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# *Redes de Computadores*

## **Introduction**

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# *Introduction to the Course*

# *RCOM – Professors, Language*

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- ◆ Prof. Manuel Ricardo
  - [mricardo@fe.up.pt](mailto:mricardo@fe.up.pt)
  - <http://www.fe.up.pt/~mricardo>
  - Tel.: 22 209 4000
  - Office at INESC Porto (4<sup>th</sup> floor)
- ◆ Information about RCOM
  - available in moodle
- ◆ Language
  - » Slides and books in English
  - » Lectures in Portuguese
  - » *Suitable for English-speaking students*

# *Bibliografia*

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- ♦ 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*

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- ♦ **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  - » Examples on outdated networks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*

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## ♦ *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

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

# *Evaluation of RCOM*

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## Frequência

- ♦ L1 - grade of 1st lab
- ♦ L2 - grade of 2nd lab
- ♦ H - grade of homeworks
- ♦ FQ - grade of FREQUÊNCIA
  
- ♦  $FQ = 0,4 * L1 + 0,4 * L2 + 0,2 * H$
  
- ♦ if ( FQ < 8,0 ) FQ = "No Admission to Exams"

## Classificação Final

- ♦ E - grade of final exam
- ♦ FQ - grade of FREQUÊNCIA
- ♦ AD - grade of distributed evaluation
- ♦ CF - final grade
  
- ♦ if ( FQ > E + 5 ) AD = E + 5 else AD = FQ
  
- ♦  $CF = 0.4 * AD + 0.6 * E$
  
- ♦ if ( E < 8.0 ) CF = E

# *Learning objectives*

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- ♦ Fundamentals 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



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# *Introduction to Computer Networks*

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- » 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**,  $T_{pac}$ ?

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## *Uses of Computer Networks*

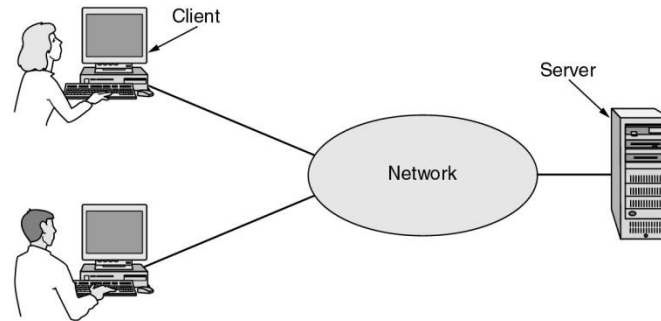
## *Some Applications Using Communications Networks*

