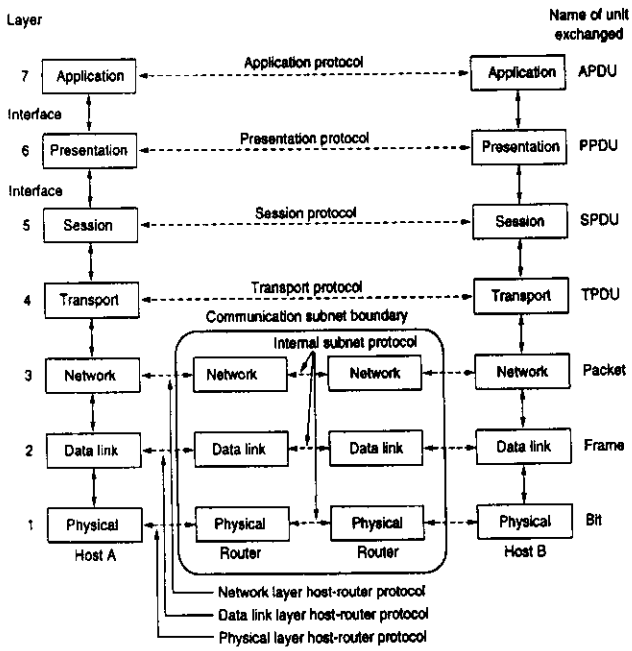
- Complex communication task: exchanging a mail message
- Top layer takes care of message (addresses, etc.), assuming it can speak reliably with a peer at the destination
- Actually, it asks for this service to a lower layer, which handles data transfer with its remote peer
- This layer in turn asks service to a a lower layer, which handles telephone lines...

An answer to complexity: Layered protocols

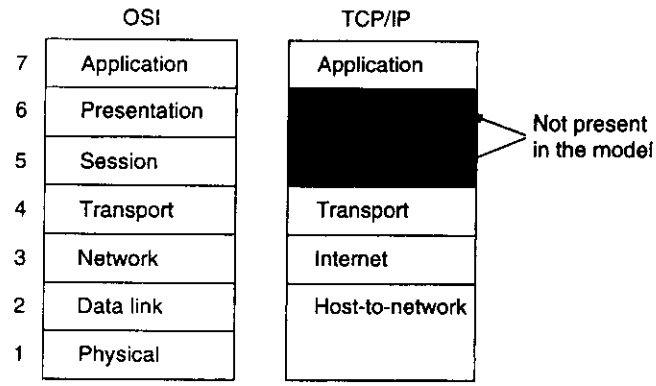



Location A
Location B
I like rabbits
Message
Philosopher
J'aime les lapins
1
3
L: Dutch
Ik hou van konijnen
Information for the remote translator
Translator
2
Fax #---
Information for the remote secretary
Secretary

OSI


Layer
Name of unit exchanged
7 Application
Application protocol
Application
APDU
Interface
6 Presentation
Presentation protocol
Presentation
PPDU
Interface
5 Session
Session protocol
Session
SPDU
4 Transport
Transport protocol
Transport
TPDU
Communication subnet boundary
Internal subnet protocol
3 Network
Network
Packet
2 Data link
Data link
Frame
1 Physical
Physical
Bit
Host A
Router
Router
Host B
Network layer host-router protocol
Data link layer host-router protocol
Physical layer host-router protocol

