MIEEC

Computer Networks

Lecture note 1

Introduction

Faculdade de Engenharia da Universidade do Porto

FEUP DEEC > DEPARTAMENTO DE ENGENHARIA ELECTROTÉCNICA E DE COMPUTADORES

Introduction to the course

Learning objectives

- Network design and analysis
  - Communication channels and data link control
  - Delay models in computer networks
  - Multi-access communications
  - Routing in computer networks
  - Flow and congestion control
- Technologies
  - Ethernet, WLAN, Internet, TCP/IP stack
- Implementation
  - Protocol development, Linux
  - Computer network communication
  - Planning of a simple network

Syllabus: the communications stack

- Physical layer
- Data link layer
- Delay models
- Medium access control
- Network layer
- Transport layer
- Application layer

T+L Classes

- Ricardo Morla (T)
  - Fundamentals of Computer Networks
  - Additional reading required at home
  - Weekly homework (Moodle)
  - Wednesdays 9:30-11:30

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- Teresa Andrade (L)
  - 2 lab projects
  - Protocol development (Linux, C, file transfer)
  - Computer network configuration (switches, routers)

Moodle

- Link through SiFEUP
- Preferred medium of communication
  - Slides, assignments, homework, etc.

Language

- Classes in Portuguese / English
- Slides and books in English
- Suitable for English-speaking students

Evaluation

- The grading scale is from 0 to 20.
  - L1 - grade of 1st lab work
  - L2 - grade of 2nd lab work
  - H - grade of the homework
  - E - grade of the final exam

Details in SiFEUP/ RCOM

- FQ - GRADE OF FREQUÊNCIA
  - FQ = 0,4*L1 + 0,4*L2 + 0,2*H
  - if (FQ < 8,0) FQ = "No Admission to Exams"
- CF - FINAL GRADE
  - CF = 0,4*FQ + 0,6*E
  - if (E < 8,0 or CF < 10,0) CF = "Not approved“

Bibliography

- Main source
  - Andrew **Tanenbaum**. Computer Networks.
  - Class slides. *Fundamentals only; details in the books*.
- Complementary sources
  - Dimitri **Bertsekas**, Robert Gallager. Data networks. *Fundamental (math) aspects; outdated networks (1992)*.
  - James F. **Kurose**, Keith W. Ross. Computer networking. *Top-down*.
  - W. Richard **Stevens**. TCP/IP illustrated. Detailed *TCP/IP stack*.
  - Lary L. **Peterson**, Bruce S. Davie. Computer Networks. *TCP and implementation*.
  - William **Stallings**. Data and Computer Communications. *Also telecom networks*.

Acknowledgements

- Course content and lab work:
  - Manuel Ricardo
  - José Ruela

Introduction to Computer Networks

TO THINK

- What are computer networks?
- What do we need computer networks for?
- Why do we need computer networks?

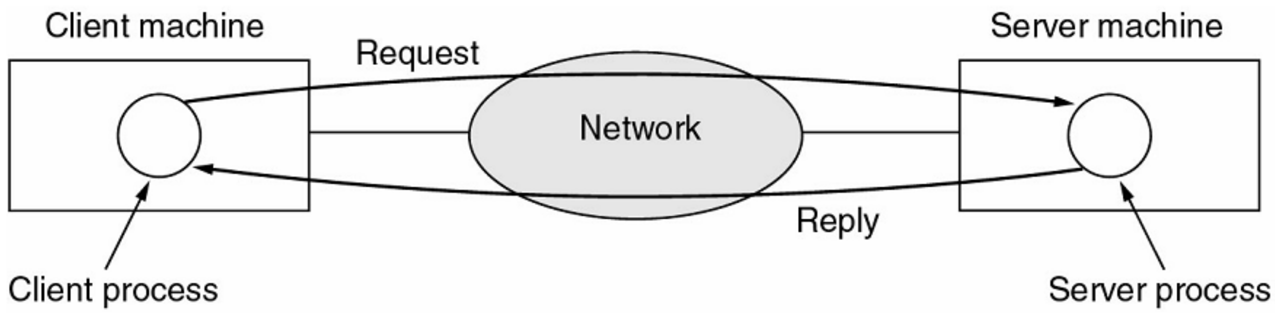
Applications

- Video streaming
- Social networking
- Web
- E-mail
- IM
- VoIP
- Video conferencing
- MMOG
- User-generated content distribution
- P2P file sharing
- Remote login
- Industrial control applications
- Mobile: sensor networks, personal devices
- …

Application architectures

- Client-server
- Peer-to-peer
- Hybrid

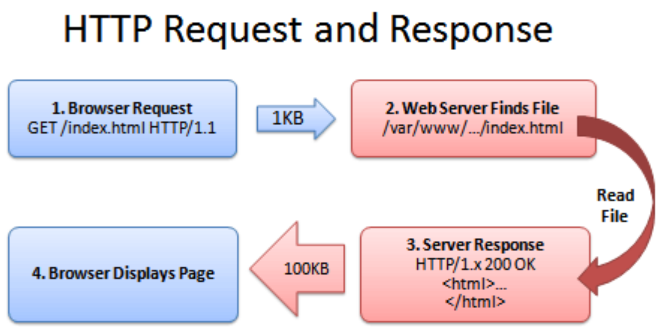
Client-server architecture



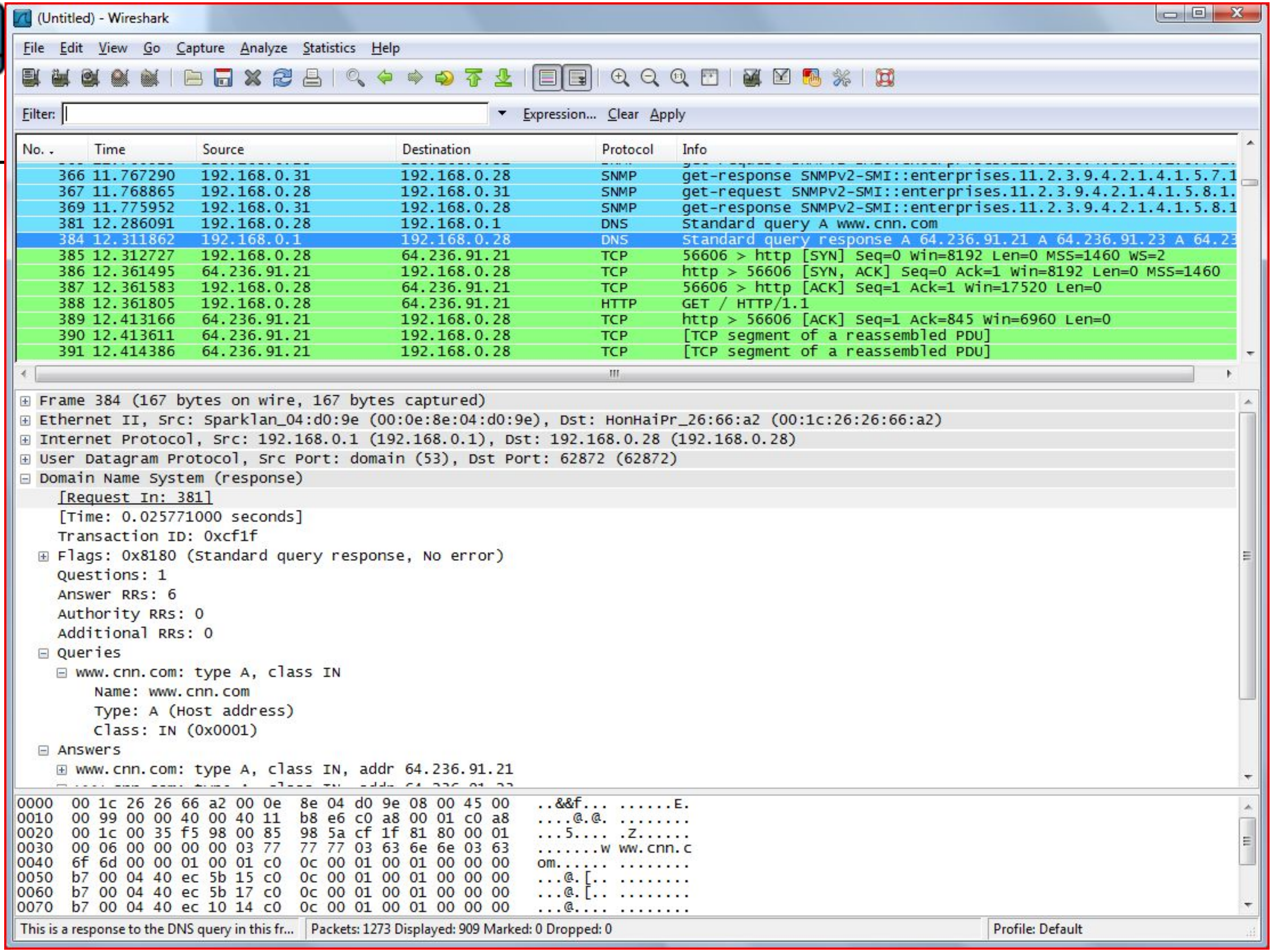
- Client
  - Issues request to server
  - Server replies back
  - Doesn't contact other clients
  - Doesn't need to be always on
  - Address may change
- Server
  - Always on
  - Well-known address

Example – HTTP and the Web

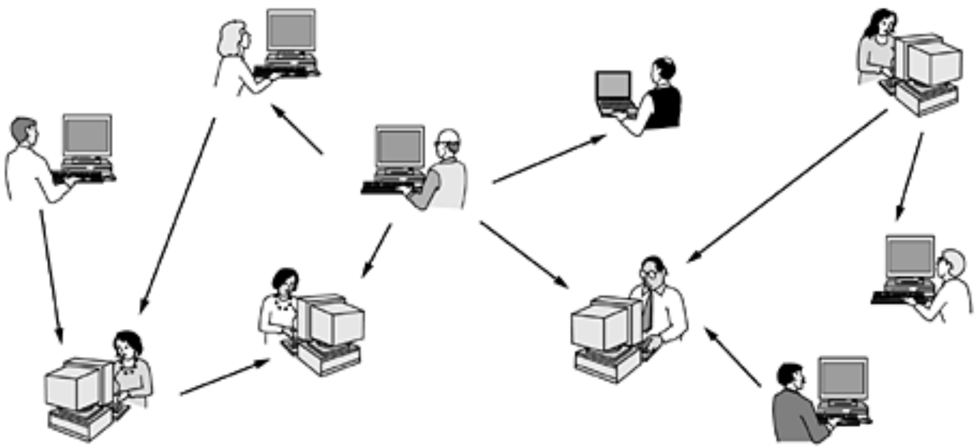
- Client – Firefox 6.0
- Server – Apache 2.2.20