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

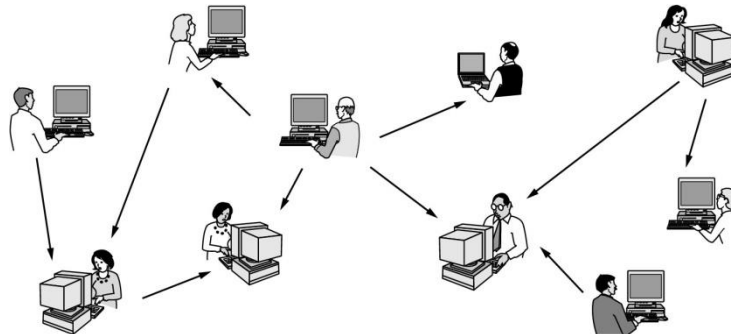
# *Application Architectures*

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## ◆ Client-server

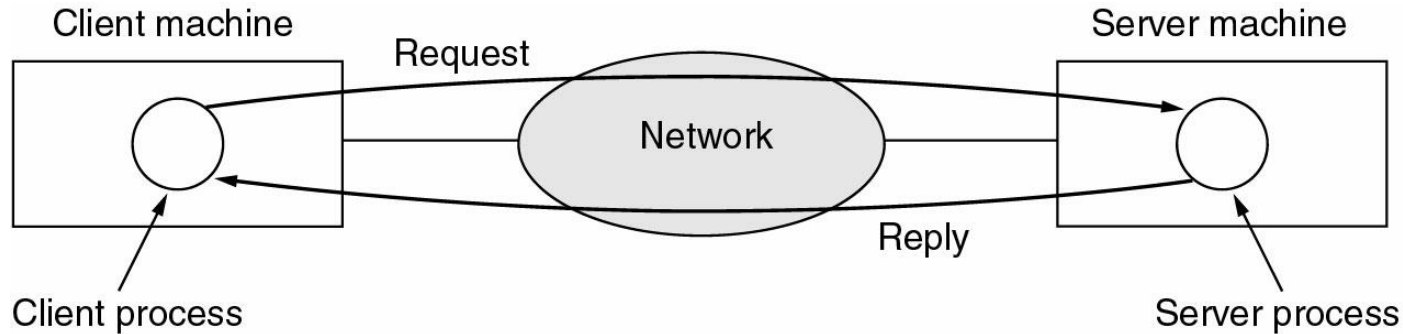


## ◆ Peer-to-peer (P2P)



# *Client-server Architecture*

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## ◆ Server

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

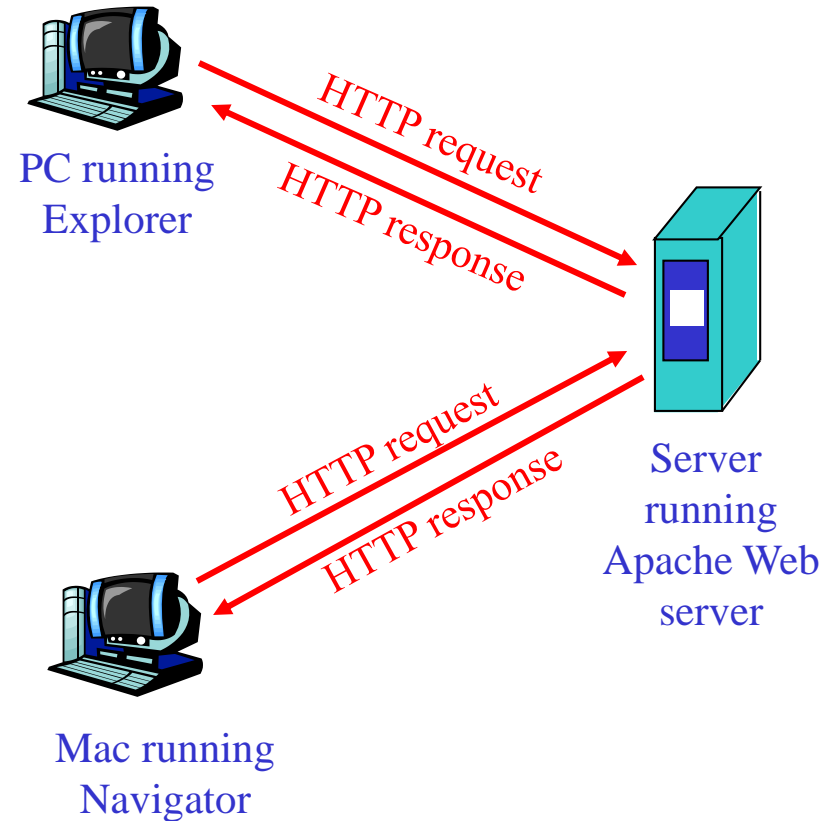
## ◆ Clients

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

# *Client-server Example – The Web*

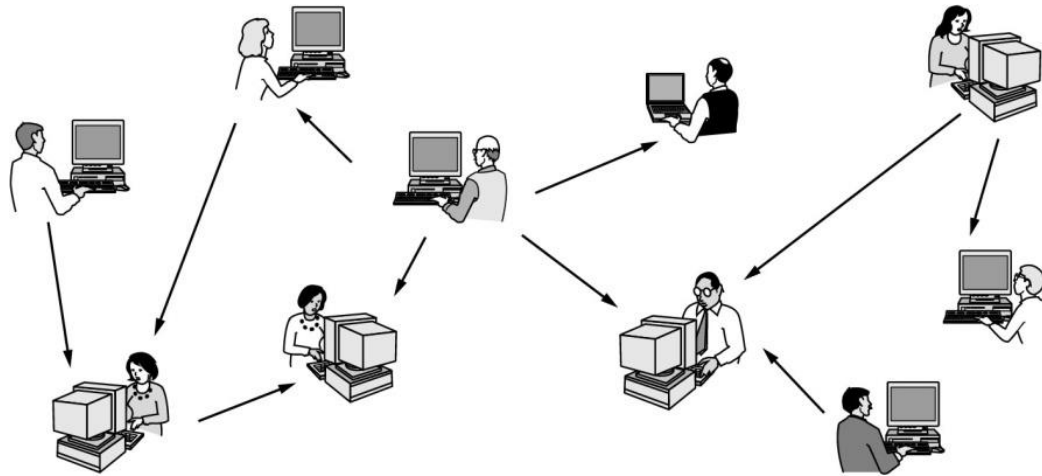
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- ◆ Client/server model
- ◆ Client: browser
  - » requests, receives, displays Web objects
- ◆ Server: web server
  - » sends objects in response to requests