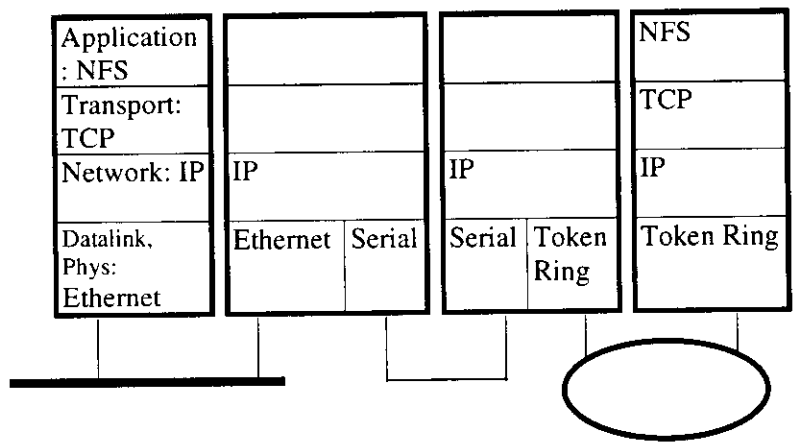
The TCP/IP



Layers involved in this lecture

- Network layer: carries messages from any host to any other host , even passing through intermediate nodes: we can ignore
- Data link layer: specifies how data are passed from one node to another with which it can speak directly. Format, error checking, etc.
- Physical layer: between a host and a cable.

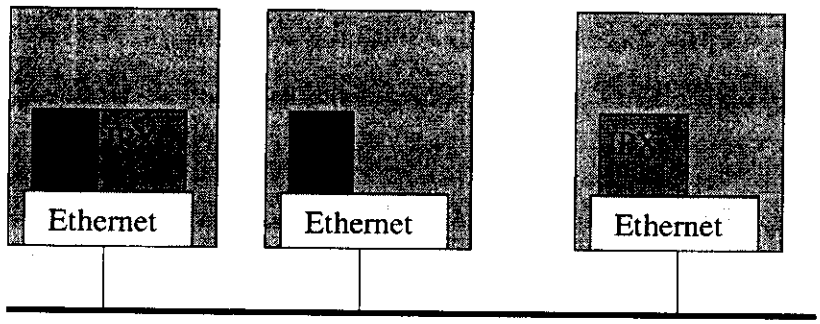
Combination



Combination

Application: telnet	Application: File Server	Application: NFS
Transport: TCP		Transport: UDP
IP	IPX	IP
Ethernet		

Combination



Coexistence of multiple protocol stacks

LAN standards

- Ethernet
  - » Born in 1980 from DEC, Intel, Xerox, revised 1985
  - » Standardized by IEEE

  By far the most popular
- IEEE standardization: family of protocols
  - 802.3 Ethernet
  - 802.5 Token Ring
  - 802.2 Logical Link control
  - ...

LAN Interconnections

- REPEATER Physical Level
- BRIDGE Data Link Level
- ROUTER Network Layer
- GATEWAY Above network Layers

  The term Router is often also used to denote gateways
- Combinations: BROUTERS

The Ethernet Frame

Preamble	Destination address	Source address	Length/ Protocol	Data + padding	CRC
8 bytes	6 bytes	6 bytes	2 bytes	46-1500 bytes	4 bytes

Covered by CRC

The Ethernet MAC protocol (CSMA/CD)

- Wait until cable free
- Start transmitting; listen while transmitting
- If received ≠ transmitted, stop: collision!
  - wait random time
  - try again
  - if fail again, wait longer random time
  - after 16 failures, give up

CSMA/CD: implications

- Collisions are normal
- Collisions detected only during transmission:
  - A packet, trasmitted from the farthest station immediately before my packet gets there, must arrive here before I complete my transmission
  - Relation between propagation speed of signal, transmission speed, minimum frame size, and maximum network length

CSMA/CD: implications

- L[m] < 2 P[m/s] S[b] / T[b/s]
- P ≅ 0.7 c ≅ $2.1*10^8$ m/s
- T = 10^7 b/s
- S = 576 b (Ethernet Spec)

◆ L < ~ 5.5 km (station to station!)

- Actual limits stricter on all media: delays of electronics

The Ethernet physical layers

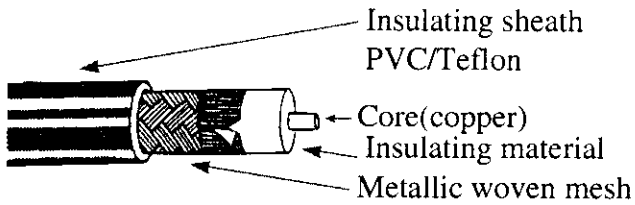
◆ Originally only 'thick coax defined'