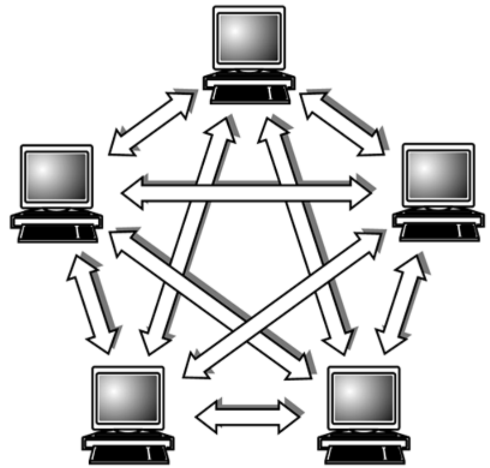


- Server – on at address www.fe.up.pt
- Client – on/off on user laptop
  - Requests https://www.fe.up.pt/si/imagens/BotaoAutentica
  - Replies back with picture


(Untitled) - Wireshark
File Edit View Go Capture Analyze Statistics Help
Filter: Expression... Clear Apply
No. Time Source Destination Protocol Info
366 11.767290 192.168.0.31 192.168.0.28 SNMP get-response SNMPv2-SMI::enterprises.11.2.3.9.4.2.1.4.1.5.7.1
367 11.768865 192.168.0.28 192.168.0.31 SNMP get-request SNMPv2-SMI::enterprises.11.2.3.9.4.2.1.4.1.5.8.1.
369 11.775952 192.168.0.31 192.168.0.28 SNMP get-response SNMPv2-SMI::enterprises.11.2.3.9.4.2.1.4.1.5.8.1
381 12.286091 192.168.0.28 192.168.0.1 DNS Standard query A www.cnn.com
384 12.311862 192.168.0.1 192.168.0.28 DNS Standard query response A 64.236.91.21 A 64.236.91.23 A 64.23
385 12.312727 192.168.0.28 64.236.91.21 TCP 56606 > http [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS=2
386 12.361495 64.236.91.21 192.168.0.28 TCP http > 56606 [SYN, ACK] Seq=0 Ack=1 Win=8192 Len=0 MSS=1460
387 12.361583 192.168.0.28 64.236.91.21 TCP 56606 > http [ACK] Seq=1 Ack=1 Win=17520 Len=0
388 12.361805 192.168.0.28 64.236.91.21 HTTP GET / HTTP/1.1
389 12.413166 64.236.91.21 192.168.0.28 TCP http > 56606 [ACK] Seq=1 Ack=845 Win=6960 Len=0
390 12.413611 64.236.91.21 192.168.0.28 TCP [TCP segment of a reassembled PDU]
391 12.414386 64.236.91.21 192.168.0.28 TCP [TCP segment of a reassembled PDU]
Frame 384 (167 bytes on wire, 167 bytes captured)
Ethernet II, Src: Sparklan_04:d0:9e (00:0e:8e:04:d0:9e), Dst: HonHaiPr_26:66:a2 (00:1c:26:26:66:a2)
Internet Protocol, Src: 192.168.0.1 (192.168.0.1), Dst: 192.168.0.28 (192.168.0.28)
User Datagram Protocol, Src Port: domain (53), Dst Port: 62872 (62872)
Domain Name System (response)
[Request In: 381]
[Time: 0.025771000 seconds]
Transaction ID: 0xcf1f
Flags: 0x8180 (Standard query response, No error)
Questions: 1
Answer RRs: 6
Authority RRs: 0
Additional RRs: 0
Queries
www.cnn.com: type A, class IN
Name: www.cnn.com
Type: A (Host address)
Class: IN (0x0001)
Answers
www.cnn.com: type A, class IN, addr 64.236.91.21
0000 00 1c 26 26 66 a2 00 0e 8e 04 d0 9e 08 00 45 00 ..&&f... ......E.
0010 00 99 00 00 40 00 40 11 b8 e6 c0 a8 00 01 c0 a8 ....@.@. ....
0020 00 1c 00 35 f5 98 00 85 98 5a cf 1f 81 80 00 01 ...5.... .Z......
0030 00 06 00 00 00 00 03 77 77 77 03 63 6e 6e 03 63 ....w ww.cnn.c
0040 6f 6d 00 00 01 00 01 c0 0c 00 01 00 01 00 00 00 om...... ....
0050 b7 00 04 40 ec 5b 15 c0 0c 00 01 00 01 00 00 00 ...@.[.. ....
0060 b7 00 04 40 ec 5b 17 c0 0c 00 01 00 01 00 00 00 ...@.[.. ....
0070 b7 00 04 40 ec 10 14 c0 0c 00 01 00 01 00 00 00 ...@.... ....
This is a response to the DNS query in this fr...
Packets: 1273 Displayed: 909 Marked: 0 Dropped: 0
Profile: Default

