Redes de Computadores

Introduction

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Introduction to the Course

RCOM – Professors, Language

- Prof. Manuel Ricardo
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  - http://www.fe.up.pt/~mricardo
  - Tel.: 22 209 4000
  - Office at INESC Porto (4th floor)
- Information about RCOM

  available in moodle
- Language
  - » Slides and books in English
  - » Lectures in Portuguese
  - » *Suitable for English-speaking students*

Bibliografia

- Main book

  Andrew Tanenbaum, David Wetherall,

  Computer Networks, 5/E

  Prentice Hall

  2011

- Slides presented in classes
  - » Follow the main book
  - » Complemented with information from other sources
  - » Oriented towards the fundamentals; details are in the book

Bibliografia – Other books

- **Dimitri Bertsekas, Robert Gallager, Data Networks, 2nd Edition, 1992, Prentice Hall**
  - » Oriented to the fundamental aspects of data networks with formal (math) descriptions
  - » Available also in http://web.mit.edu/dimitrib/www/datanets.html
  - » Examples on outdated networks

- **Larry L. Peterson, Bruce S. Davie, Computer Networks - A Systems Approach, 4th Edition, 2007, Morgan Kaufmann**
  - » Less generic than Tanenbaum; oriented to TCP/IP and implementation aspects

- **James F. Kurose, Keith W. Ross, Computer Networking - a Top-Down Approach, 2010, 5th Edition, Pearson**
  Similar to Tanenbaum; uses top-down approach; more focused on applications than in physical layer

- **W. Richard Stevens, TCP/IP Illustrated: The Protocols (Vol. 1), 1994, Addison-Wesley.**
  - » The book of TCP/IP stack

- **William Stallings, Data & Computer Communications, 8th Edition, 2007, Prentice Hall**
  - » Generic and good book; addresses also telecom networks

Types of Classes

- ***Aulas teóricas***
  - » Oriented to the fundamental aspects of Computer Networks
  - » Additional reading required at home
  - » Weekly homeworks

    questions to be answered before next lecture **through moodle**

- ***Aulas laboratoriais***

  2 laboratory projects
  - » 1st lab: protocol development, Linux, C programming, file transfer
  - » 2nd lab: configuration computer network (switches, routers, computers)

Avaliação de RCOM

Notas de 0 a 20 valores

E - nota do exame escrito
L1 - nota do 1º trabalho laboratorial
L2 - nota do 2º trabalho laboratorial
H - nota dos trabalhos de casa
FQ - NOTA DE FREQUÊNCIA
CF - CLASSIFICAÇÃO FINAL

FQ = 0,4*L1 + 0,4*L2 + 0,2*H
CF = 0,4*FQ + 0,6*E

se (FQ < 8,0) FQ = “Reprovado por Falta de Frequência"
se (E < 8,0) CF = E

Learning objectives

- Fundaments of network design and analysis
  - Communication channels and data link control
  - Delay and loss models in data networks
  - Multi-access communications
  - Routing in computer networks
  - Flow and congestion control
- Technologies in use
  - Ethernet, WLAN, Internet, TCP/IP communications stack
- Implementation
  - Protocol development in UNIX
  - Computer network configuration

Introduction to Computer Networks

» *What are the **main uses** of computer networks?*

» *What are the main **types of networks**?*

» *What is a **protocol**? What is a **service**?*

» *What is a **protocol stack**?*

» *What are the communication layers of the **Internet reference model**?*

» *What are the differences between **circuit switching** and **packet switching**?*

» *What is the **propagation delay**, T_{prop} ?*

» *What is the **packet transmission delay**, T_{pac}?*

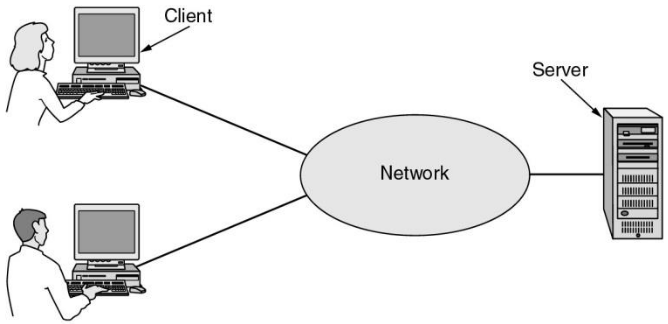
Uses of Computer Networks

Some Applications Using Communications Networks

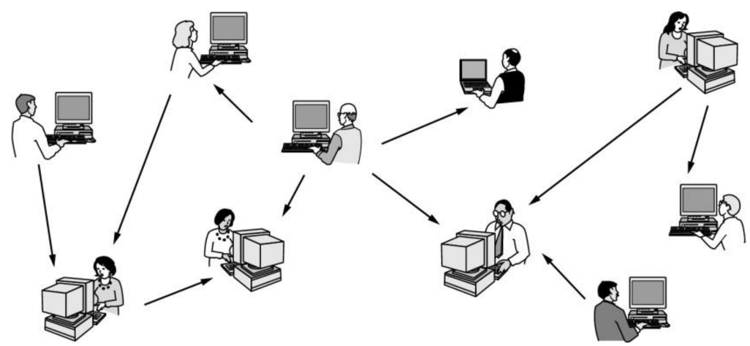
- E-mail
- Web
- Remote login
- P2P file sharing
- Multi-user network games
- Video retrieval
- Voice over IP
- Video streaming
- Real-time video conferencing
- …

Application Architectures

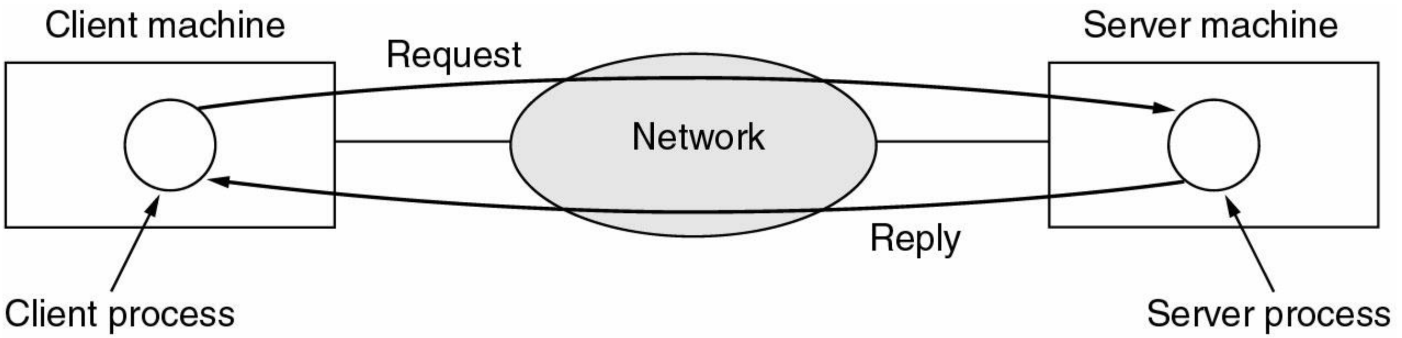
- Client-server



- Peer-to-peer (P2P)