◆ many more defined in IEEE 802.3 framework

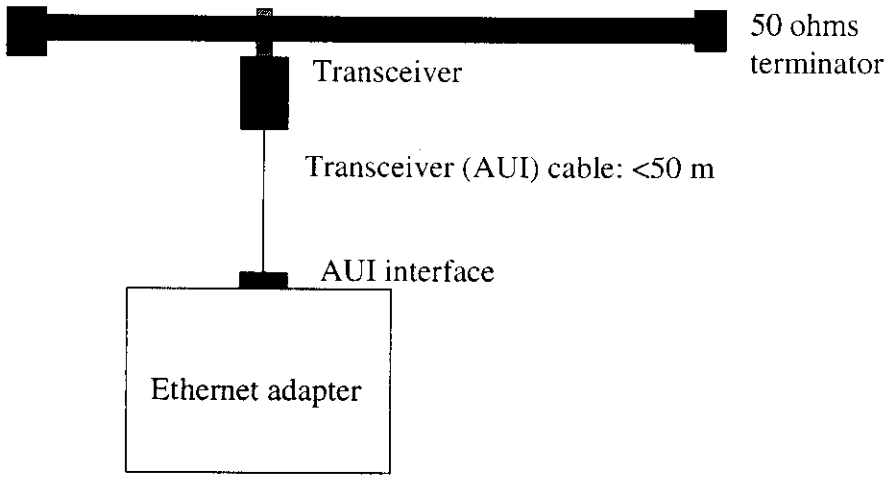
◆ mixing possible and cheap due to identical frame format and MAC

The origin: 10base5 ("thick", "yellow cable")

- 10(Mbits/sec)base(band modulation)500meters)
- Coaxial cable, 50 ohms
- 1 cm thick, minimum curvature radius ~ 40 cm



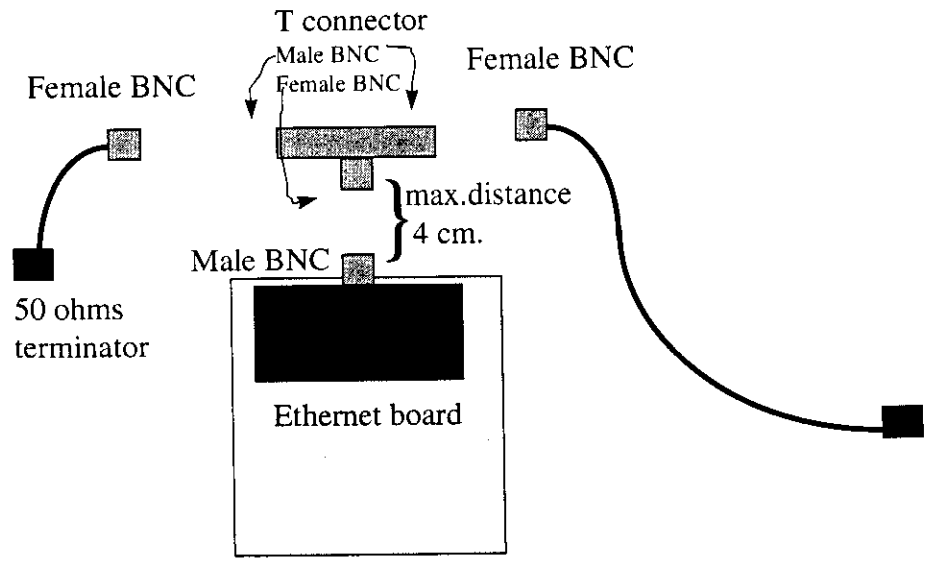
10base5 scheme



10base2("thin","black cable")

- Coax, 50 ohms (RG 58)
- '2' for 200 meters: actually, 185 m max
- about 6.4 mm thick, curvature radius ~ 3 cm
- attachement: "T" connectors