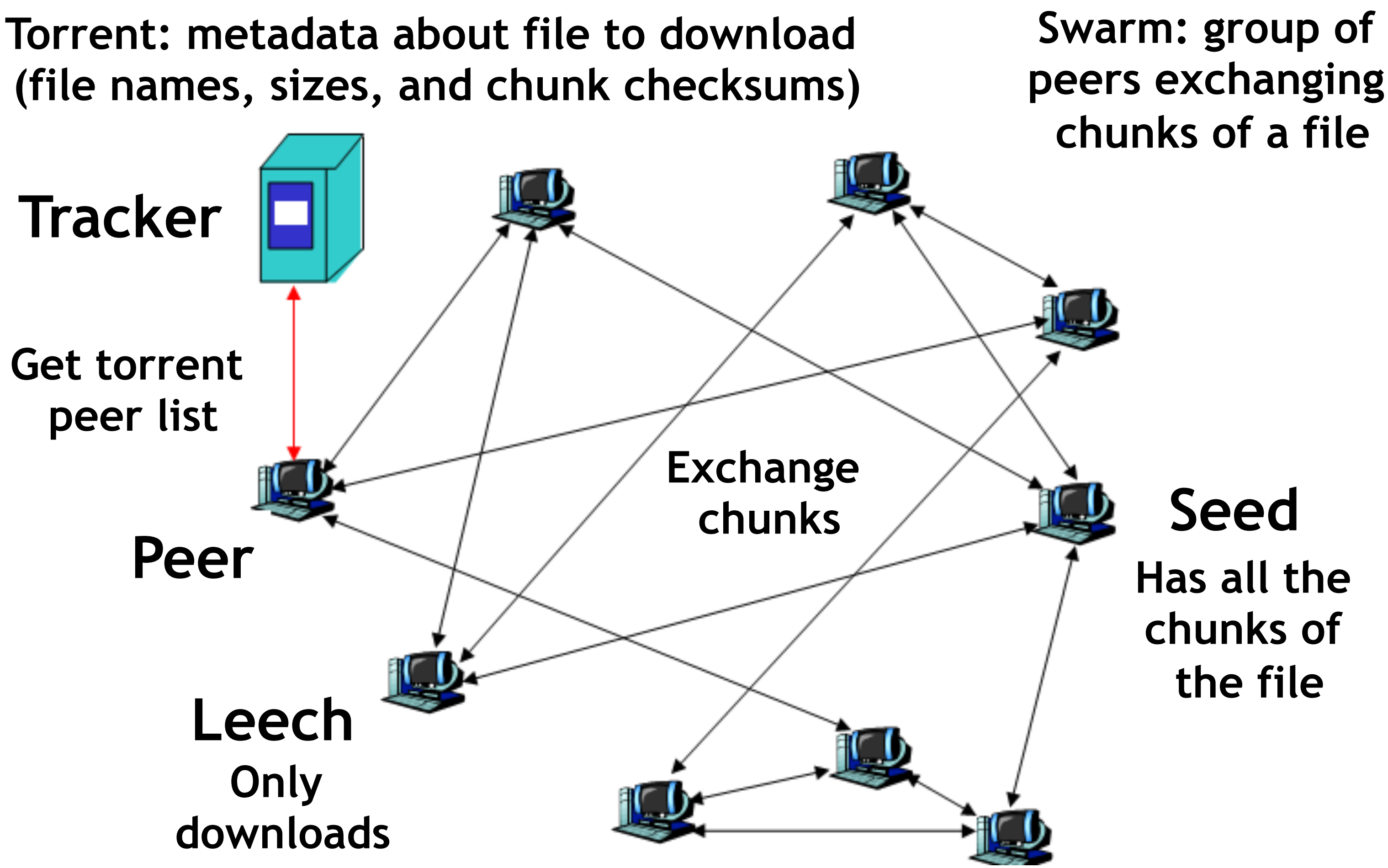
Peer-to-peer





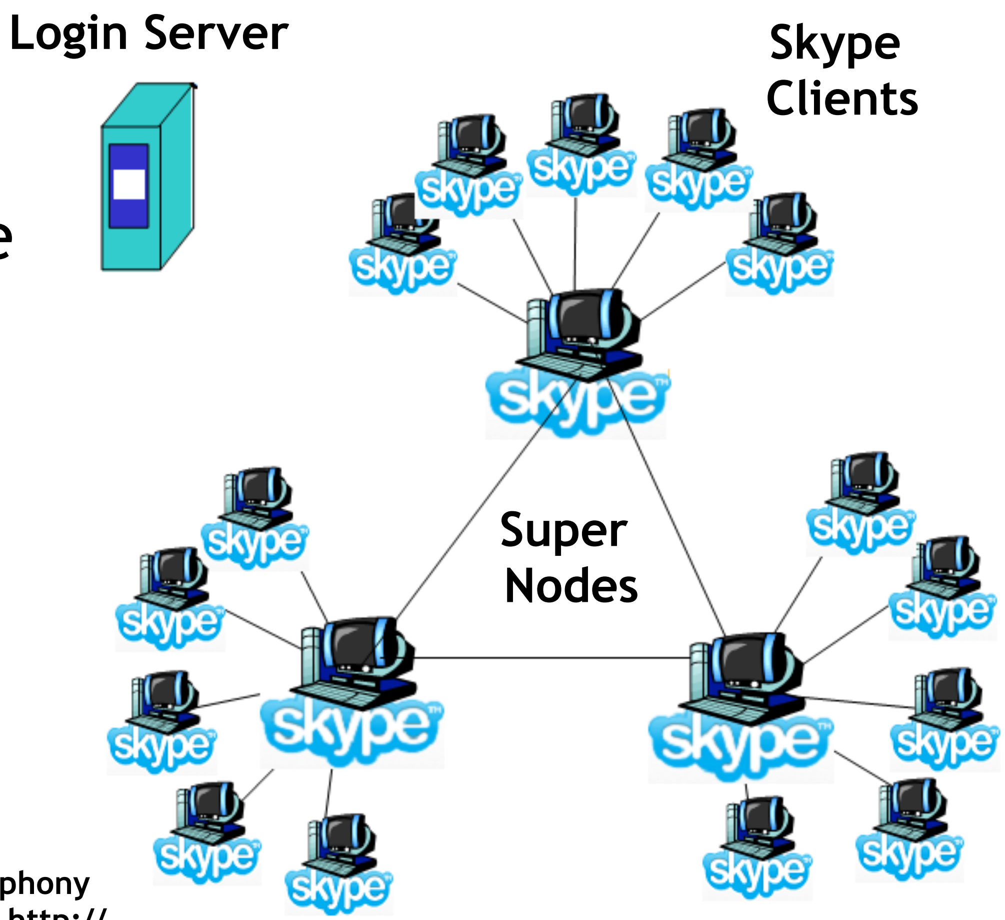
- No server
- Nodes don't need to:
  - be always on
  - have well-known address
- Nodes can:
  - request/reply
  - contact any other node

Example: BitTorrent



Example: Skype architecture

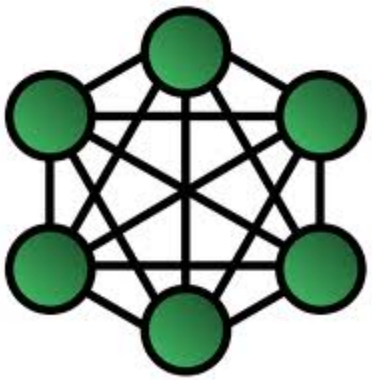
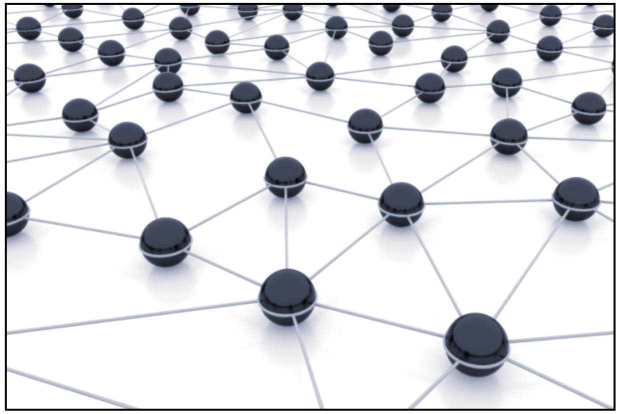
- Login server
  - Centralized
- Hybrid architecture
- Client-Server
  - between Clients and Super Nodes
- P2P
  - between Super Nodes
- Distributed Skype user search



An Analysis of the Skype Peer-to-Peer Internet Telephony Protocol. Salman A. Baset and Henning Schulzrinne http://arxiv.org/ftp/cs/papers/0412/0412017.pdf

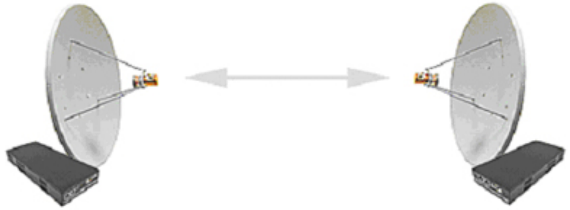
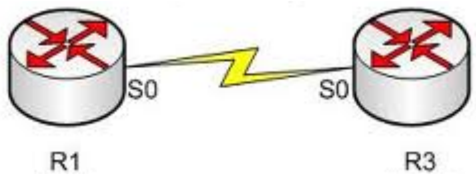
TO THINK

- What are computer networks?
- What do we need computer networks for?
- Why do we need computer networks?

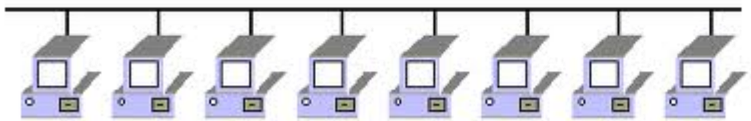
 

Types of Computer Networks

- By transmission technology
  - Point-to-point link

  - Broadcast / Shared link



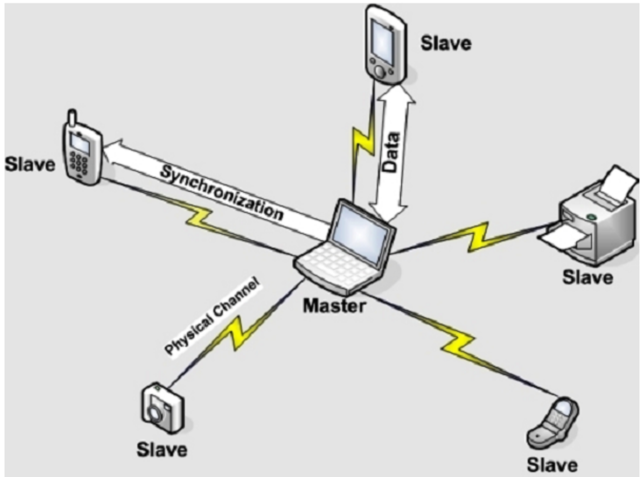

Types of Computer Networks

- By scale
  - PAN - Personal Area
  - LAN – Local Area
  - MAN – Metropolitan Area
  - WAN - Wide Area
  - The Internet

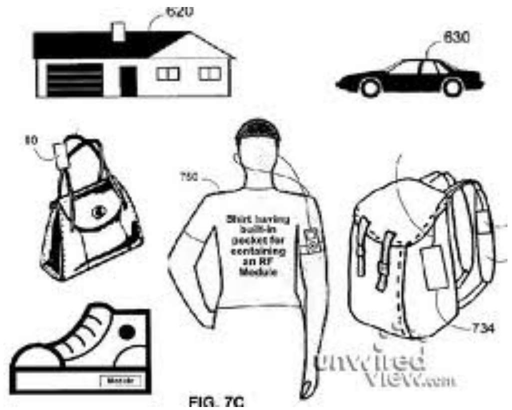
Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Personal Area Networks