# *P2P Architecture*

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



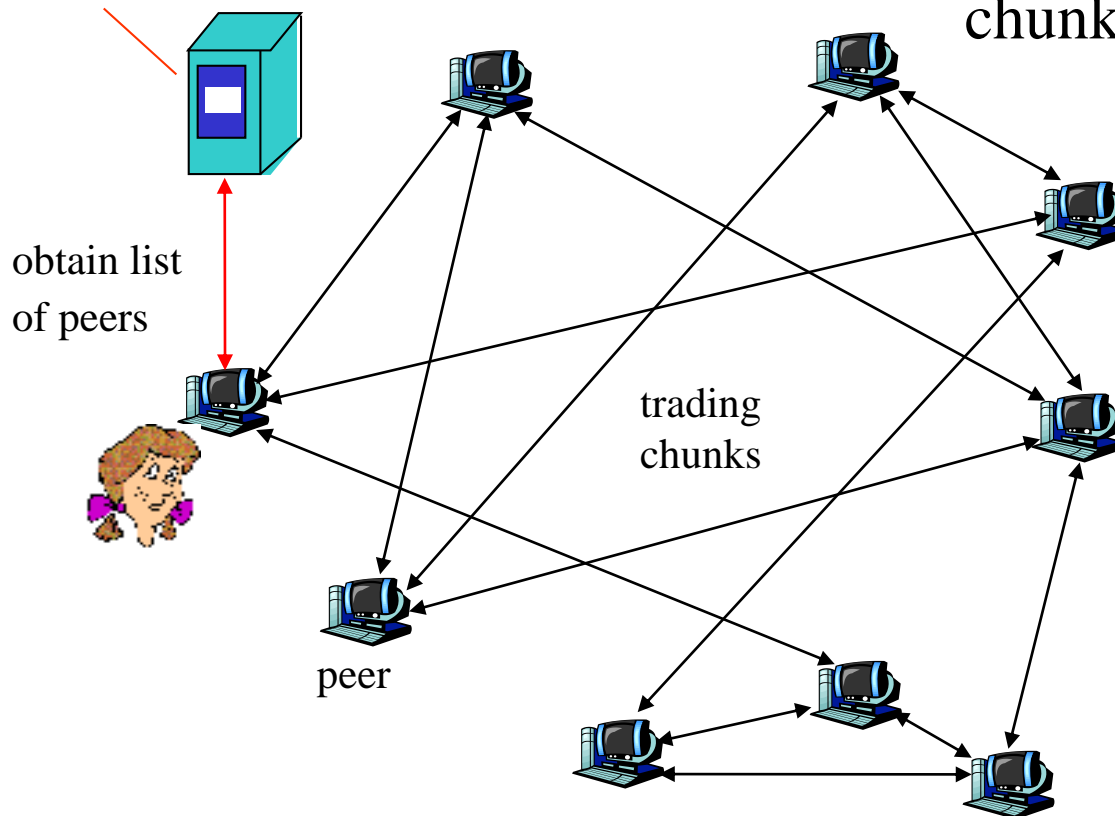
# *P2P Example - BitTorrent*

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## P2P file distribution

tracker: tracks peers  
participating in torrent

torrent: group of  
peers exchanging  
chunks of a file



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## *Types of Networks*

# *Classification of Communications Networks*

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- ◆ By scale

- » distance between processors

- ◆ PAN - Personal Area Network

- ◆ LAN - Local Area Network

- ◆ MAN - Metropolitan Area Network

- ◆ WAN - Wide Area Network

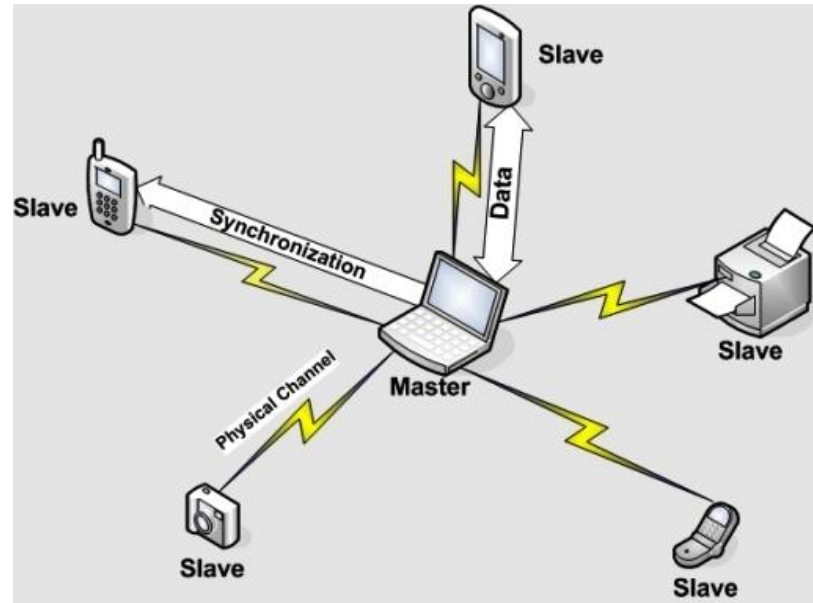
- ◆ Internet

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*

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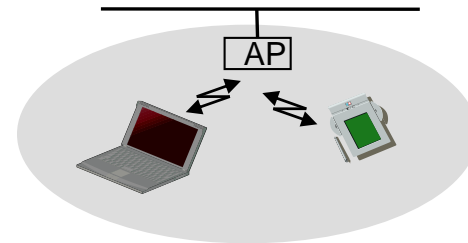
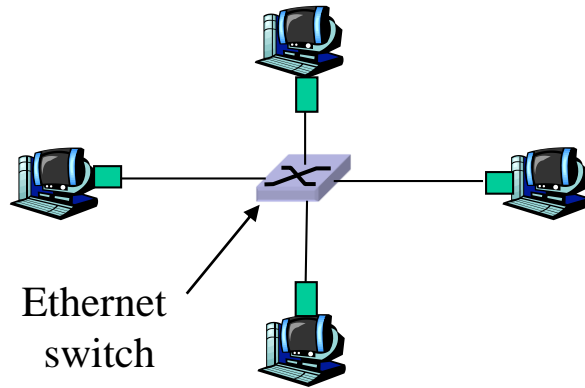
## Bluetooth network



# *Local Area Networks*

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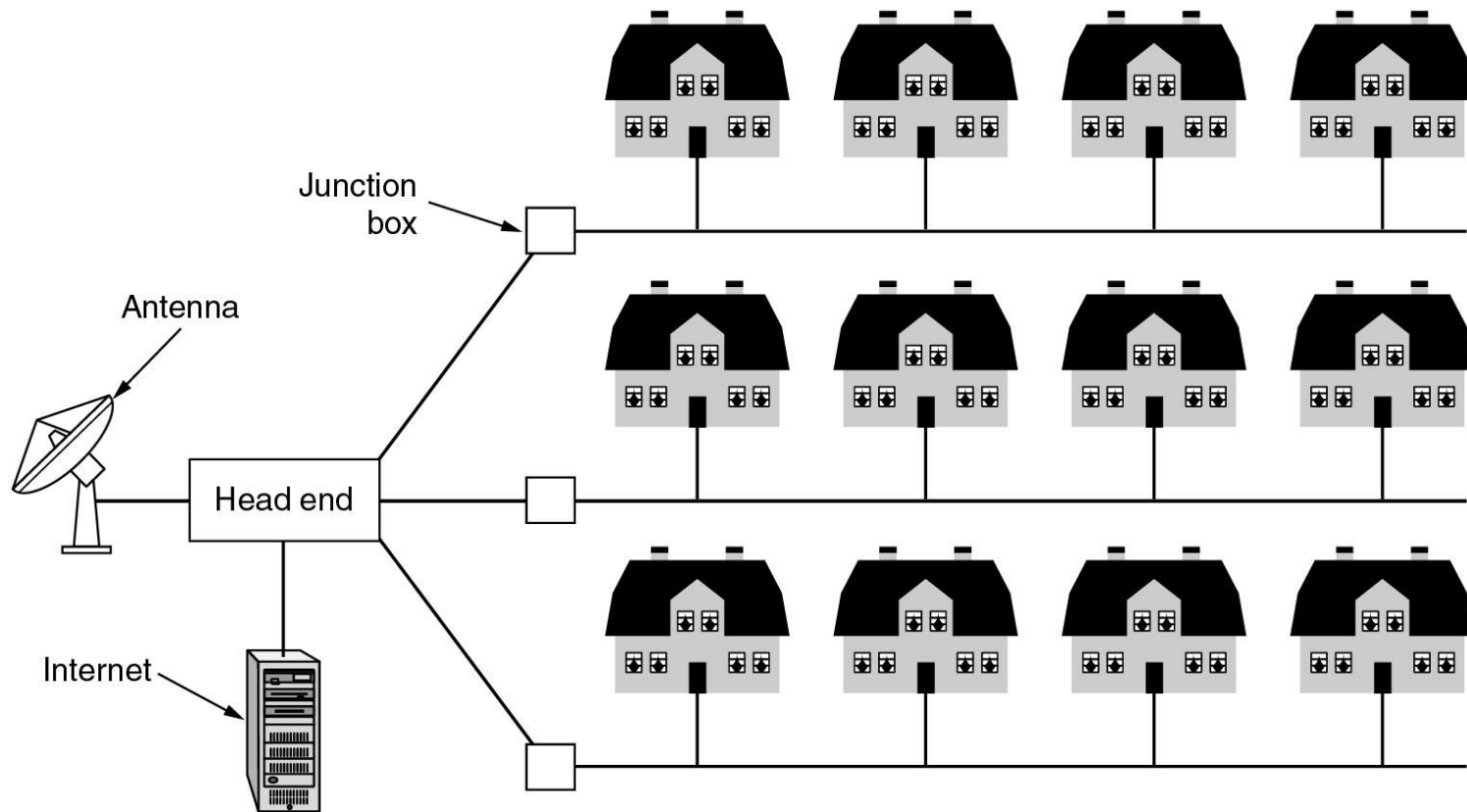
- ◆ Local Area Networks