Client-server Architecture

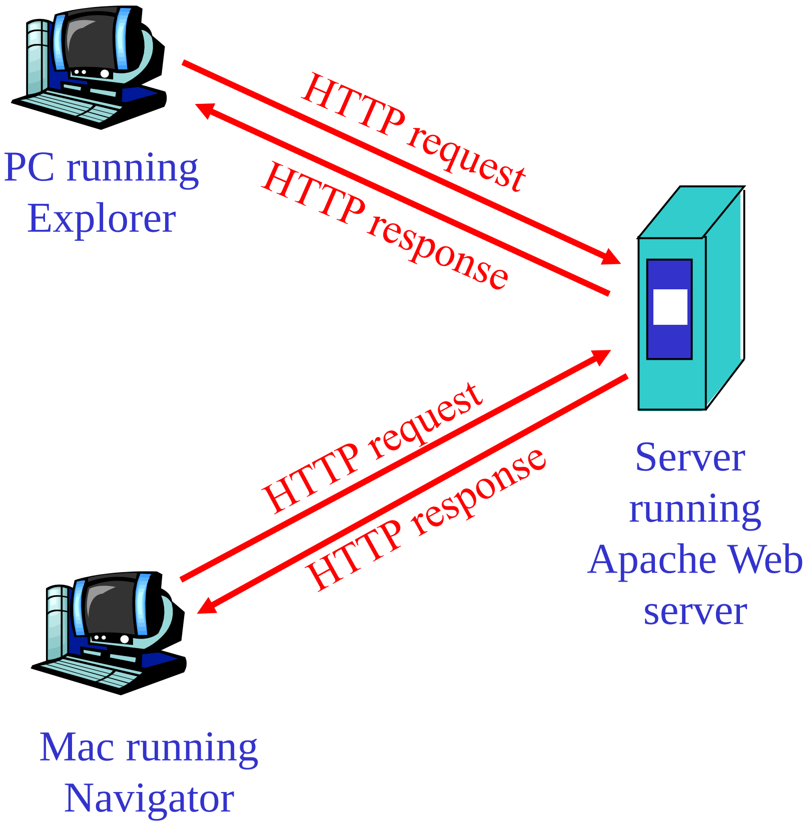


- Server
  - » always-on computer
  - » permanent IP address, well-known name

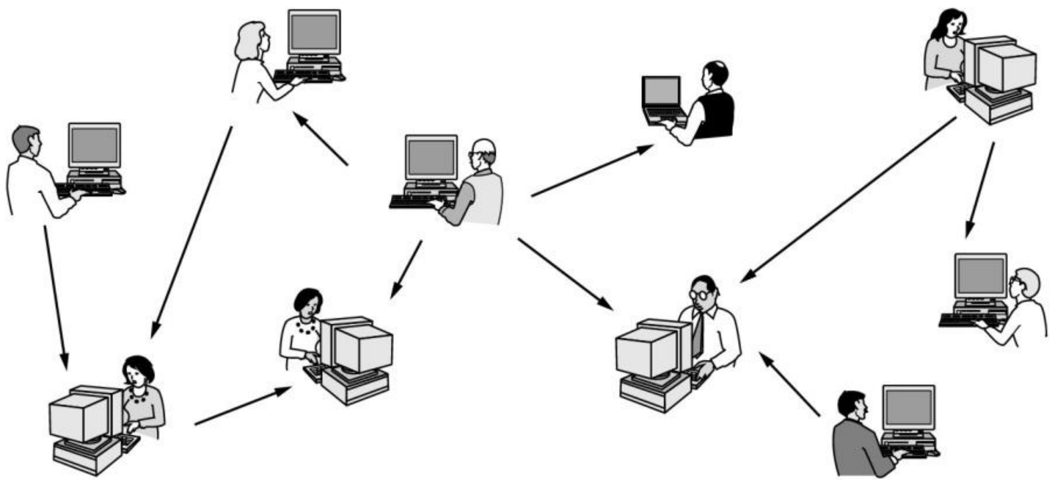
- Clients
  - » communicate with server
  - » may be intermittently connected
  - » do not communicate directly with other clients

Client-server Example – The Web

- Client/server model
- Client: browser
  - » requests, receives, displays Web objects
- Server: web server
  - » sends objects in response to requests



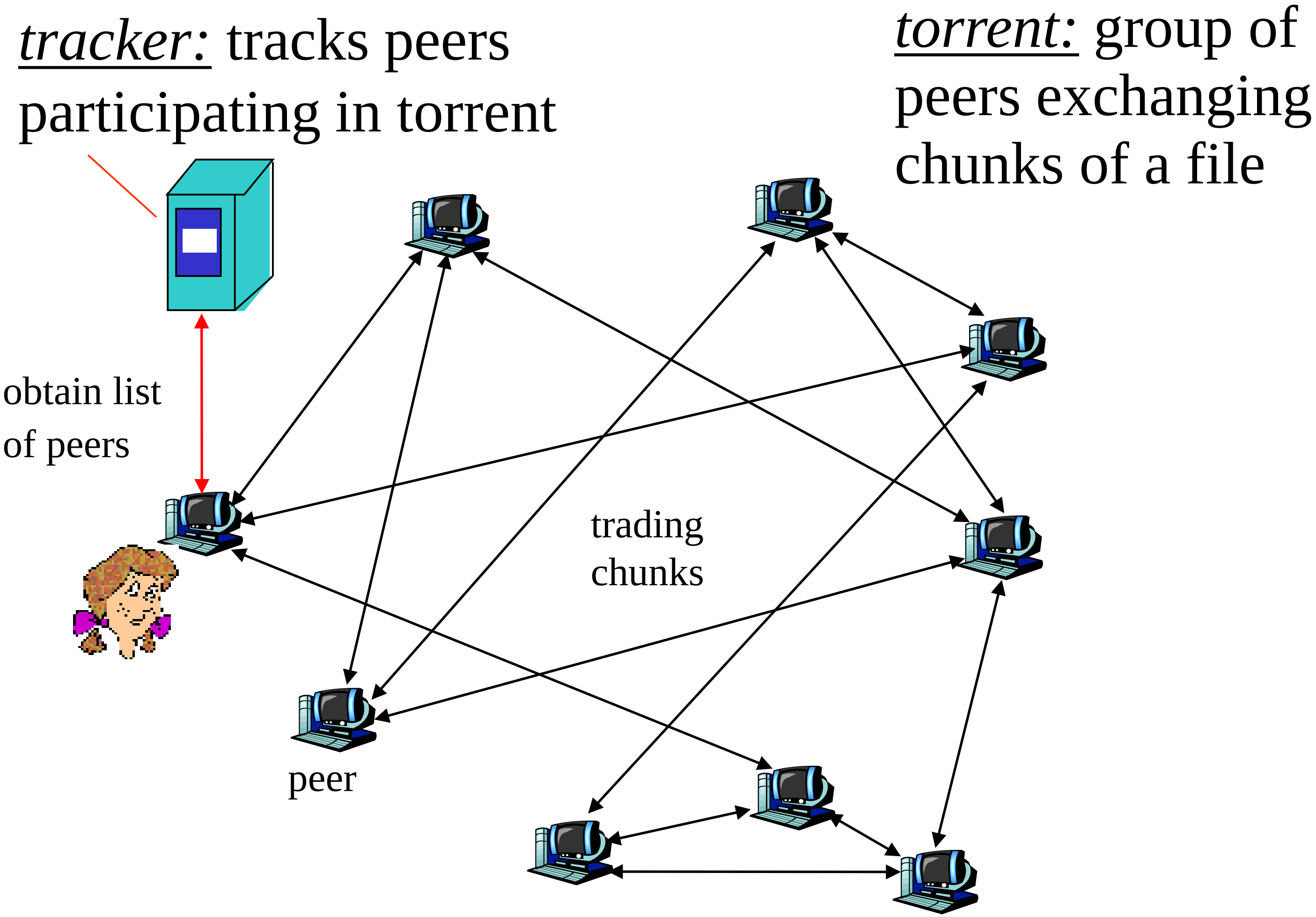
P2P Architecture



- No always-on server
- Arbitrary end systems communicate directly
- Peers are intermittently connected and may change IP addresses