- Bluetooth

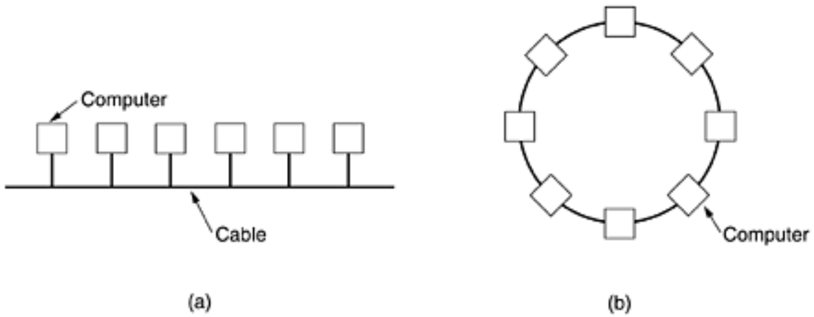


- Other personal devices

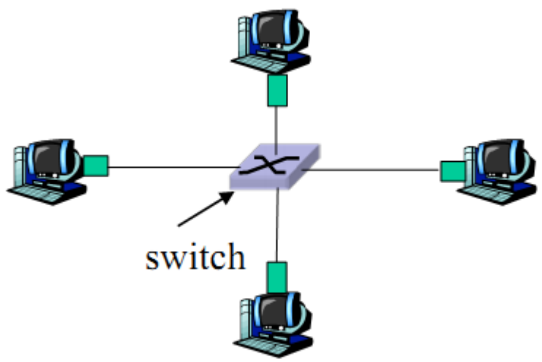


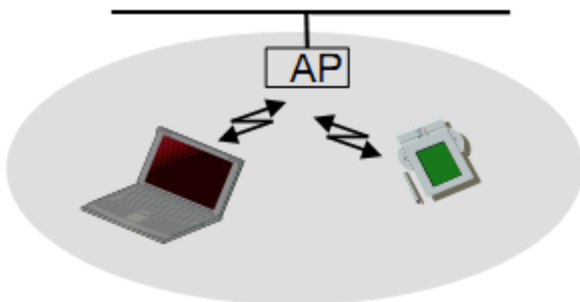
Local Area Networks

- Broadcast LANs
  - Bus/Ring



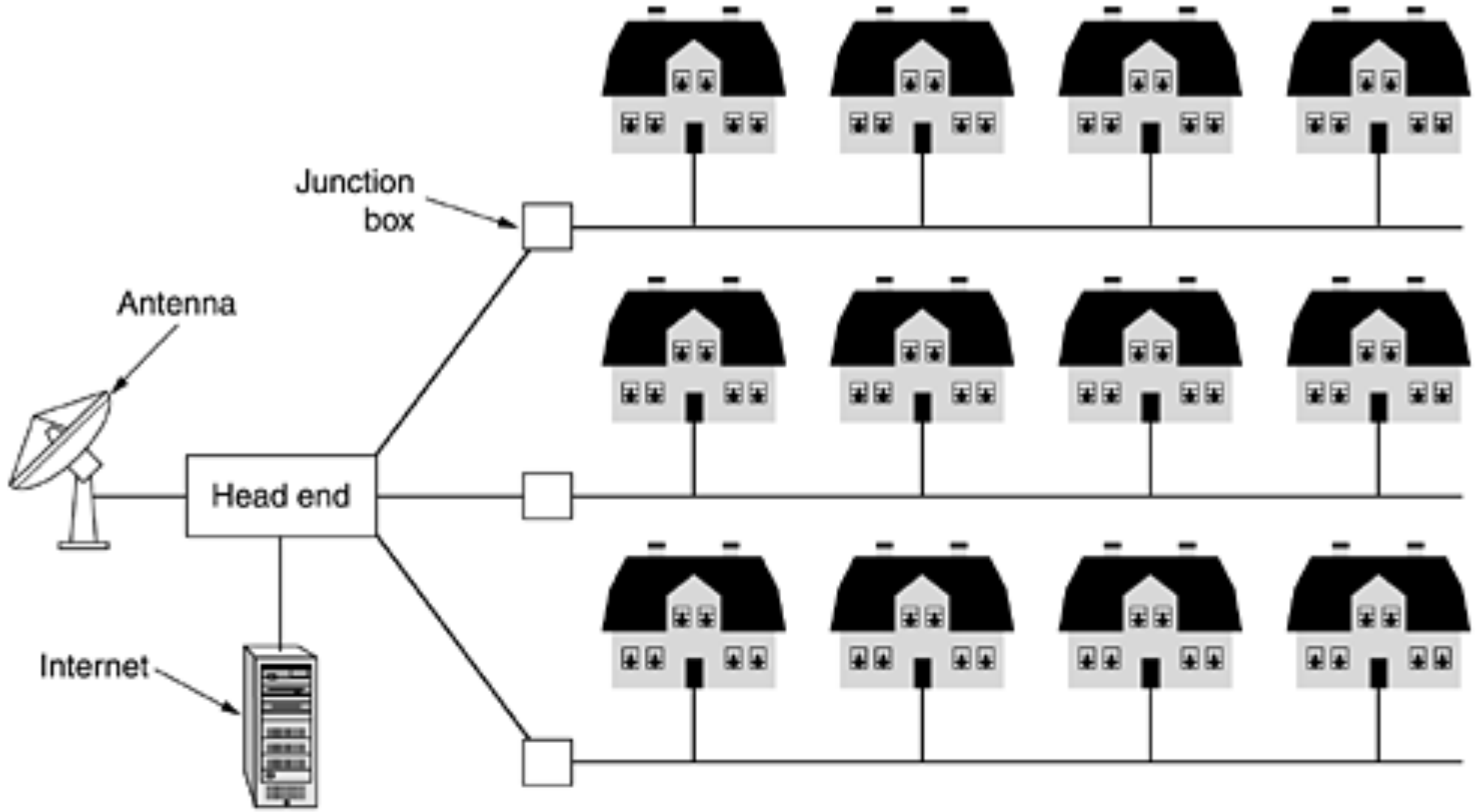
- More common LANs





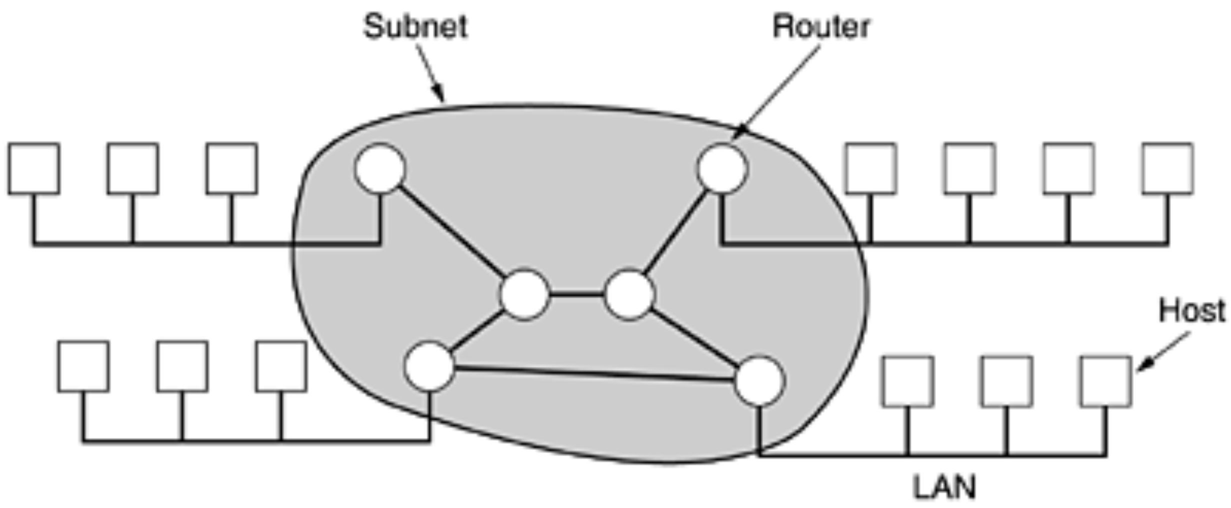
Metropolitan Area Networks

A metropolitan area network based on cable TV



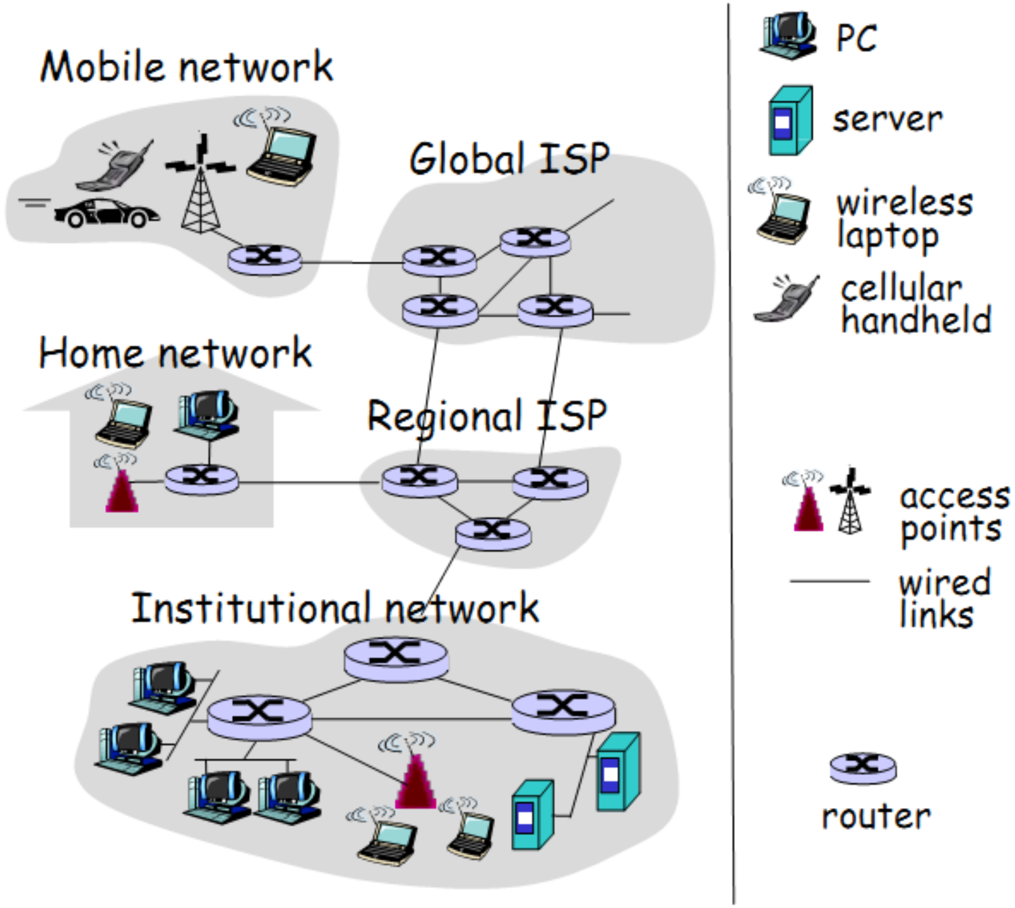
Wide Area Networks

- Subnet connects different LANs

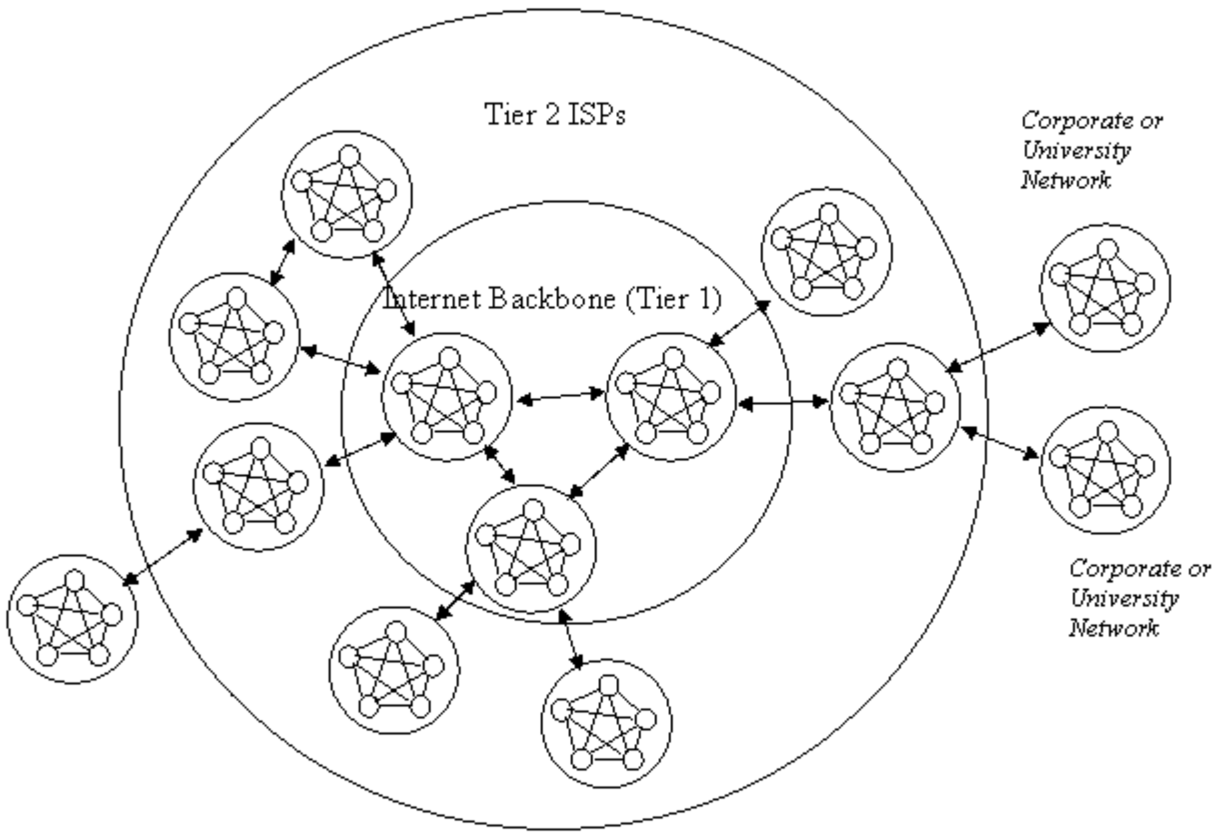


The Internet

- Network interconnection
- Access Network
  - LANs, MANs
- Core Network
  - WANs
  - Interconnected routers
  - Network of networks