# *Metropolitan Area Networks*

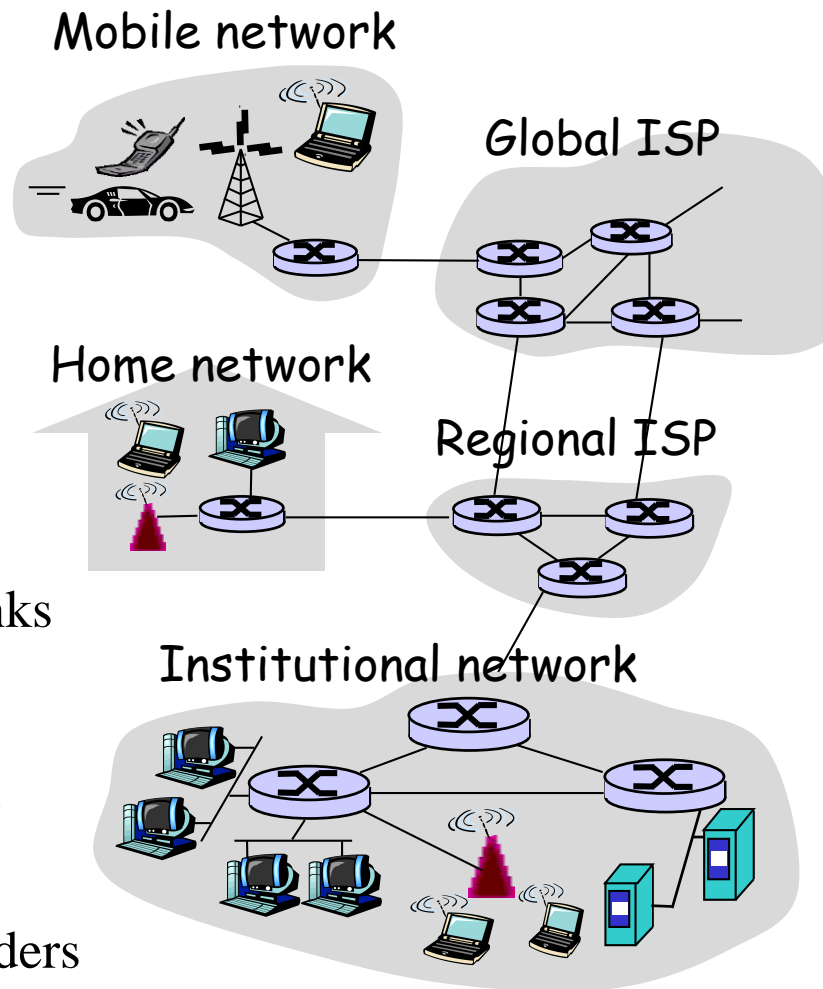
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A metropolitan area network based on cable TV



# *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



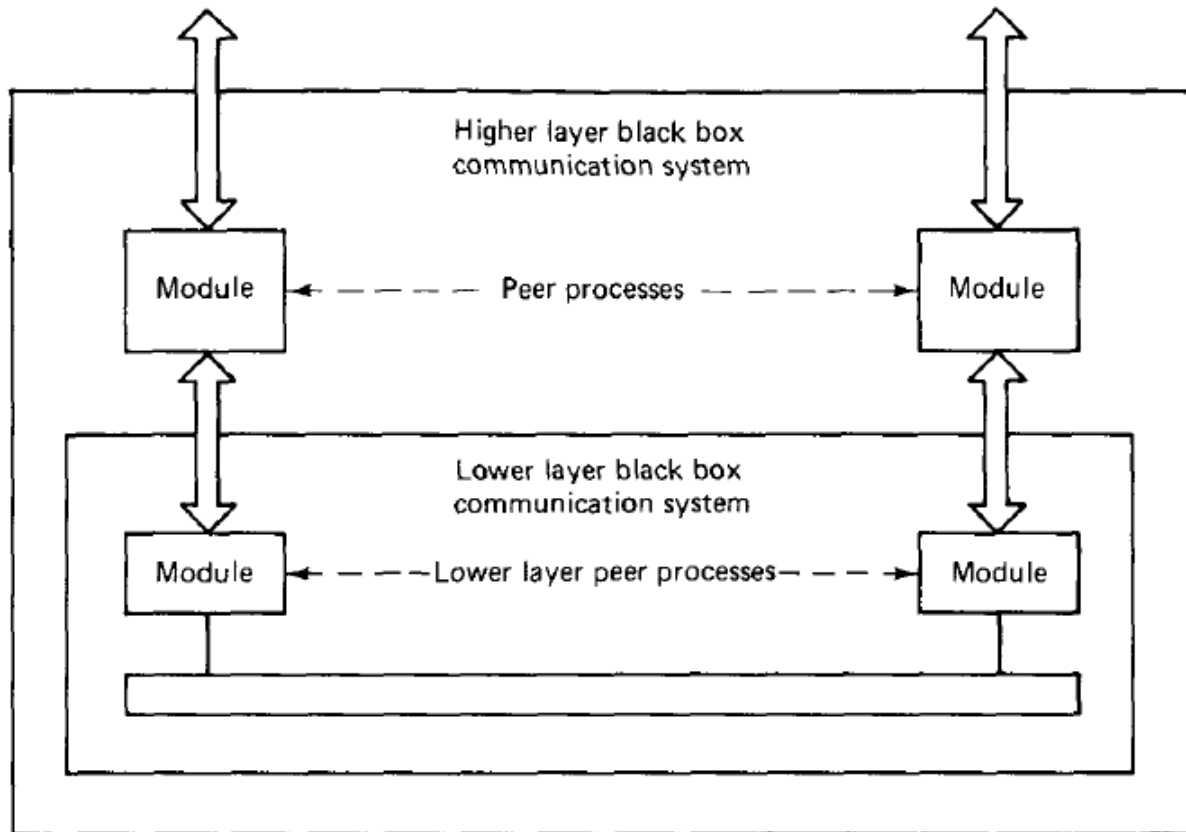
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# *Network Software*