P2P Example - BitTorrent

P2P file distribution



Types of Networks

Classification of Communications Networks

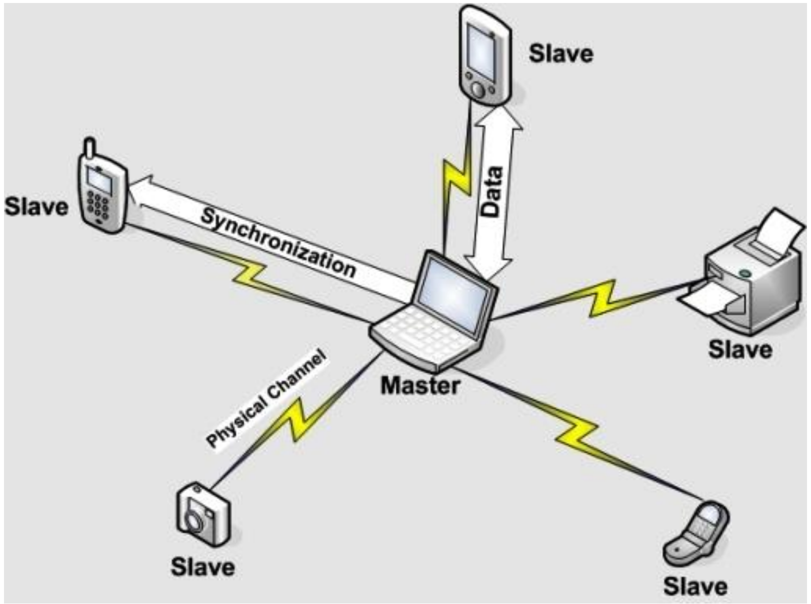
- By scale
  - » distance between processors

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

- PAN - Personal Area Network
- LAN - Local Area Network
- MAN - Metropolitan Area Network
- WAN - Wide Area Network
- Internet