  - Realm of the Internet Service Providers

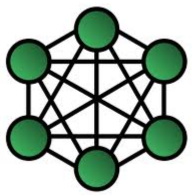


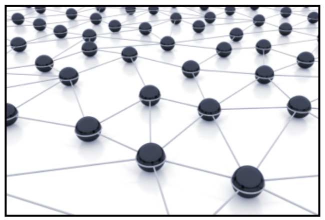
The Internet – ISP Tier model

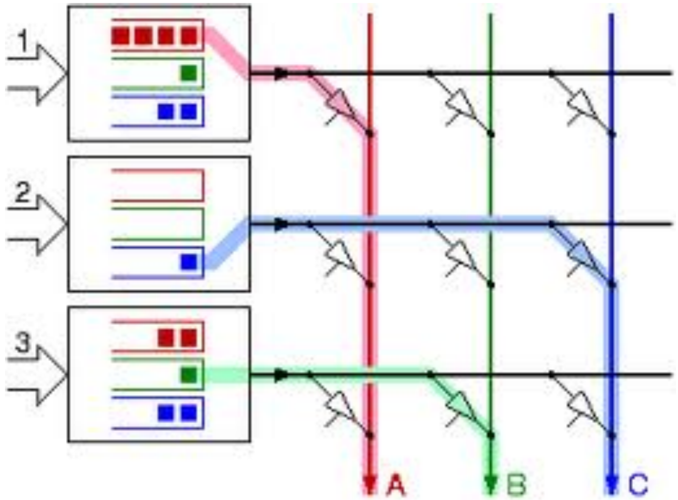


TO THINK

- How do you transmit information through a computer network?







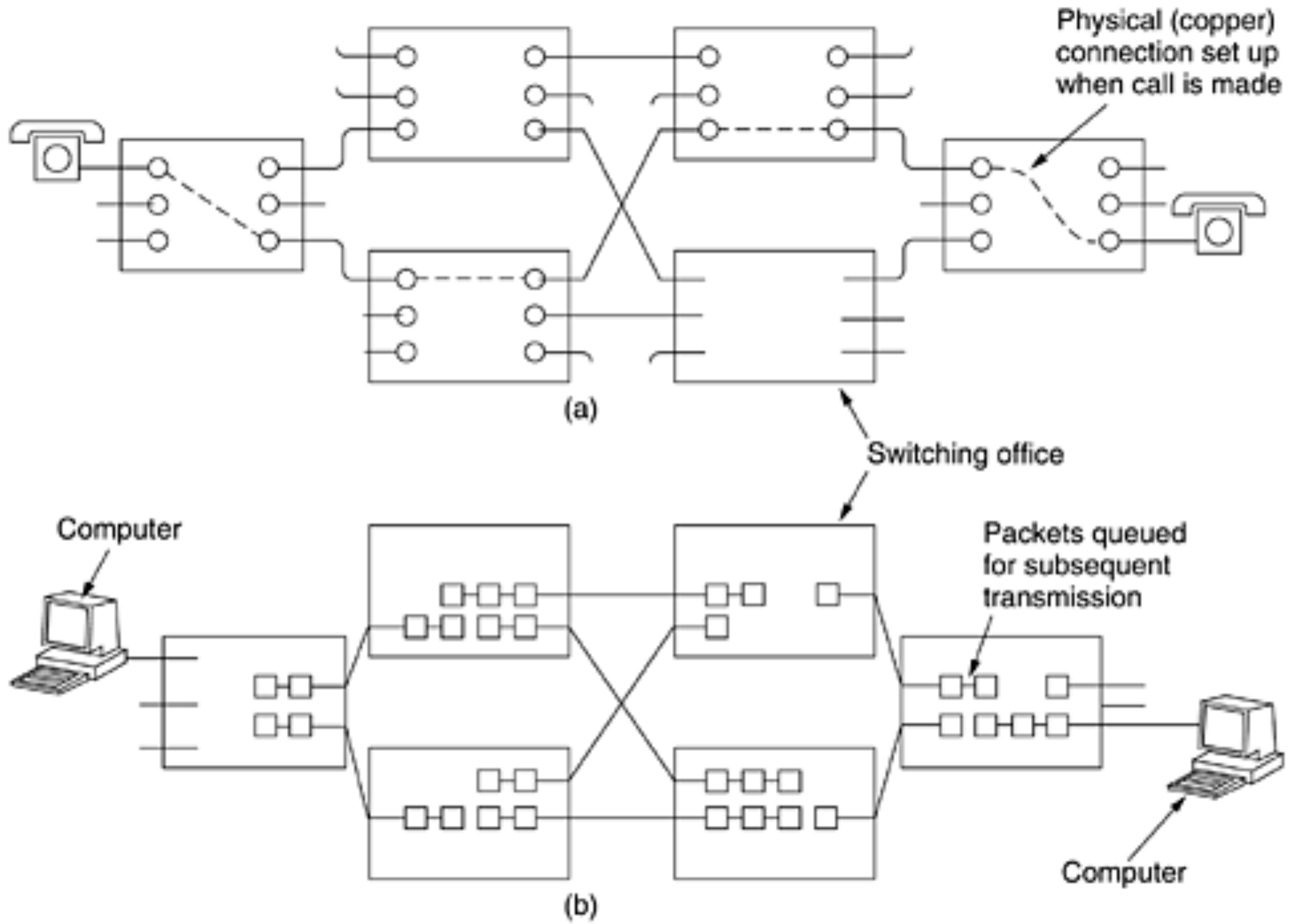
Information

- Many definitions
  - Information theory
- In our case
  - Digital representation of information
  - Aka data, 001001b, 0xF423A
  - Images, voice, application-specific data
  - 1 byte = 1 octet = 8 bits
  - 1 kbit = 10^3 bit, 1 Mbit=10^6 bit, 1Gbit=10^9 bit
  - 1 KB = 2^{10} bytes (1024!), 1 MB = 2^{20} bytes, 1 GB = 2^{30} bytes
- Link capacity, information flow
  - byte/s, bit/s