The 10base2 connection



Pro's and con's of 10base2

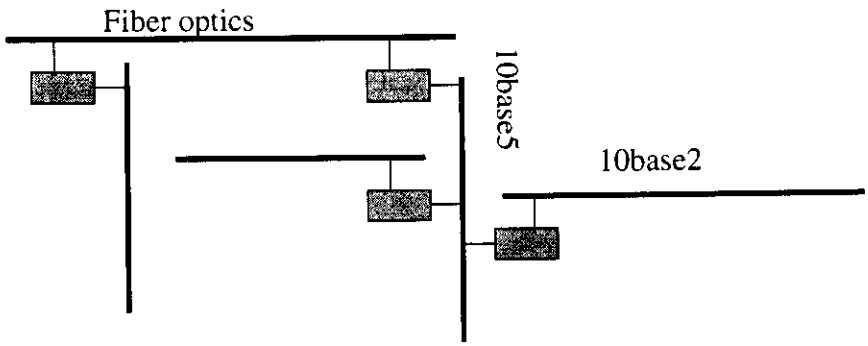
- PRO
  - Extremely cheap
    - » 0.3$/meter, 10$/attachement
    - » 30 attachements per cable
  - Very easy to install
- CON
  - Limited size
    - » 185 mt/cable
  - Vulnerable:
    - » bus down to desktop
    - » intrusive attachement
    - » intrinsecally vulnerable cable

Combining Ethernet segments

- Limitations of length depend from attenuation of signal
- multiple segments can be combined in a single network using **repeaters**
  - repeaters regenerate signal and forward it
  - they do not detect or filter collisions
  - they introduce a delay, therefore one can use a limited number of them

Ethernet topology with repeaters

- Arbitrary tree, subject to maximum distance limitations



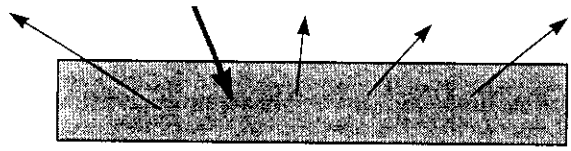
- Segments don't need to be of same type

The 10baseFL

- First definition (FOIRL) in original Ethernet, as a way to interconnect repeaters
- Later, 10baseF
  - up to 2000 m (more in some implementations)
  - multi-mode fiber (single mode implementations exist)
  - external or integrated transceiver; if external, uses standard AUI interface

10baseF: topology

- Fiber optics intrinsically point-to-point
  - one receiving, one transmitting fiber
- Broadcast nature of Ethernet satisfied through multi-point repeater (hub)



10baseF: limits and 5-4-3 rule

- When 5 segments, inter-repeater fiber optics segments limited to 500 m
- when 4 segments, inter-repeater fiber optics segments limited to 1000 m
- when 3 segments (2 repeaters), inter-repeater fiber optics segment up to 2000 m
- DTE/repeater up to 400 m
- Total diameter ~2.8 km
- non-standard up to 4 km

Pro's and con's of 10baseF

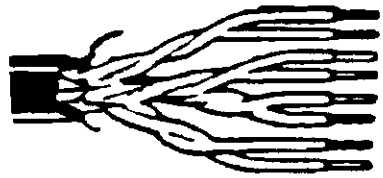
- Pro's
  - large distance
  - immunity to electromagnetic disturbance
  - no grounding problems (backbone!)
- Con's
  - High cost
    - » 1-10 $/meter
    - » attachement 2-3 times as expensive as 10baseT or 10base2/external

The 10baseT (Twisted pair)

- Standard published in 1989
- The most popular version at present
- Based on **T**wisted **P**air (Usually Unshielded Twisted Pair, UTP)
  - Uses existing telephone cabling, if of very good quality
  - cables compatible with almost every other LAN protocol

10baseT: the twisted pair

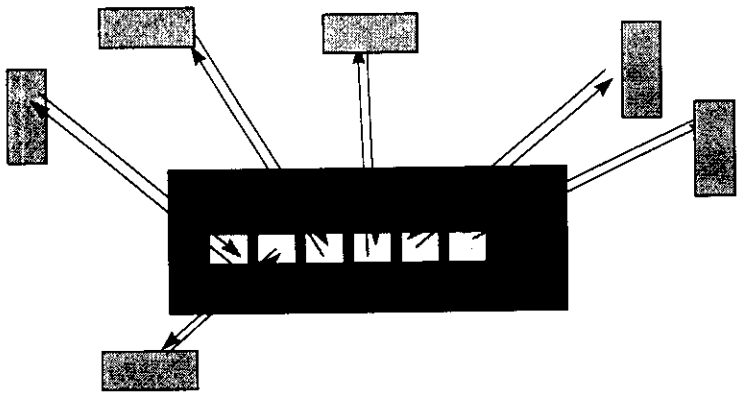
- Two copper wires, twisted together to reduce e.m. interference.
  - Constant inter-wire distance and twist rate define quality
- UTP cable, usually 4 pairs