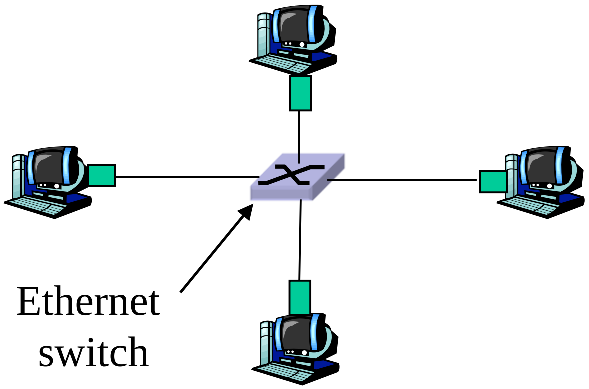
Personal Area Networks

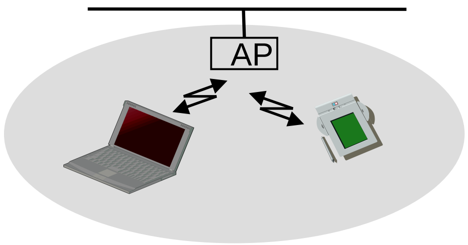
Bluetooth network



Local Area Networks

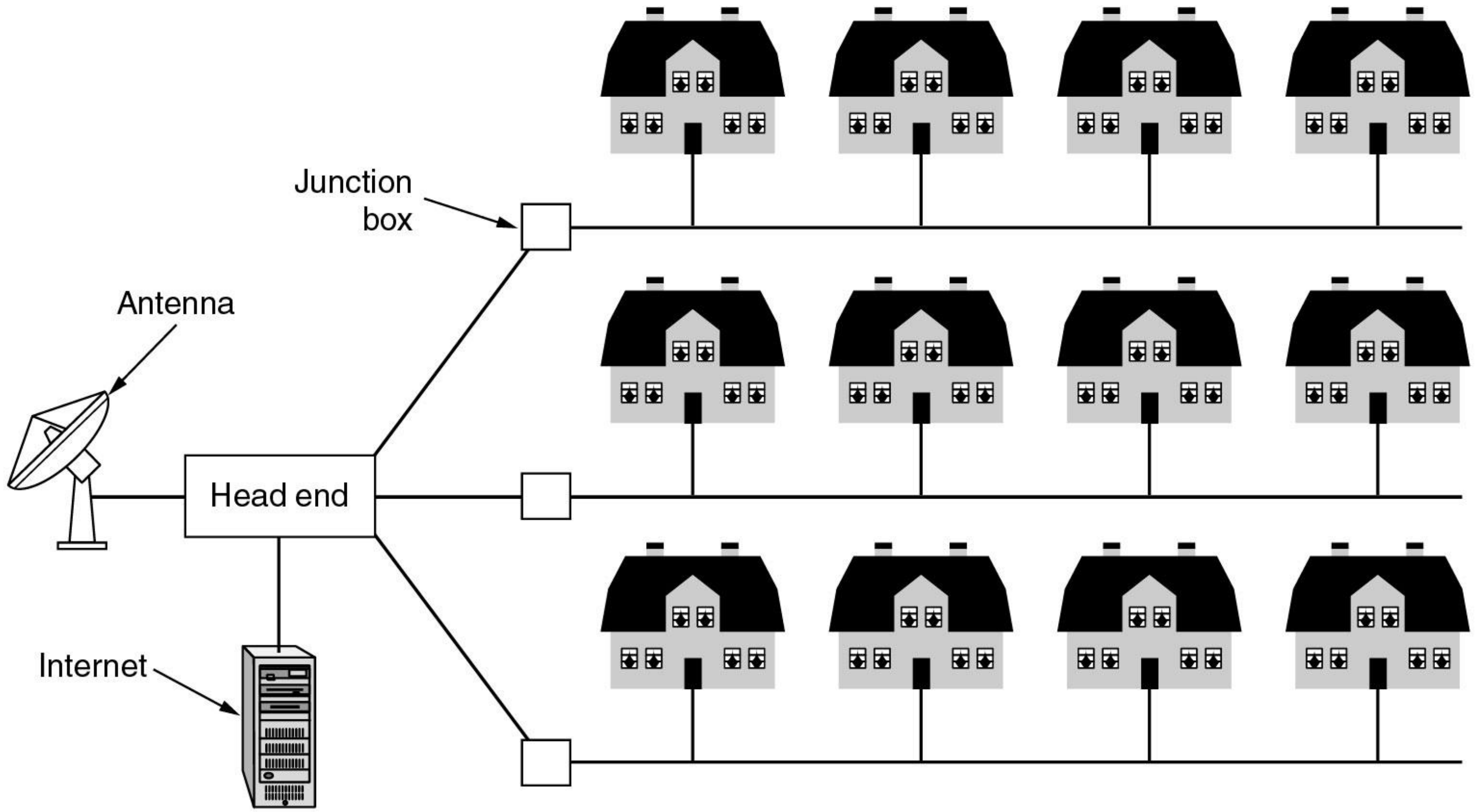
- Local Area Networks





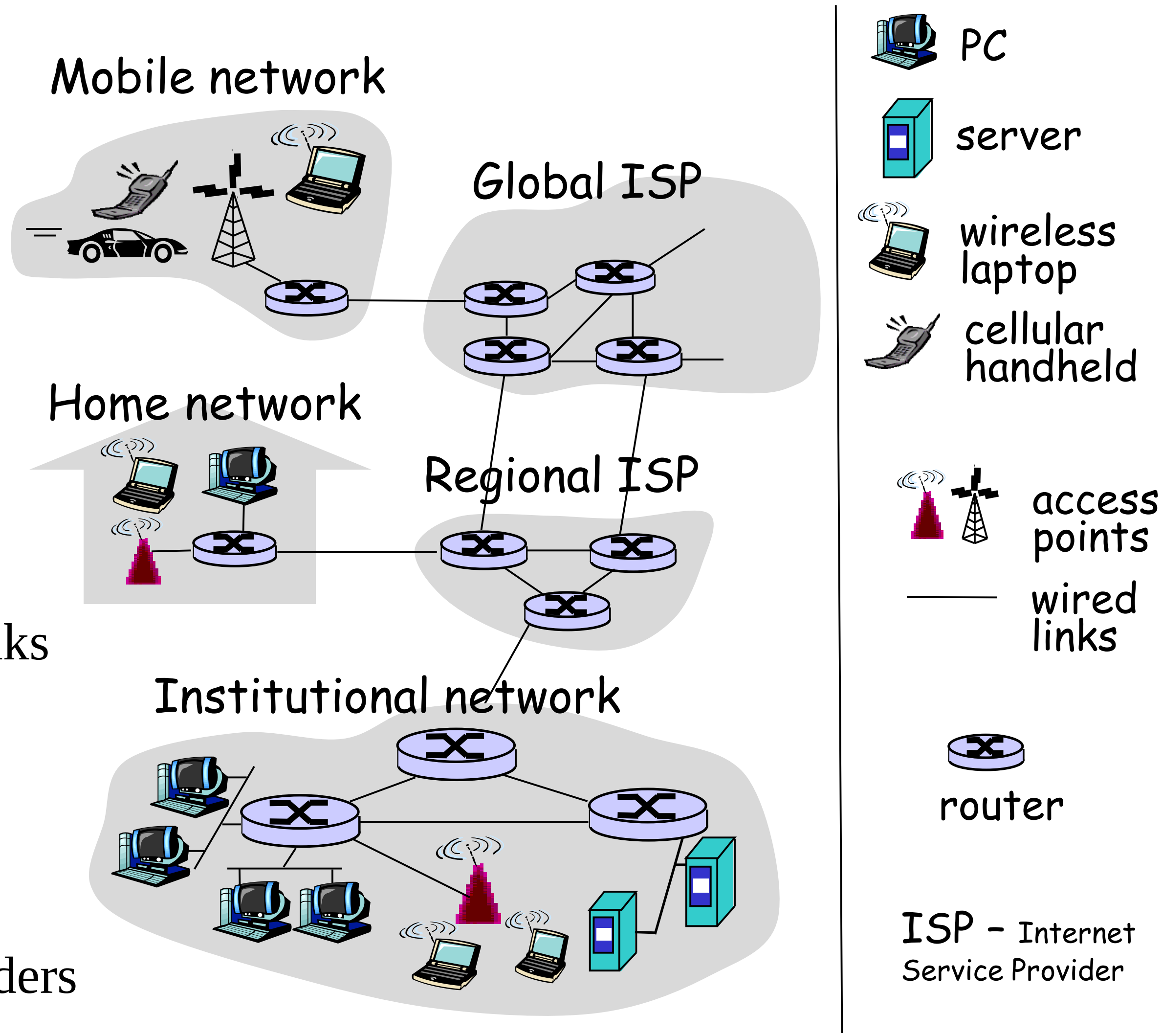
Metropolitan Area Networks

A metropolitan area network based on cable TV



Internet – Interconnecting networks

- Network edge
  - » Hosts
  - » Applications
- Access networks
  - » LANs, MANs
  - » Home, Institutional
  - » Mobile
  - » Wired and wireless links
- Network core
  - » Interconnected routers
  - » Network of networks
  - » Internet Service Providers