# *Communications Software Organized in Black Boxes*

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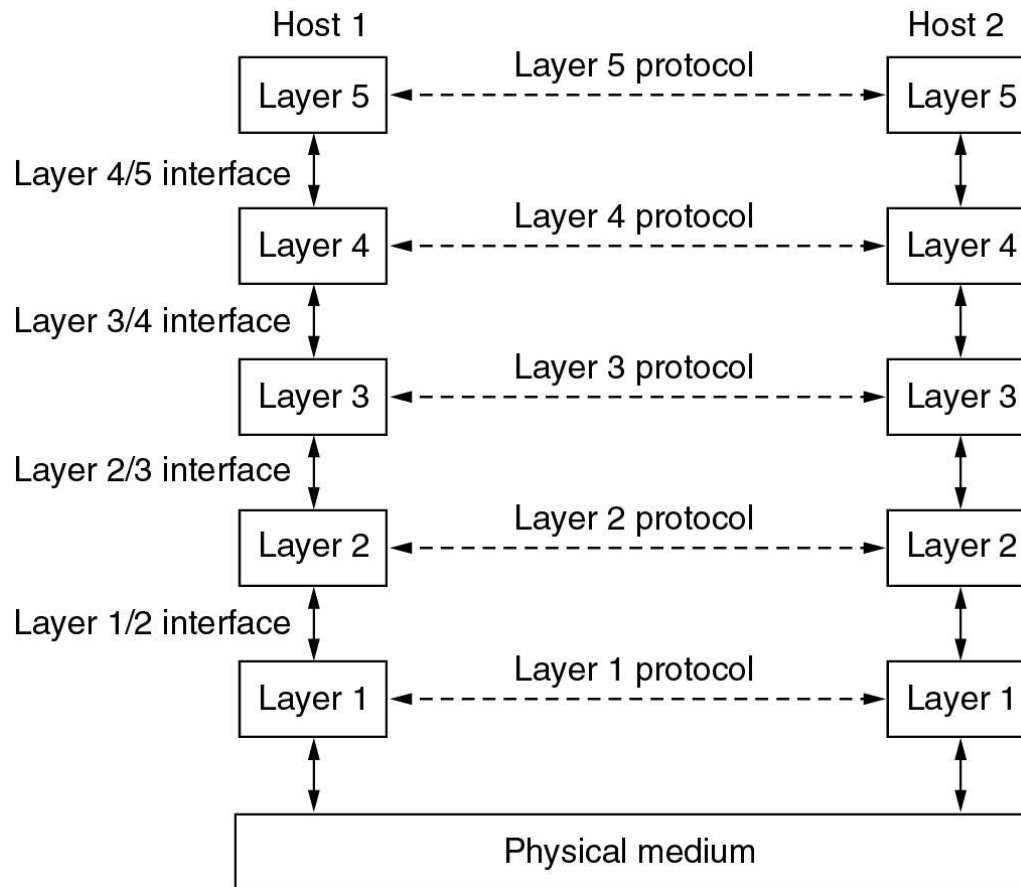


**Figure 1.7** Peer processes within a black box communication system. The peer processes communicate through a lower-layer black box communication system that itself contains lower-layer peer processes.

# *Protocol Hierarchies*

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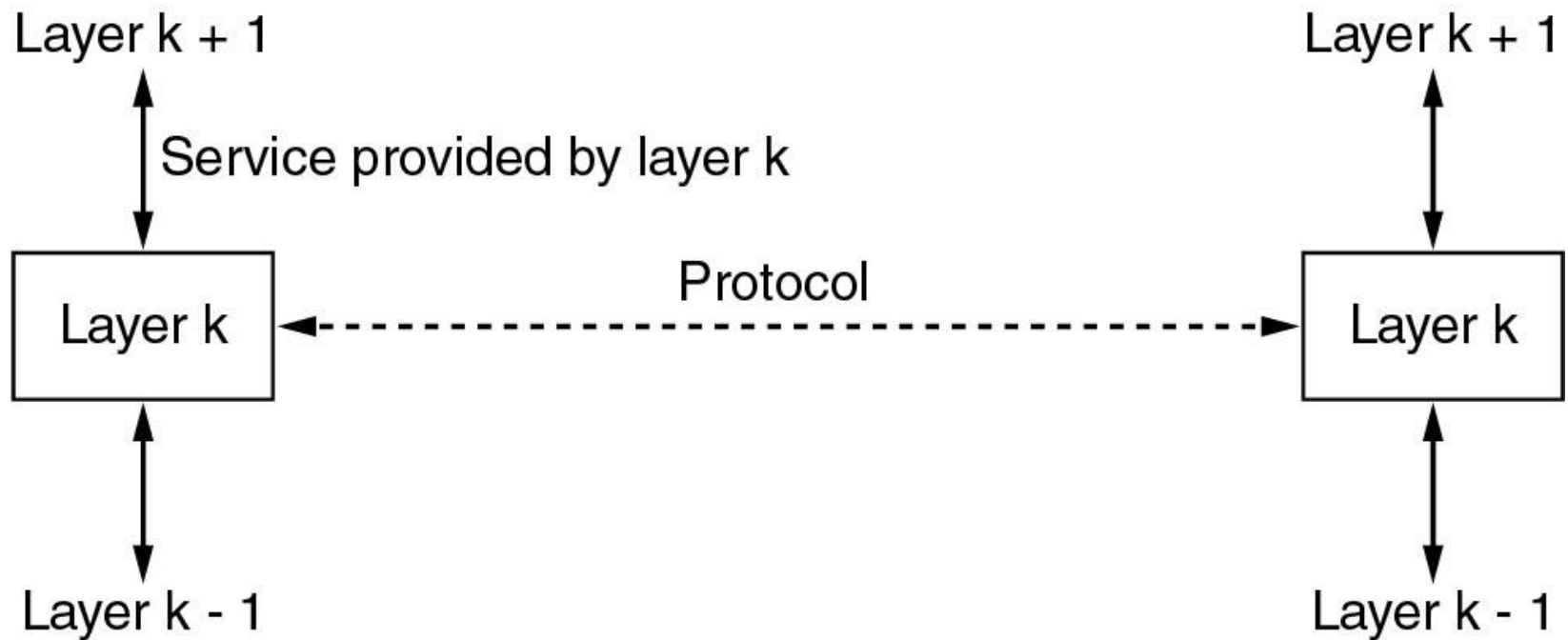
## Layers, protocols, and interfaces