10 base T: topology

- 10baseT is NOT a broadcast medium:
  - signals carried on a pair
  - 1 pair for transmitting, 1 for receiving ⇒ point-to-point link!
- To recover broadcast Ethernet protocol, star topology and central "repeating hub"

10baseT: topology



The hub retransmits on **all** his ports (except input one) every input
Collisions as usual detected only by hosts, never by hub
Hub extends jam, like repeaters

10baseT: connections

- 4-pairs unshielded twisted pair (Category 3 or higher)
- 2 pairs used by the protocol
- 2 pairs not used (yes, available for telephone; no, not for another LAN connection)
- Connectors: 8 pins RJ-45 (telephone type)
  - pins 1-2 for (transmit) and 3-6 (receive)
  - standard connection: pairs 1-2, 3-6, 4-5, 7-8

10baseT: connections

- Cable category: measures transmission quality. Refers to cables, connectors,jacks, patch cords, etc.
- based on attenuation, cross-talk, etc.
- Category 3 : up to Ethernet
- Category 5 : up to Fast Ethernet, ATM (155 Mb/sec)

10baseT hubs

- Ethernet repeaters: regenerate the signal and forward it
- Collision detect only at DTE
- Line integrity check: every 1/60 second, hub sends test signal on all ports; if no response, port deactivated (LED)
  - different pairs for receiving and transmitting: one-way failure would cause no busy and collision detect, network flooding...

Pro's and con's of 10baseT

- Pro's
  - Robust (one cable failure does not break network)
  - Flexible if cabling structure is good
- Con's
  - Moderately expensive (one cable and a hub port per host)
  - If no pre-existing cabling, initial investments are high
  - Limited distance

Bridges

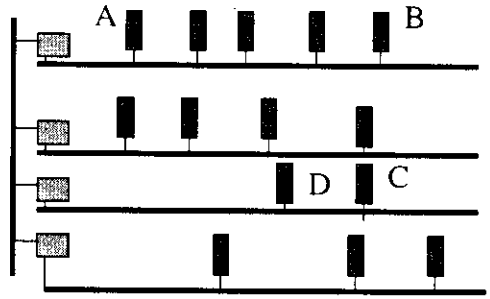
- Until now, broadcast
  - All traffic (even local one) passed from one segment to another
  - Collisions passed from one segment to another
- How to keep local traffic in the local segment?

Bridges

- Do not propagate collisions
  - No number limit, no limit on total network size
- Introduce larger delay than repeaters (receive whole packet, then start transmitting)
- More complex (protocol handling!)
- More expensive (~1000 US$)
  - Complex electronics can serve more than 2 ports: multiport bridges ~200-300 $/port

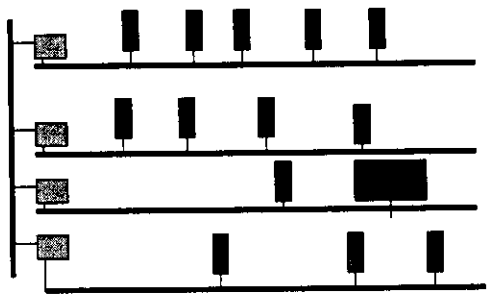
Bridges: example

- Backbone
  - keeps traffic local
    - » A-B, C-D traffic on their segment
    - » A-C on both segments and on backbone



Bridges: example

- No point if traffic non-local: for instance only one server and most traffic with server