Network Software

Communications Software Organized in Black Boxes

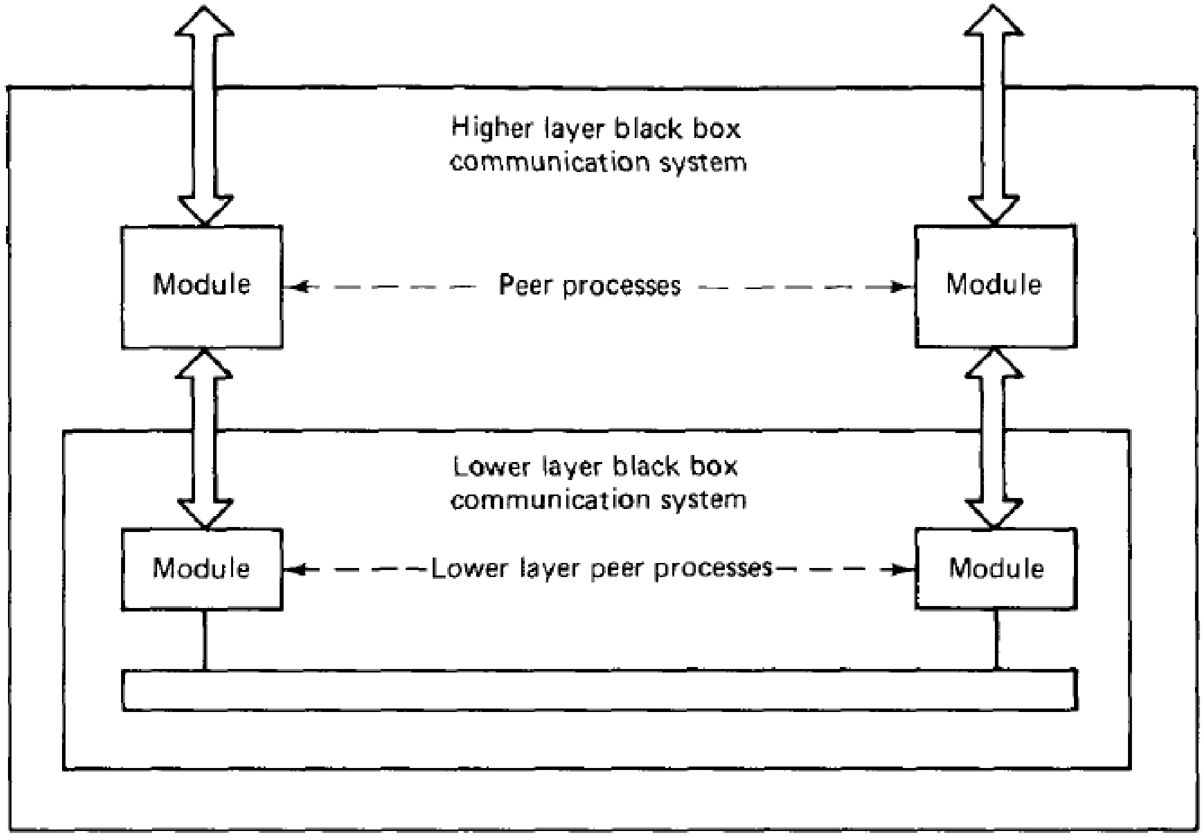
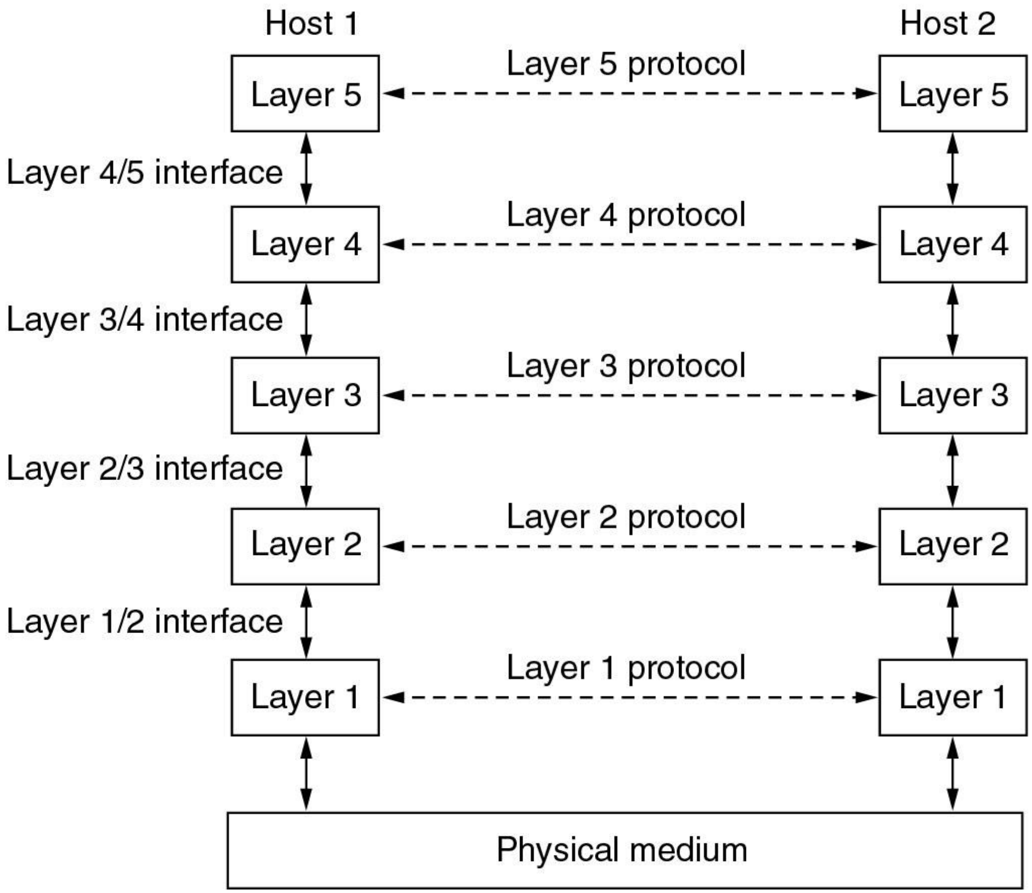


Figure 1.7 Peer processes within a black box communication system. The peer processes communicate through a lower-layer black box communication system that itself contains lower-layer peer processes.