# *Services to Protocols Relationship*

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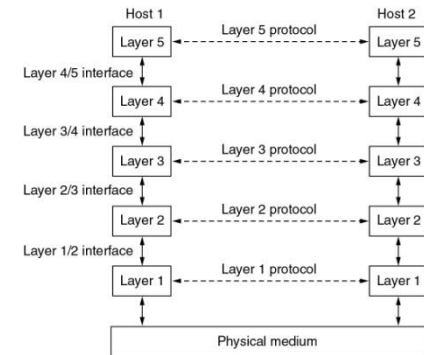
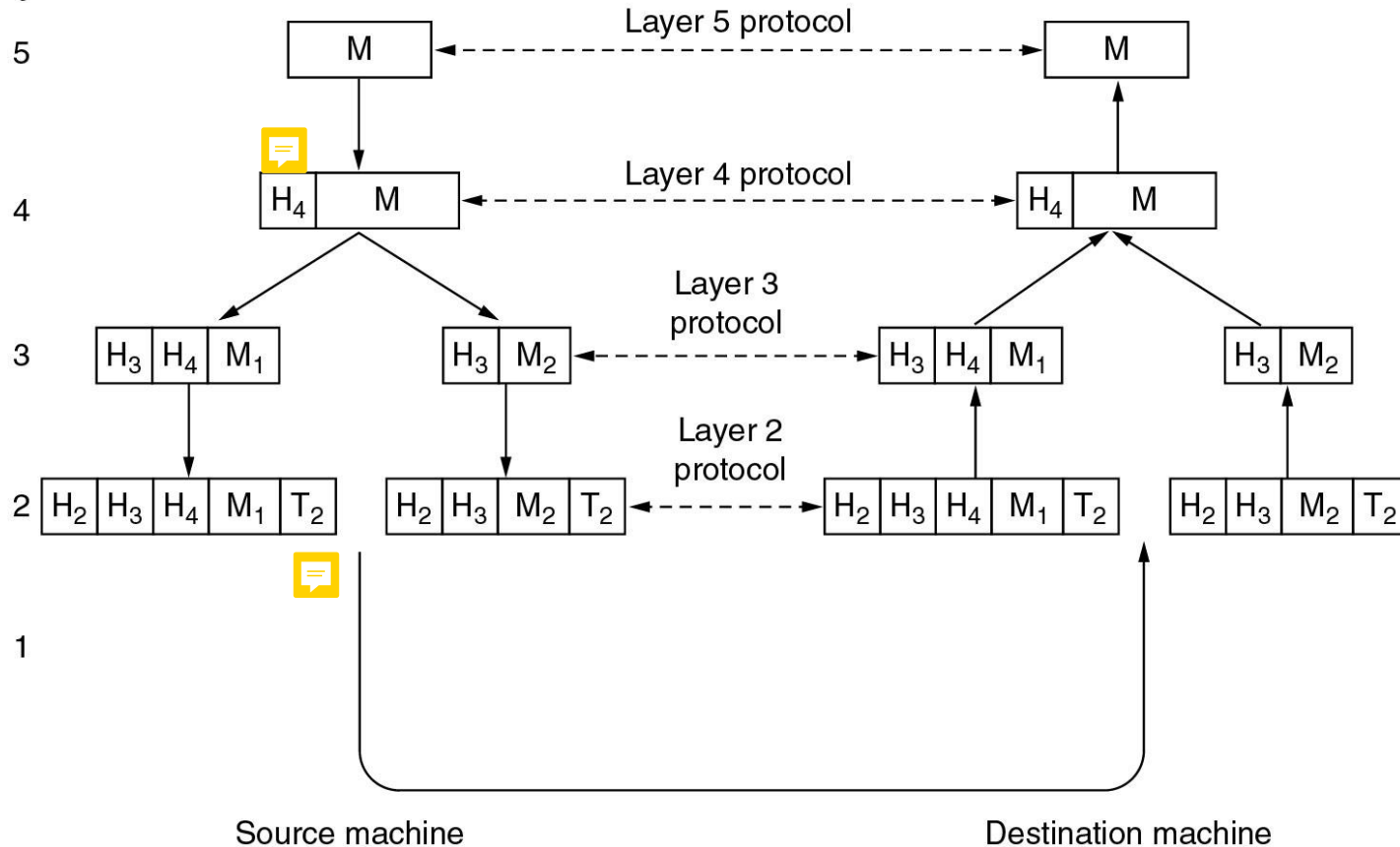
The relationship between a service and a protocol



# Transference of Information

## Information flow supporting virtual communication in layer 5

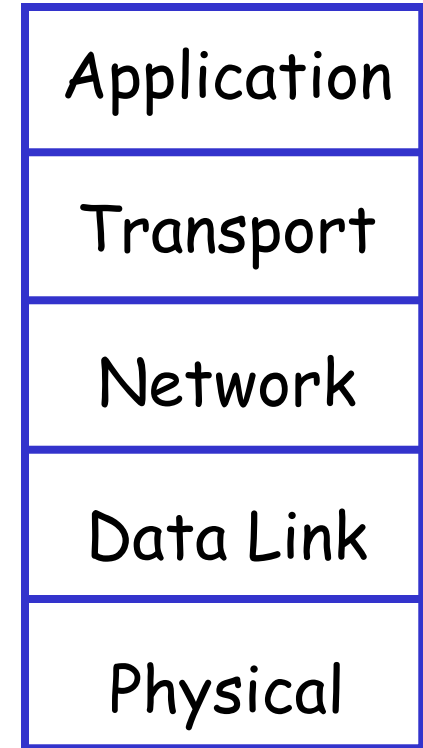
Layer



# *Internet (TCP/IP) Reference Model*

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- ◆ 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”



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# *Transferring Data Through a Network*

# *Information and Data*

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## ♦ Data

- » term used to represent *information*
- » e.g. text, voice, video, image, graphics