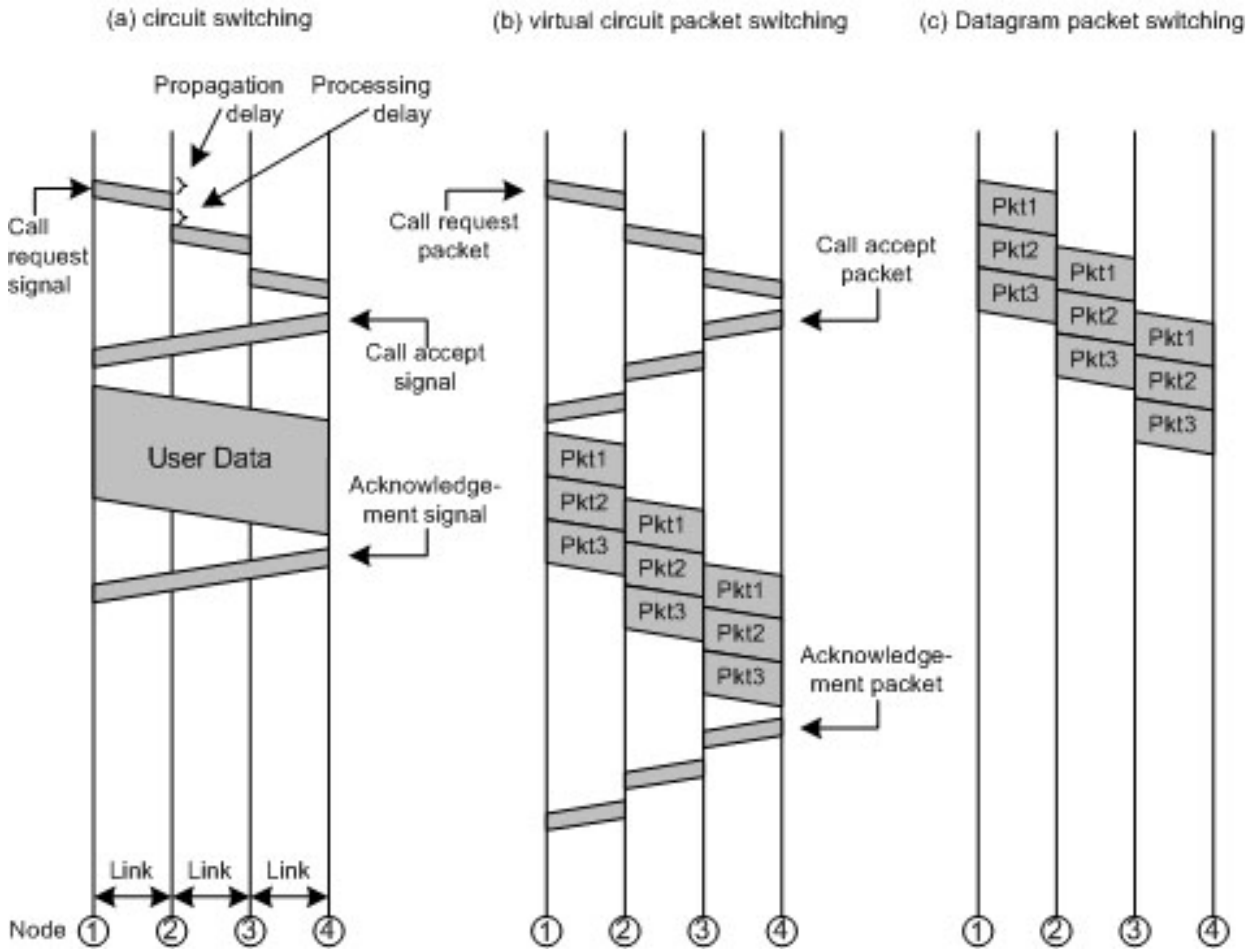
Circuit switching vs. packet switching

Circuit switching

Packet switching



Switching: circuit, virtual circuit, and datagram



Circuit switching vs. packet switching

Item	Circuit switched	Packet switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
Time of possible congestion	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

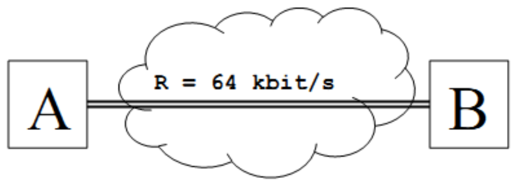
Types of delay in switching

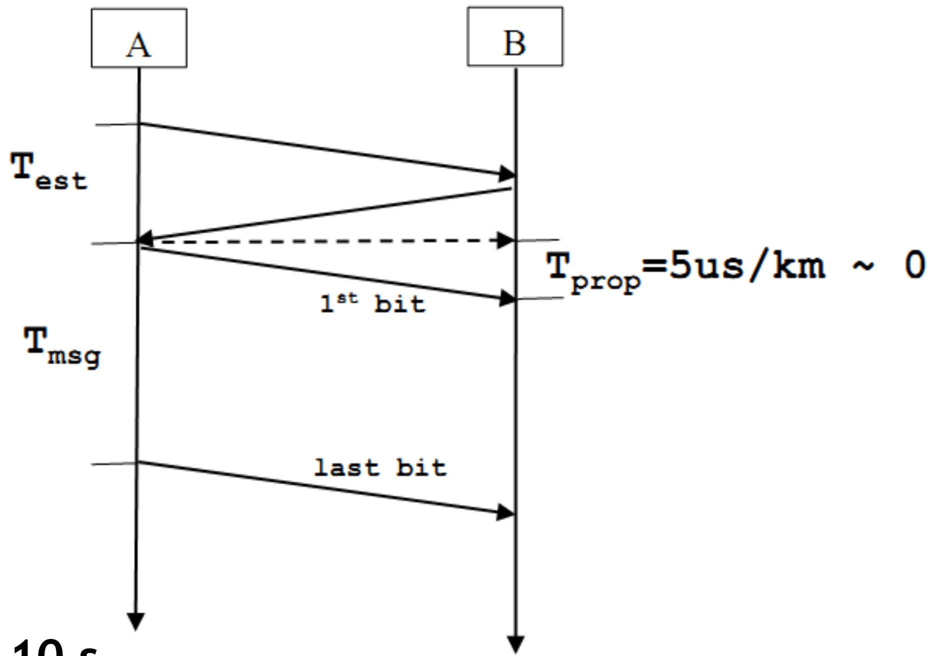
- Processing delay
- Queuing delay
- Transmission delay
- Propagation delay

- Connection establishment delay
- End-to-end delay

Delay - circuit switching example

How long does it take for an application to send an L=640 kbit file through an R=64 kbit/s bitrate circuit with connection establishment delay T_{est}=500 ms?



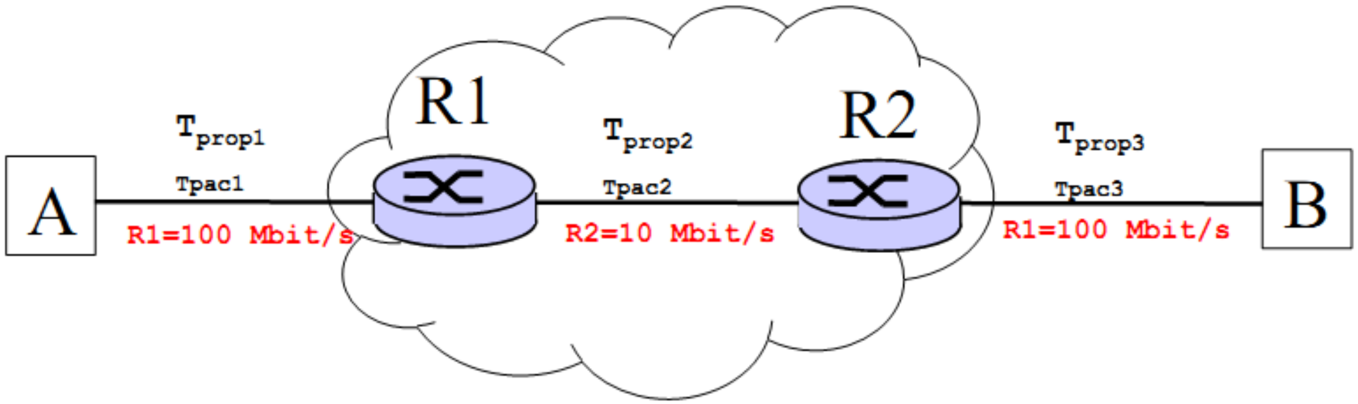


$T_{trans} = T_{msg} = L/R = 640 \text{ kbit} / 64 \text{ kbit/s} = 10 \text{ s}$

$T_{file} = T_{est} + T_{prop} + T_{trans} = 10.5 \text{ s}$

Delay - packet switching example

How long does it take for application A to send an L=10 kbit packet to B in the 2 router network below?



$$T_{total} = T_{prop1} + T_{trans1} + T_{prop2} + T_{trans2} + T_{prop3} + T_{trans3}$$

Assume all $T_{prop} = 0$, $T_{queue} = 0$

$T_{trans1} = T_{trans3} = L/R1 = 10$ kbit / 100 Mbit/s = 0.1 ms

$T_{trans2} = L/R2 = 10$ kbit / 10 Mbit/s = 1 ms

$T_{total} = 1.2$ ms

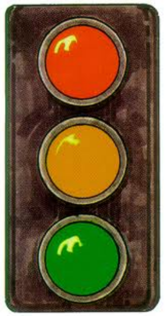
Other performance metrics

- Throughput
  - Instantaneous
  - Average
- Fairness
  - Among all nodes in the network

TO THINK

- What are some of the key issues in computer networks?



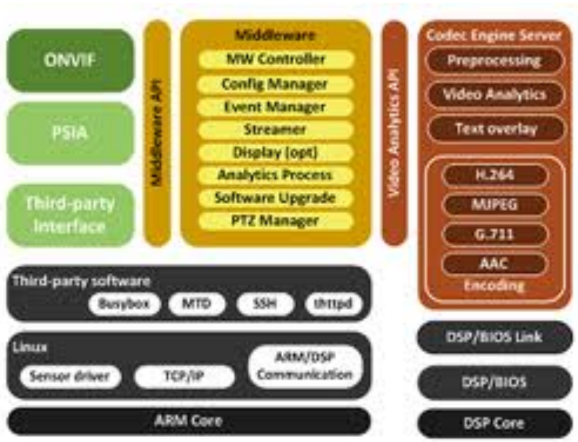






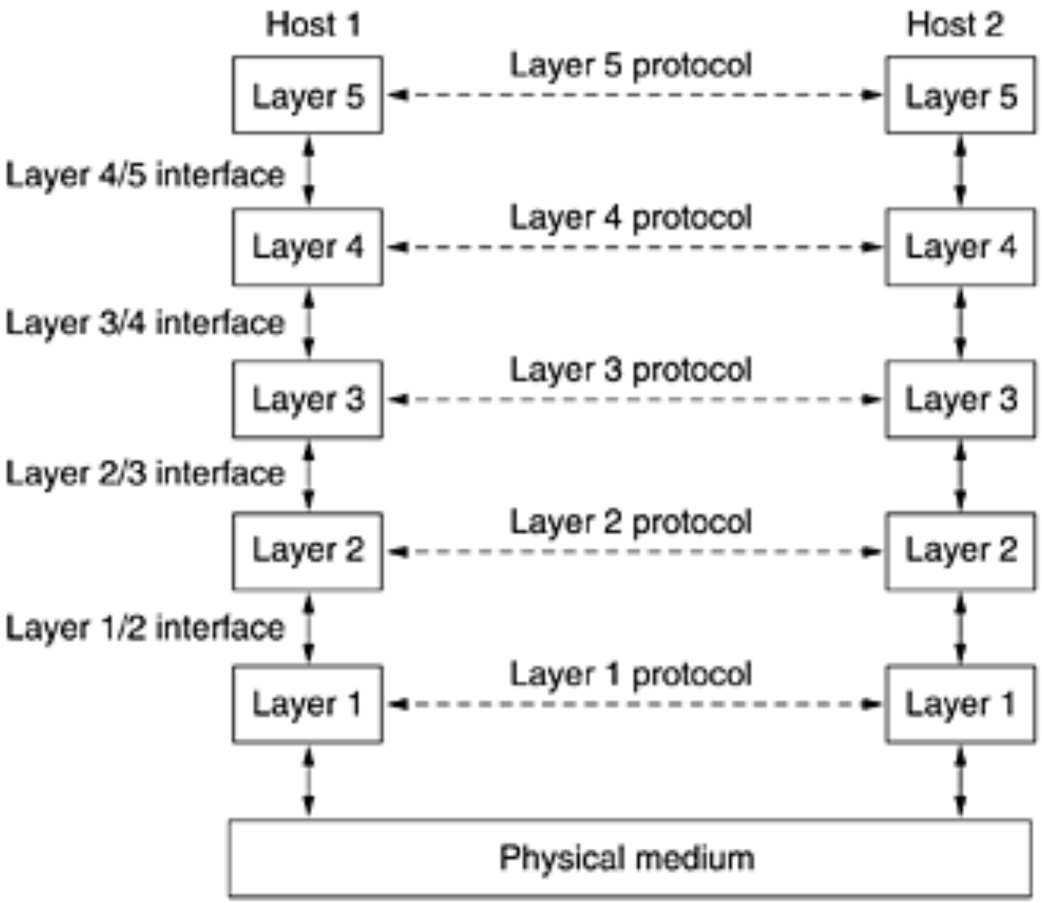
TO THINK

- How do you write large complex software?