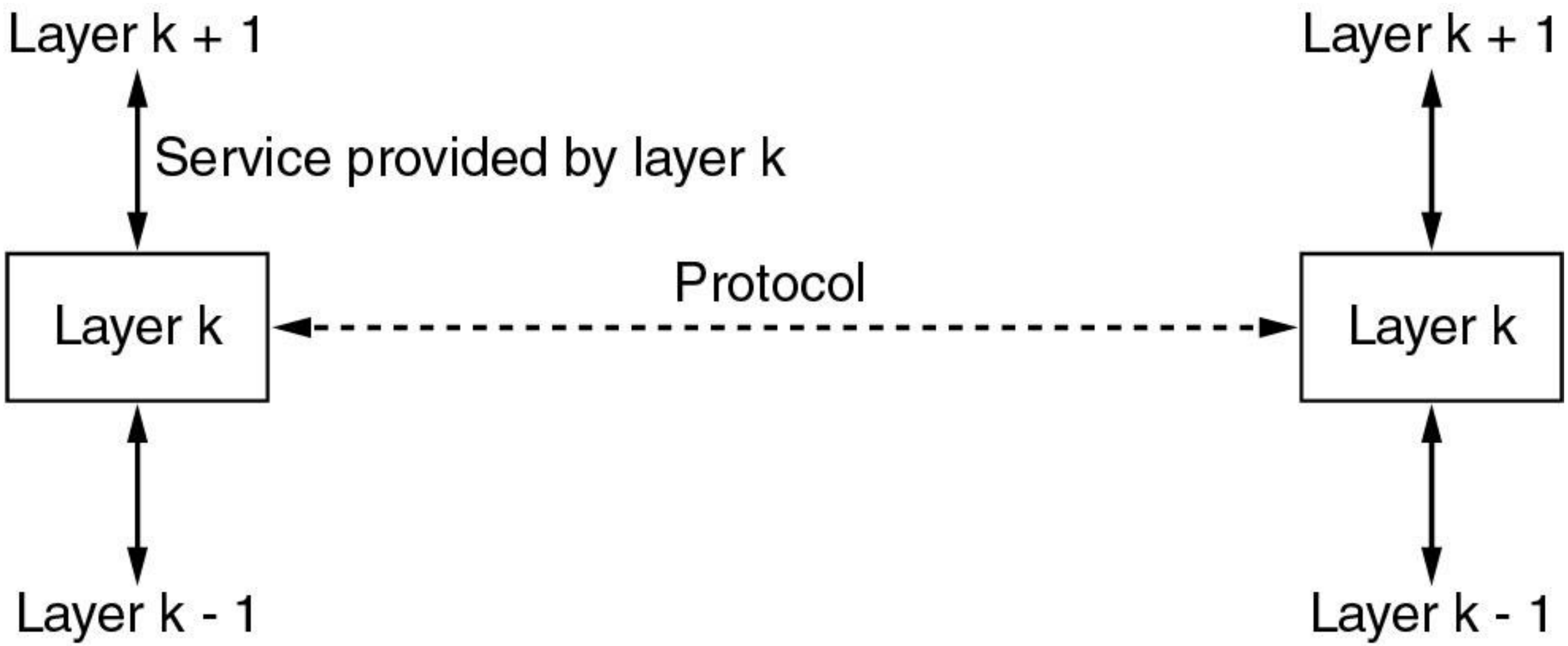
Protocol Hierarchies

Layers, protocols, and interfaces



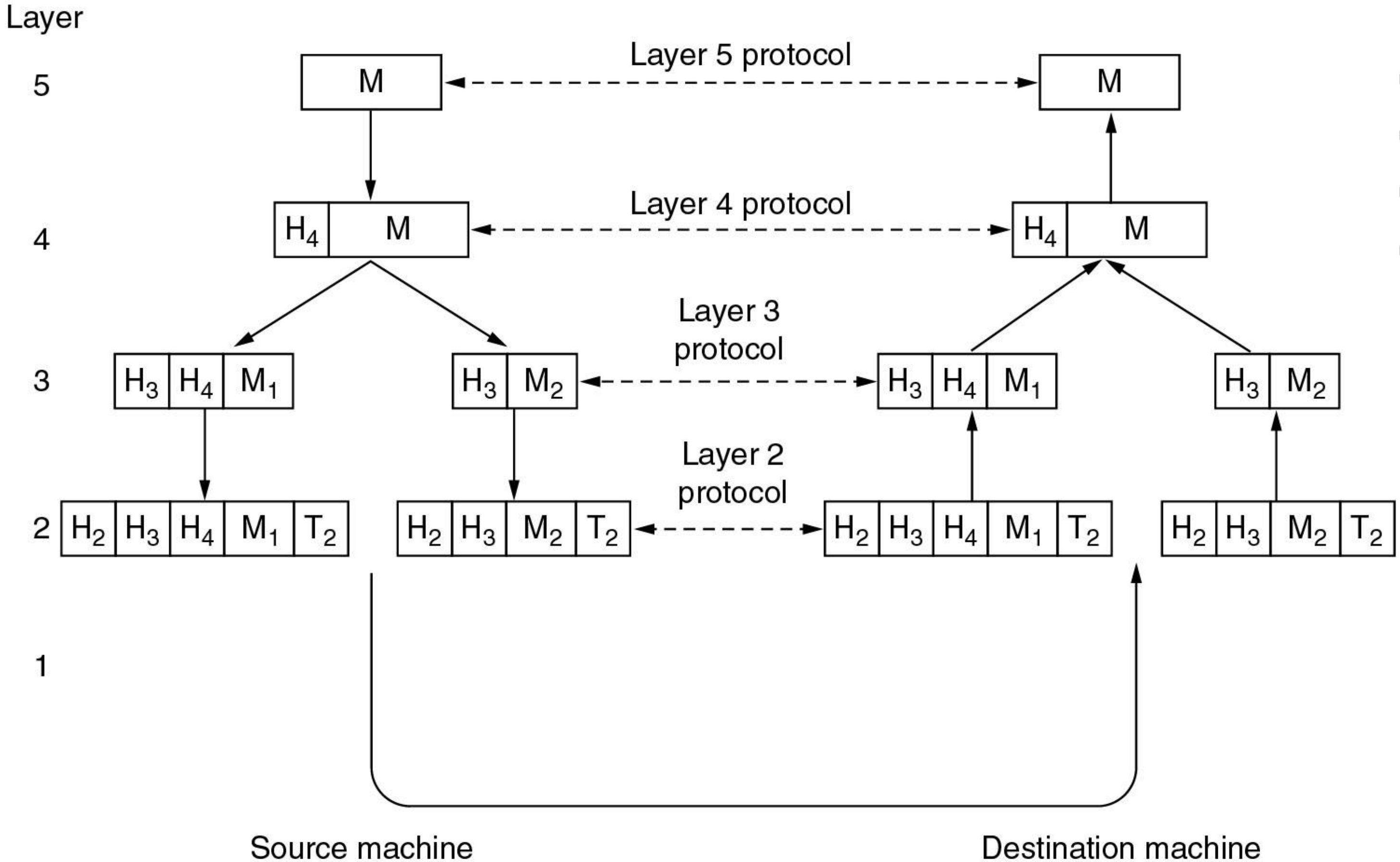
Services to Protocols Relationship

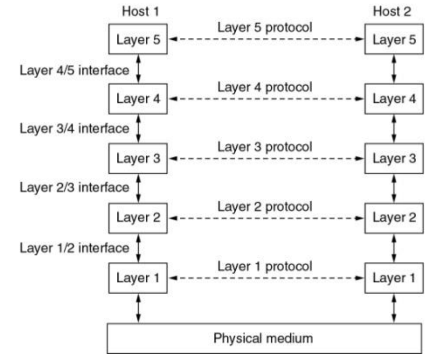
The relationship between a service and a protocol



Transference of Information

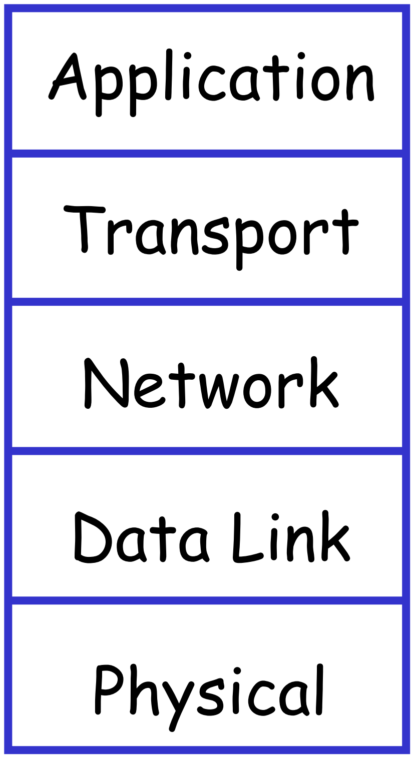
Information flow supporting virtual communication in layer 5





Internet (TCP/IP) Reference Model

- Application layer
  - » supporting network applications
  - » FTP, SMTP, HTTP, …
- Transport layer
  - » process-process (end-to-end) data transfer
  - » TCP, UDP
- Network layer
  - » routing of data packets from source to destination
  - » IP, routing protocols
- Data Link layer
  - » data transfer between neighboring network elements
  - » PPP, Ethernet, WLAN
- Physical layer
  - » bits sent “on the wire”