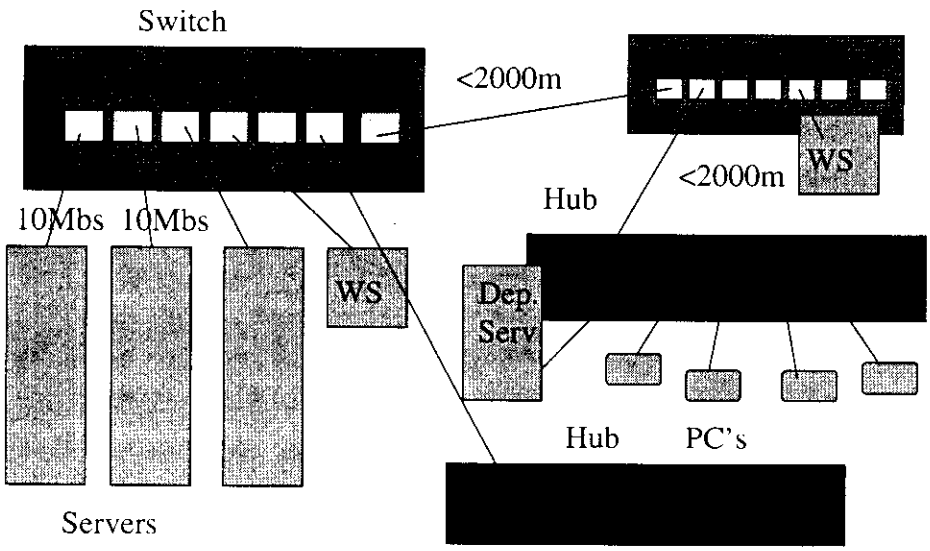
Switched Ethernet

- Development of bridges: multi-port bridges, called "Ethernet switches"
- "Collapsed Backbone": the switch acts as a backbone
- Very high bandwith (backplane of switch) > 1Gb/s
- Usually supports only 10baseT and 10baseF

Ethernet switches

- Classical bridge operation("store and forward")
- To reduce delay (and safety):
  - Cut-through (start forwarding as soon as destination address read, i.e. 64+48 bits ~ 0.1us)
    - » Problem: collision fragments are propagated!
  - Alternative: start transmitting after 64 bytes (no collision fragment so long!) delay ~ 50 us
- Often selectable at installation time

Ethernet switch: example



Ethernet switches: problems

- Overload of a channel
  - No flow control
  - "backpressure": create collisions on input port if destination port congested
    - » does not scale well

100 Mbit/s Ethernet

- Standardized on twisted-pair (100baseT) and on fiber (100baseFX)
- NO COAX
- 100 base TX, up to 100 meters, Category 5 UTP, 2 pairs (like 10baseT)
- 100base T4, up to 100 meters, Category 3,4,5, all 4 pairs
- 100baseFX, up to 400 meters, multimode fiber

Full Duplex Ethernet

- On fiber or twisted pair: why to worry about collisions?
  - Point-to-point
  - 1 wire per direction
- Ignore collisions:
  - double (and more) bandwidth
  - distance limited only by attenuation/crosstalk
    - » up to 100 km using single-mode fiber

Full-duplex Ethernet

- Not standardized!
- Not very expensive
- Exists also for 100 Mbit/s Ethernet: great for backbone

Gbit networking

- 1000 Mbit/s Ethernet, standard end 1997
- Prototypes on fiber available, only for backbone (inter-switch)
- Full duplex

Alternatives to Ethernet

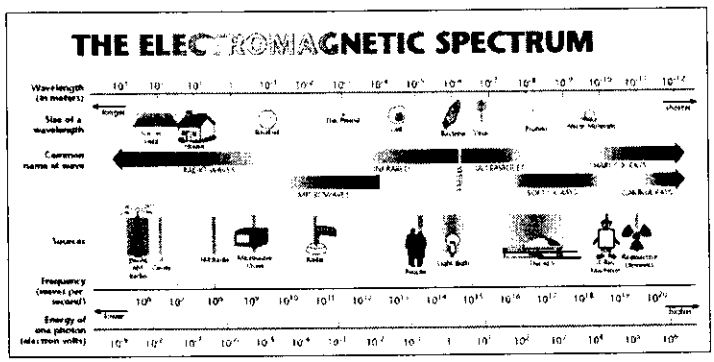
- ATM: effective, but still expensive
- Very high speed (25/625 Mb/s)
- Very different from old LAN protocols:
  - data broken in very small packets ("cells") of constant length (53 bytes)
  - 'virtual circuit' oriented:
    - » end node requests its ATM switch to open a call to other end-node
    - » connection gets an id, used by switches to route cells (cells do not contain end-node addresses)
    - » at end call is closed, connection's id freed