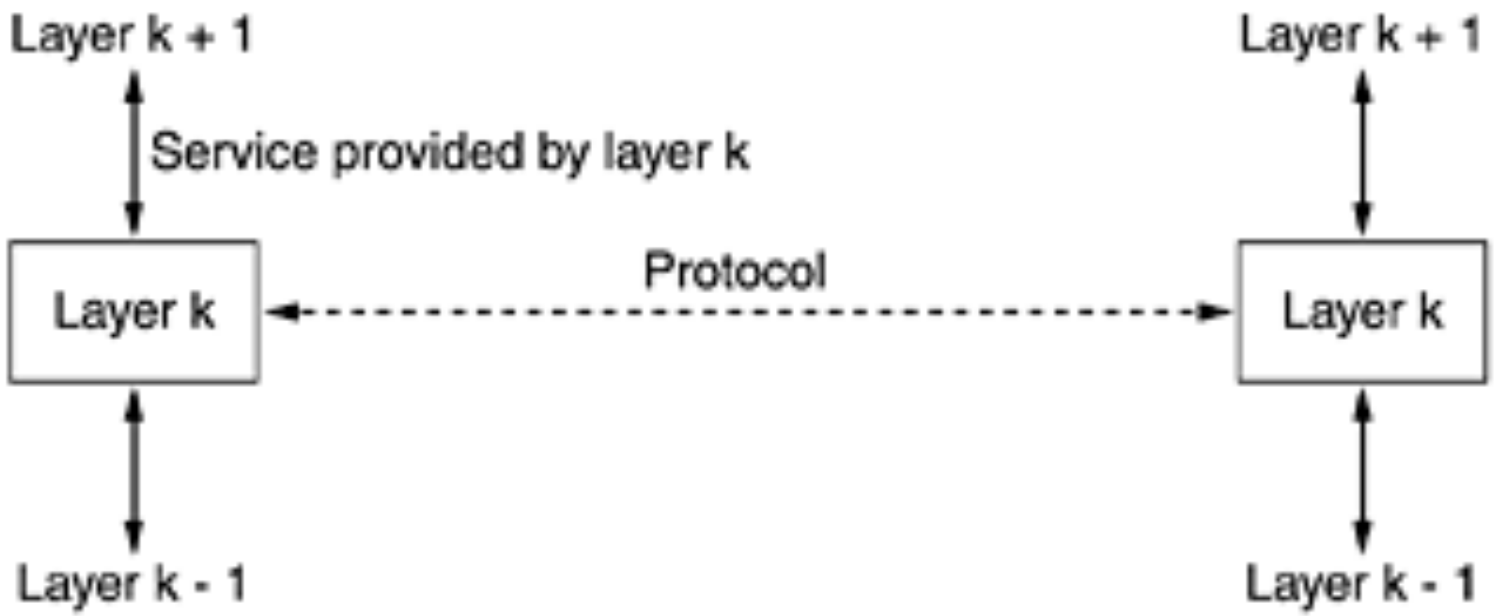


Protocol hierarchies

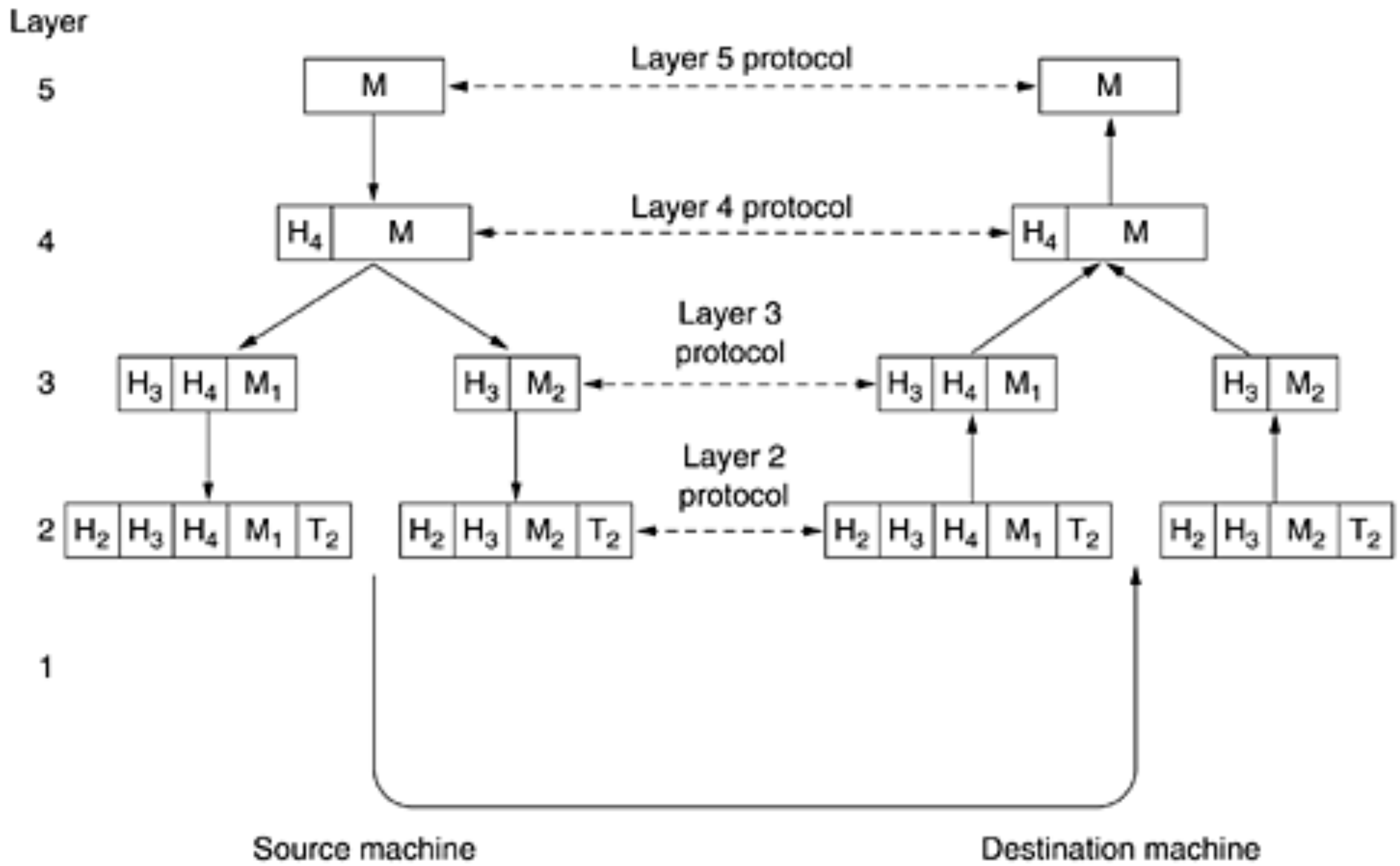
Layers, Protocols, and Service Interfaces