Transferring Data Through a Network

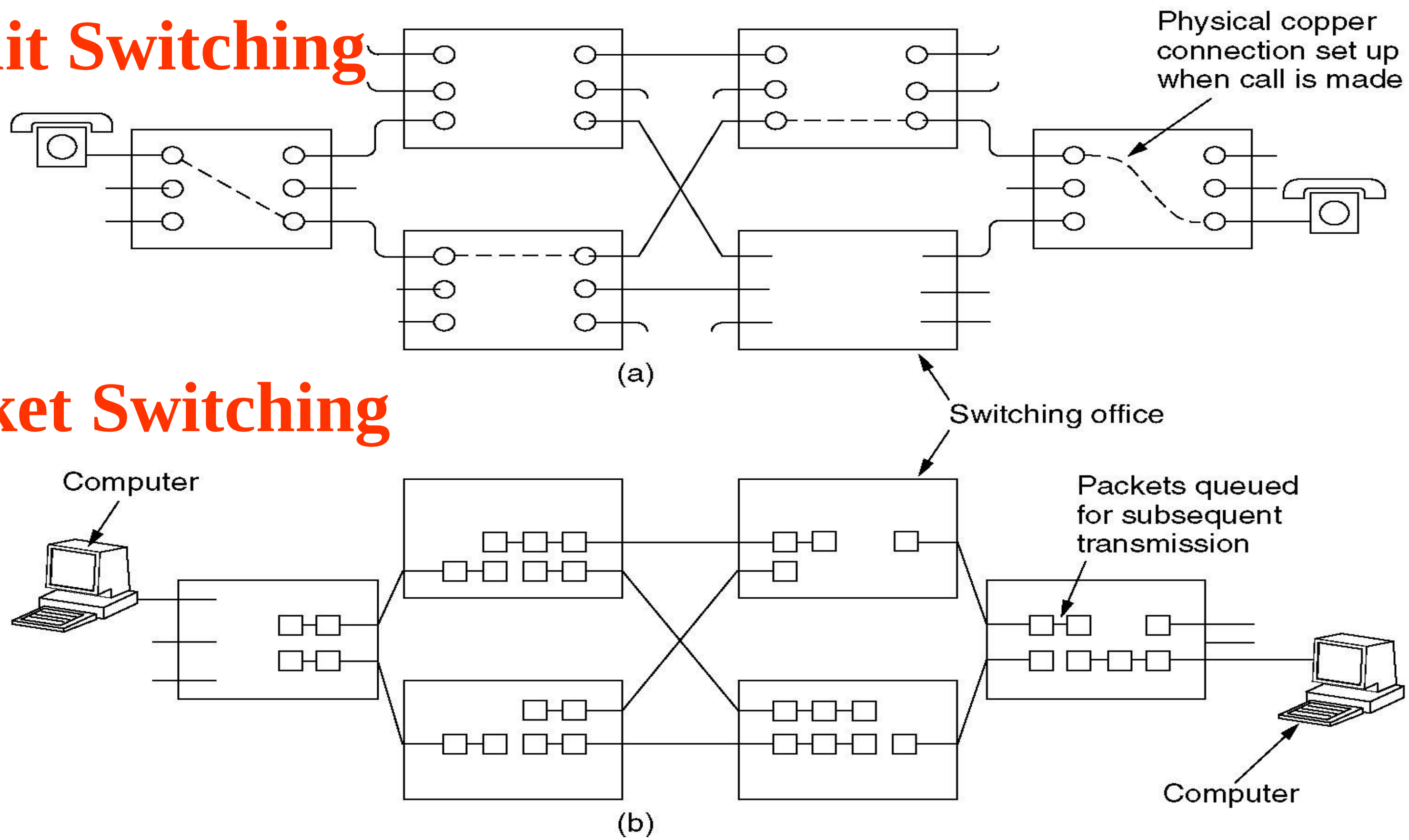
Information and Data

- Data
  - » term used to represent ***information***
  - » e.g. text, voice, video, image, graphics
- Information represented as a sequence of bits
  - » 0110110001010....
  - » 1 Byte = 1 octet = 8 bits
  - » 1 kbit = 10^3 bit; 1 Mbit = 10^6 bit; 1 Gbit= 10^9 bit
- Computer Networks
  - » transport information, from source to destination
  - » Information flow, capacity of a link ➔ Byte/s; bit/s

Circuit Switching, Packet Switching

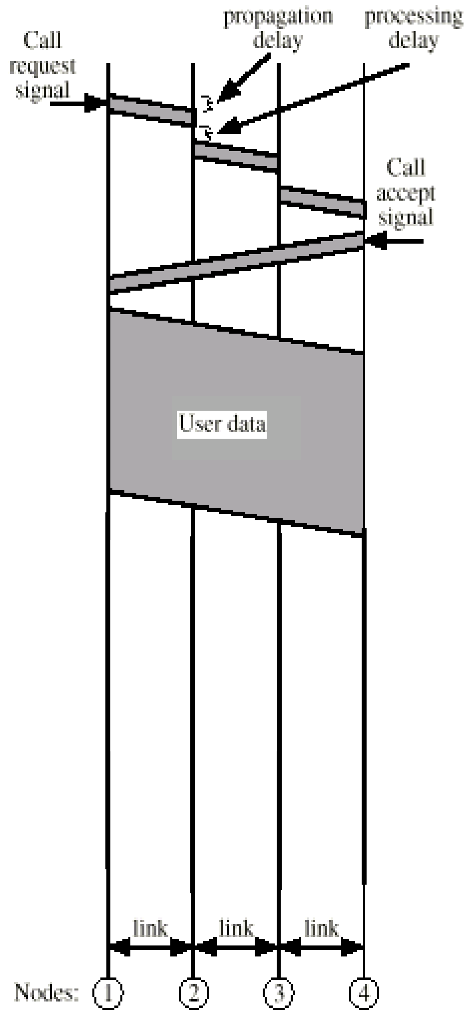
Circuit Switching

Packet Switching

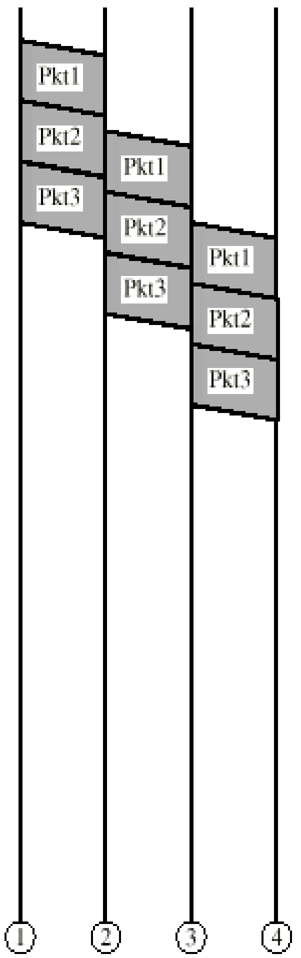


Circuit Switching, Packet Switching

Circuit Switching

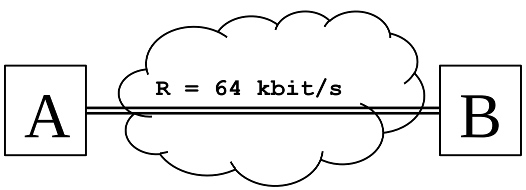


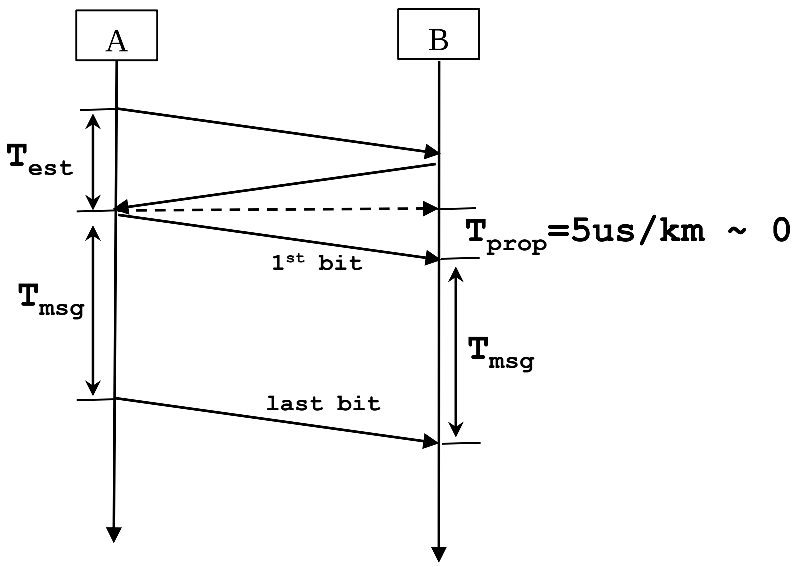
Packet Switching



Circuit Switching – Numerical Example

A file of length L=640 kbit is transferred from Host A to Host B through a circuit having a capacity of C=64 kbit/s. Assuming a circuit establishing delay T_{est}=500 ms, and a propagation delay T_{prop}~0, what is the total file transfer delay?