## ♦ Information represented as a sequence of bits

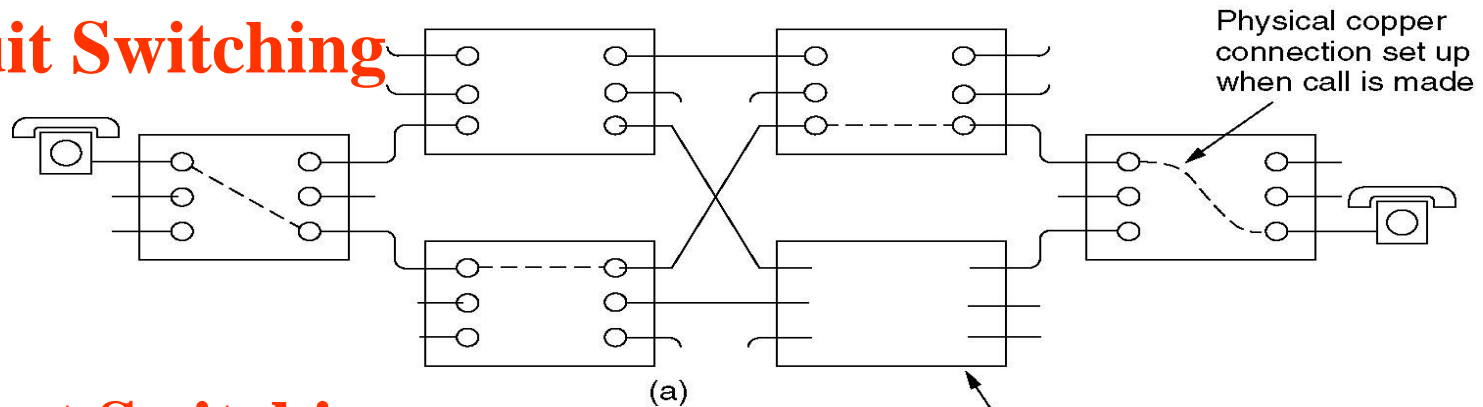
- » 0110110001010....
- » 1 Byte = 1 octet = 8 bits
- » 1 kbit =  $10^3$  bit; 1 Mbit =  $10^6$  bit; 1 Gbit =  $10^9$  bit

## ♦ Computer Networks

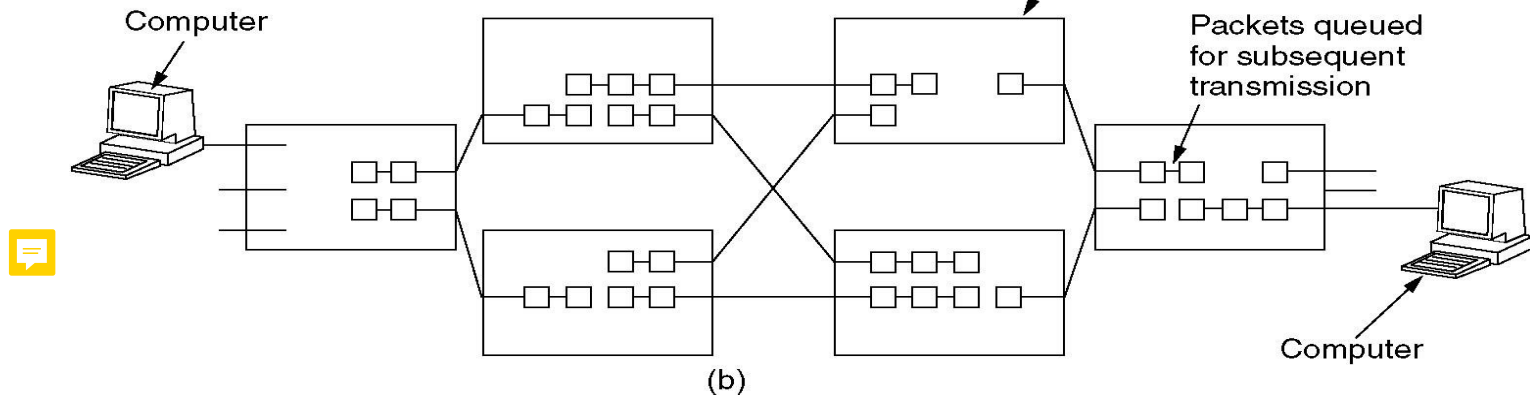
- » transport information, from source to destination
- » Information flow, capacity of a link → Byte/s; bit/s