Service vs. Protocol



Application message sending example

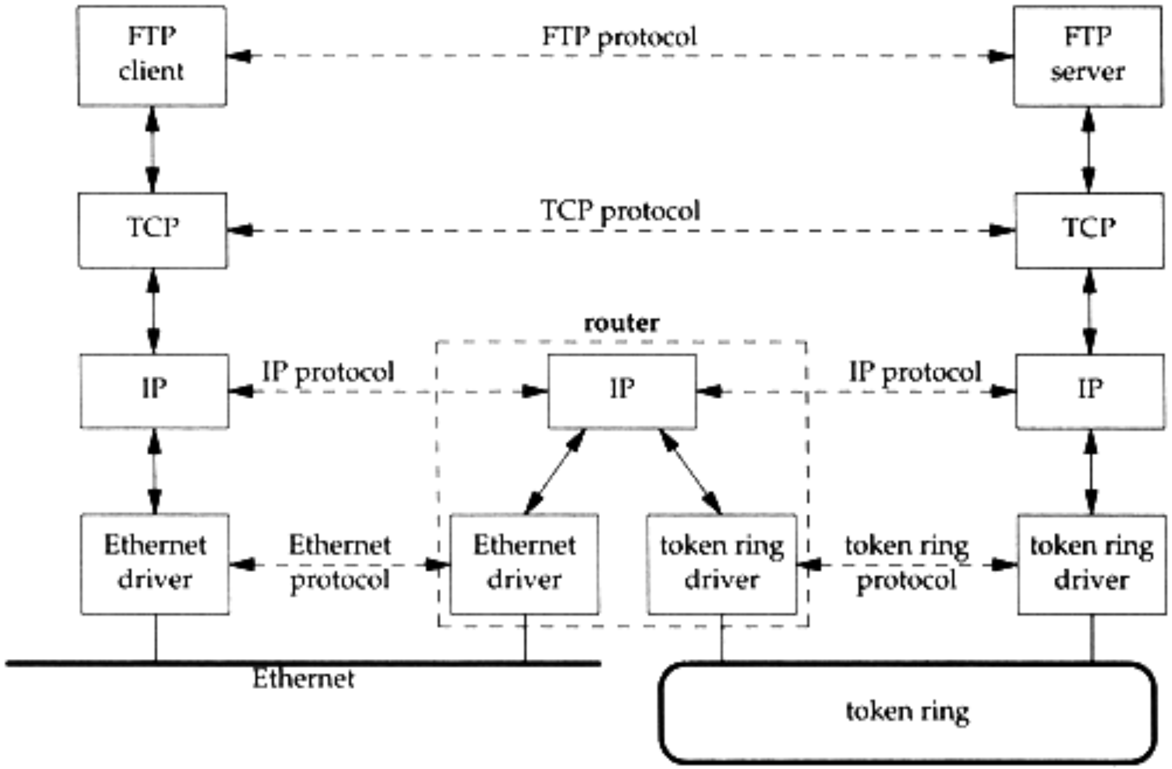


TCP/IP (Internet) reference layer model

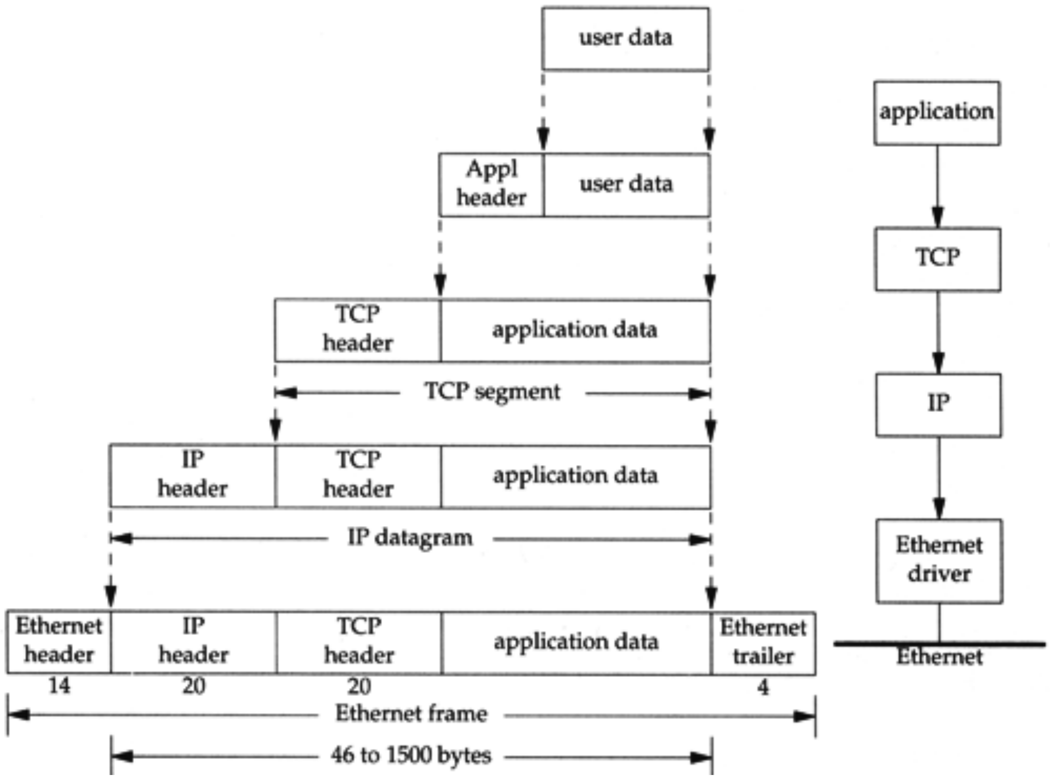
- Application layer
  - The network application
  - FTP, HTTP, SMTP
- Transport layer
  - End-to-end data transfer
  - TCP, UDP
- Network
  - Routing of data packets
  - IP, routing protocols
- Link
  - Data transfer between neighbor network nodes
  - PPP, Ethernet, WLAN
- Physical
  - Transmission over physical medium, modulation, bits to symbols

Application
Transport
Network
Link
Physical

TCP/IP Internetworking



TCP/IP Encapsulation



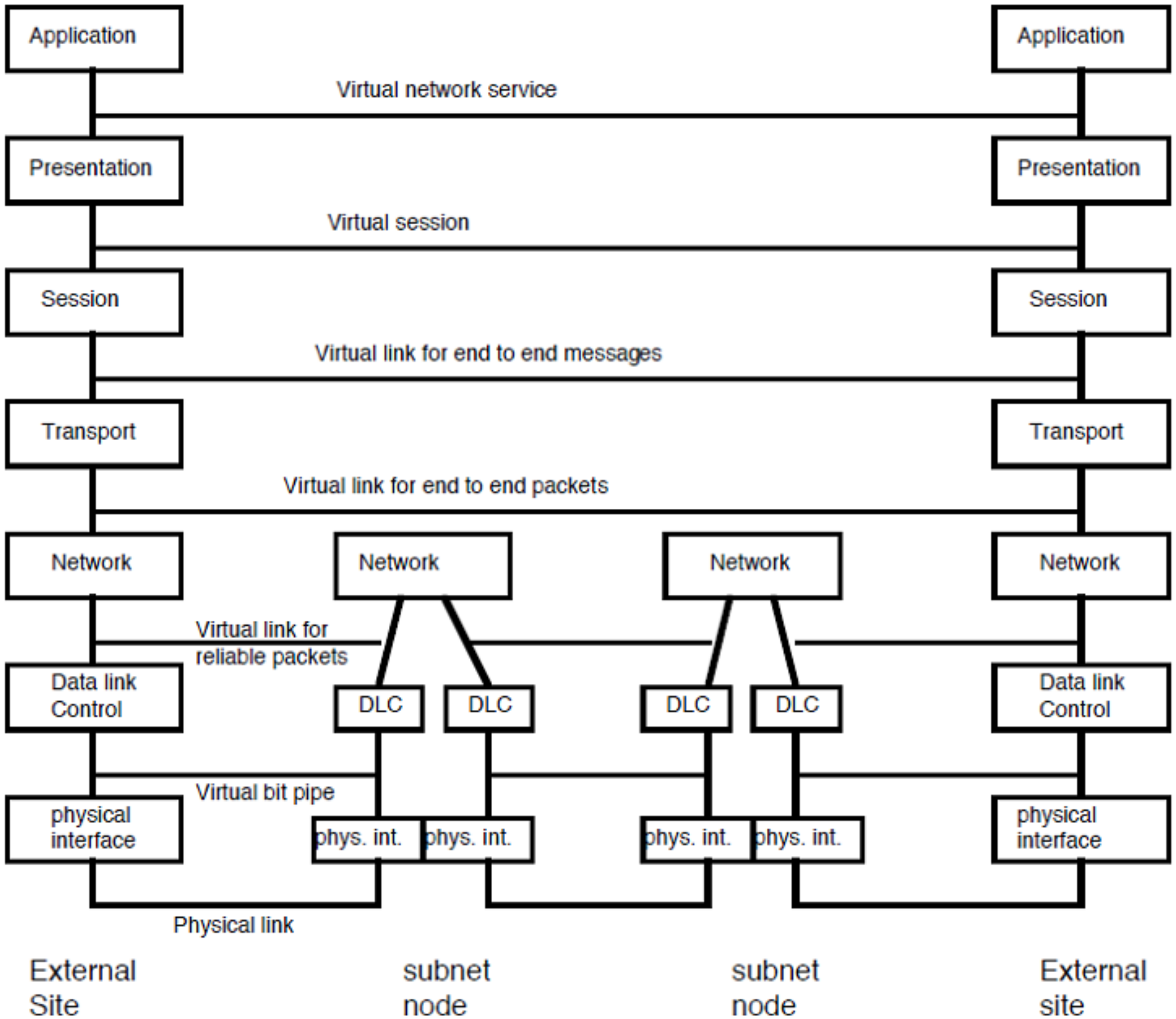
OSI 7 layer model

- Presentation
  - Meaning of data
  - Format, compression
- Session
  - Synchronization
  - Check-pointing
  - Data recovery

- In TCP/IP these functions have to be implemented by the application

OSI	TCP/IP
Application	Application
Presentation	
Session	
Transport	Transport
Network	Network
Link	Link
Physical	Physical

OSI layer services and links



Reference model in RCOM

5	Application
4	Transport
3	Network
2	Link
1	Physical

Issues at each level

- Connection/connectionless
  - Packet drop, reorder
- Flow control
  - Sender is faster than receiver
  - Prevent receiver buffer overflow
- Congestion control
  - More data than the network can handle
  - Pace down sources

Application
Transport
Network
Link
Physical

Issues at each level

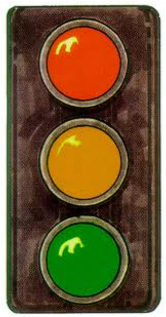
- Router architecture
  - Switching: bus, crossbar, memory
- IP Packet, Addressing, ARP, …
- Routing algorithms
  - Distributed route computation
  - Link state, Dijkstra’s
  - Distance/path vector, Bellman-ford

Application
Transport
Network
Link
Physical

Issues at each level

- Data link
  - Bit framing
  - Error detection, checksum
  - Automatic Repeat Request (ARQ)
- Medium access control
  - Decentralized access
  - Random access, collisions
  - Ethernet, origin and switching

Application
Transport
Network
Link
Physical



Issues at each level

- Transmission through a channel
  - Guided, broadcast
- Enconde bit sequences
  - Into signals for propagation
  - Noise, bit and baud rate
- Nyquist, Shannon

Application
Transport
Network
Link
Physical

HOMEWORK

- Review slides

- Read – Tanenbaum
  - Introduction - 1.
  - Switching – 2.5.5

- Do your Moodle homework