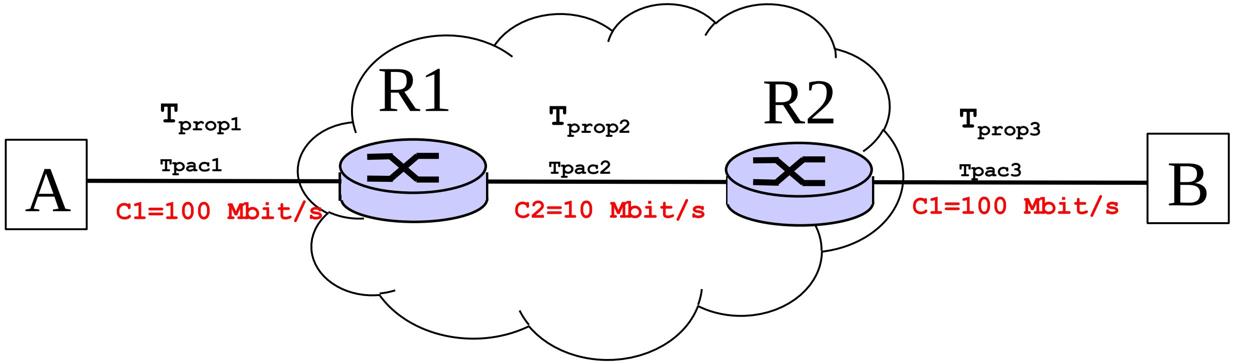




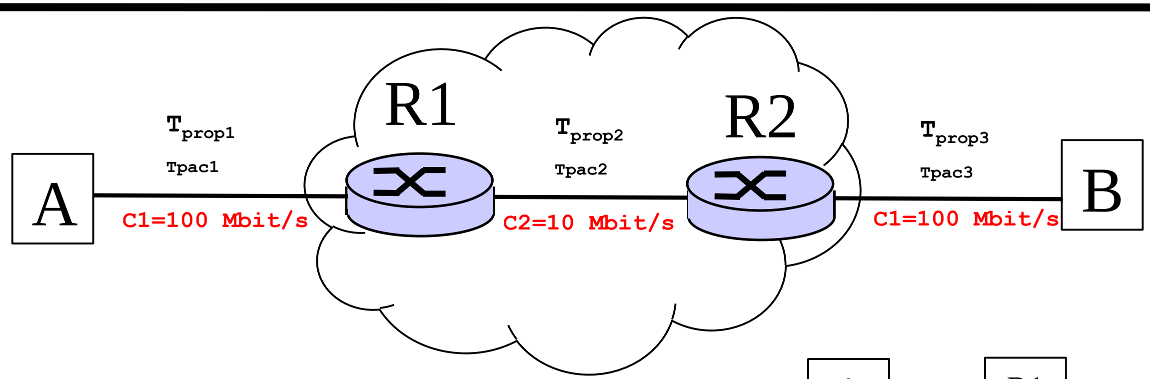
- **Answer:**
  - » T_{msg}=L/C= 640 kbit / 64 kbit/s = 10s
  - » $T_{tot}=T_{est} + T_{prop} + T_{msg}$ = 0.5 + 0 + 10 = 10.5 s

Packet Switching – Numerical Example

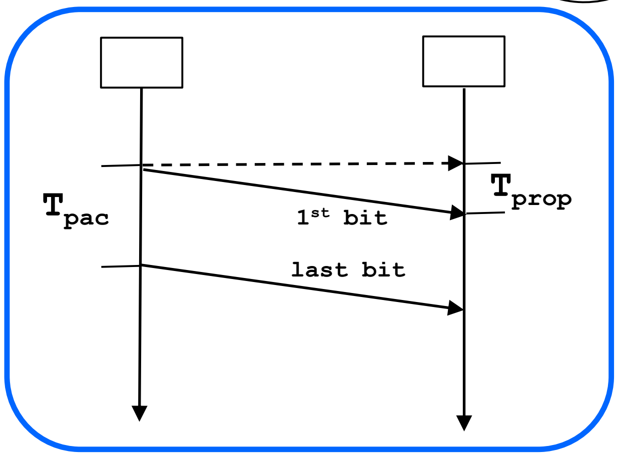
Host A sends a packet of length **`L=10 kbit`** to Host B through routers R1 and R2. Assuming propagation delay through the 3 links is T_{prop}~0 and that there are no queuing delays at the network elements (A, R1 and R2), what is the end-to-end packet delay?

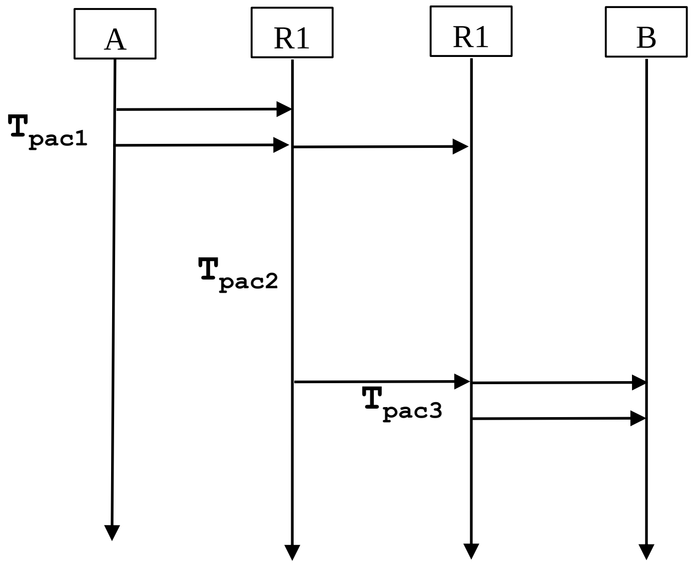


Packet Switching – Numerical Example



T_{prop}=0
T_{queue}=0





- **Answer:**
  - » T_{pac1}= T_{pac3} = L/C1 = 10 kbit / 100 Mbit/s = 0.1 ms
  - » T_{pac2}= L/C2 = 10 kbit/ 10 Mbit/s = 1 ms
  - » $T_{end\text{-}to\text{-}end}$ = T_{pac1} + T_{prop1} + T_{pac2} + T_{prop2} + T_{pac3} + T_{prop3} = 1.2 ms

Homework

1. Review slides

2. Read from Tanenbaum
   - » Chapter 1 - Introduction
   - » Section 2.6.5 – Switching

3. Answer questions at moodle