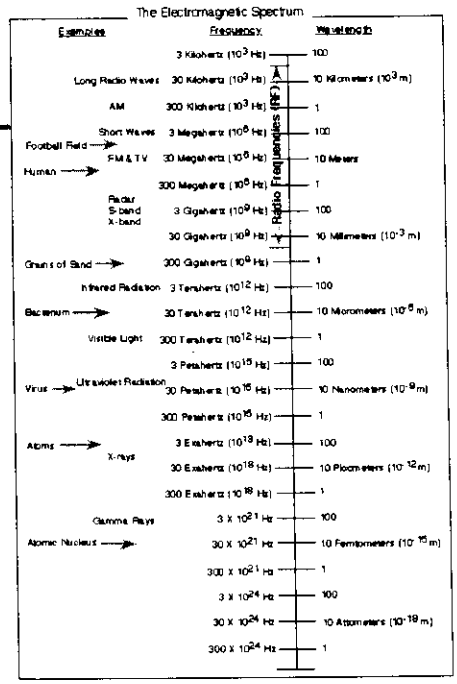
ATM

- Good for both data and voice/video
- Many aspects still under standardization
- Officially adopted by telecom operators for B-ISDN (Broadband-ISDN)
- Probably dominant technology in 10 years time
- can use same UTP and fiber cabling as Ethernet (no coax!)

Summary

- Layered protocols as ordering principle
- Ethernet as only local area solution
- Ethernet available on multiple physical media and multiple variants
- Combinations of Ethernet variants satisfactory now
- ATM coming soon


THE ELECTROMAGNETIC SPECTRUM


The Electromagnetic Spectrum
Examples
Frequency
Wavelength
3 Kilohertz (10^3 Hz)
100
Long Radio Waves
30 Kilohertz (10^2 Hz)
10 Kilometers (10^3 m)
AM
300 Kilohertz (10^3 Hz)
1
Short Waves
3 Megahertz (10^6 Hz)
100
Football Field
FM & TV
30 Megahertz (10^8 Hz)
10 Meters
Human
300 Megahertz (10^8 Hz)
1
Radar
S-band
X-band
3 Gigahertz (10^9 Hz)
100
30 Gigahertz (10^9 Hz)
10 Millimeters (10^-3 m)
Grains of Sand
300 Gigahertz (10^9 Hz)
1
Infrared Radiation
3 Terahertz (10^12 Hz)
100
Bacterium
30 Terahertz (10^12 Hz)
10 Micrometers (10^-5 m)
Visible Light
300 Terahertz (10^12 Hz)
1
3 Petahertz (10^15 Hz)
100
Virus
Ultraviolet Radiation
30 Petahertz (10^15 Hz)
10 Nanometers (10^-9 m)
300 Petahertz (10^15 Hz)
1
Atoms
X-rays
3 Exahertz (10^18 Hz)
100
30 Exahertz (10^18 Hz)
10 Picometers (10^-12 m)
300 Exahertz (10^18 Hz)
1
Gamma Rays
3 X 10^21 Hz
100
Atomic Nucleus
30 X 10^21 Hz
10 Femtometers (10^-15 m)
300 X 10^21 Hz
1
3 X 10^24 Hz
100
30 X 10^24 Hz
10 Attometers (10^-19 m)
300 X 10^24 Hz
1
Radio Frequencies (left)

Where to get more information

- Computer Networks, by A. Tanenbaum, Prentice Hall, 1994, Third ed.
- TCP/IP Illustrated, Volumes 1-4, by R.Stevens, Addison Wesley, 1996+
- The collection of Data Communications, in the Library