# *Circuit Switching, Packet Switching*

## Circuit Switching



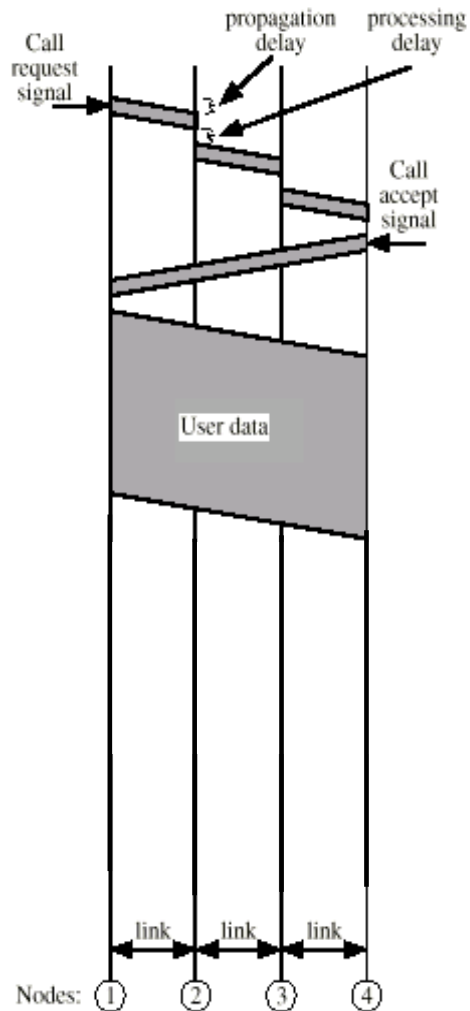
## Packet Switching



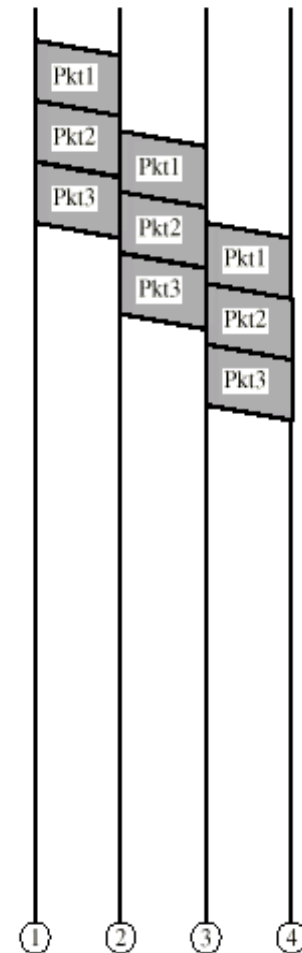


# Circuit Switching, Packet Switching

## Circuit Switching

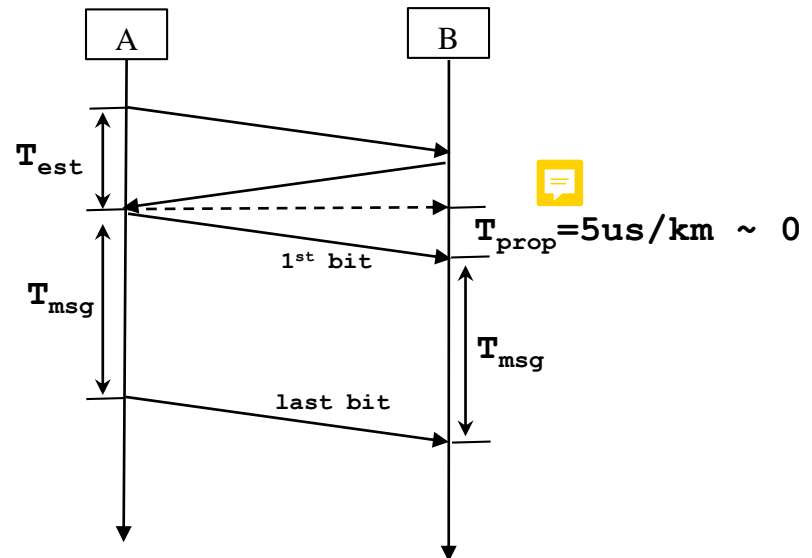
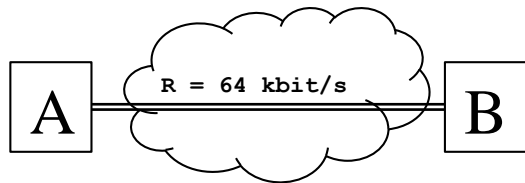


## Packet Switching



# 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  $T_{\text{est}}=500$  ms, and a propagation delay  $T_{\text{prop}} \sim 0$ , **what is the total file transfer delay?**



## ♦ Answer:

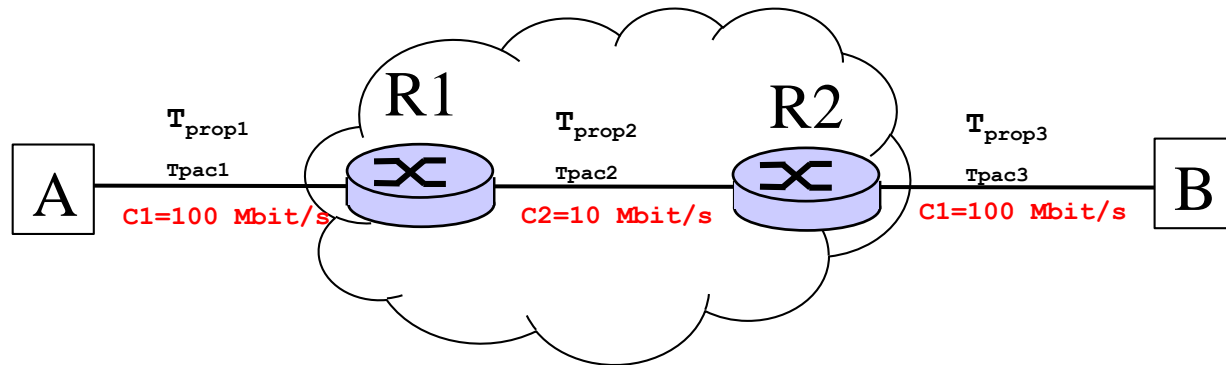
$$\gg T_{\text{msg}} = L/C = 640 \text{ kbit} / 64 \text{ kbit/s} = 10 \text{ s}$$

$$\gg T_{\text{tot}} = T_{\text{est}} + T_{\text{prop}} + T_{\text{msg}} = 0.5 + 0 + 10 = 10.5 \text{ s}$$

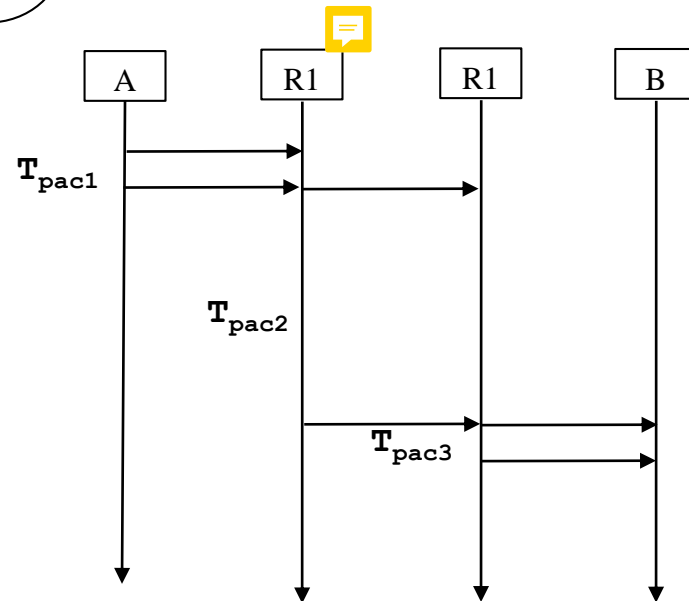
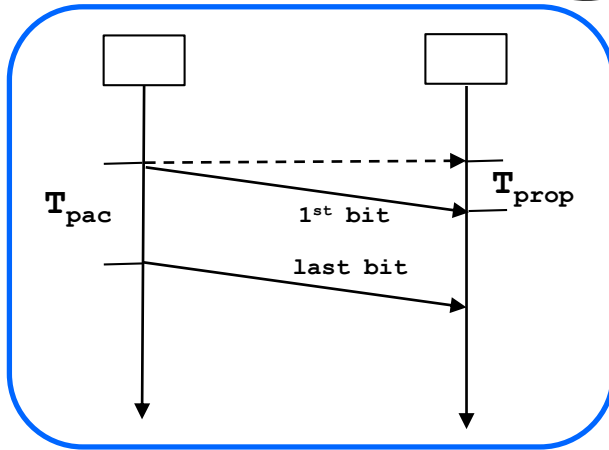
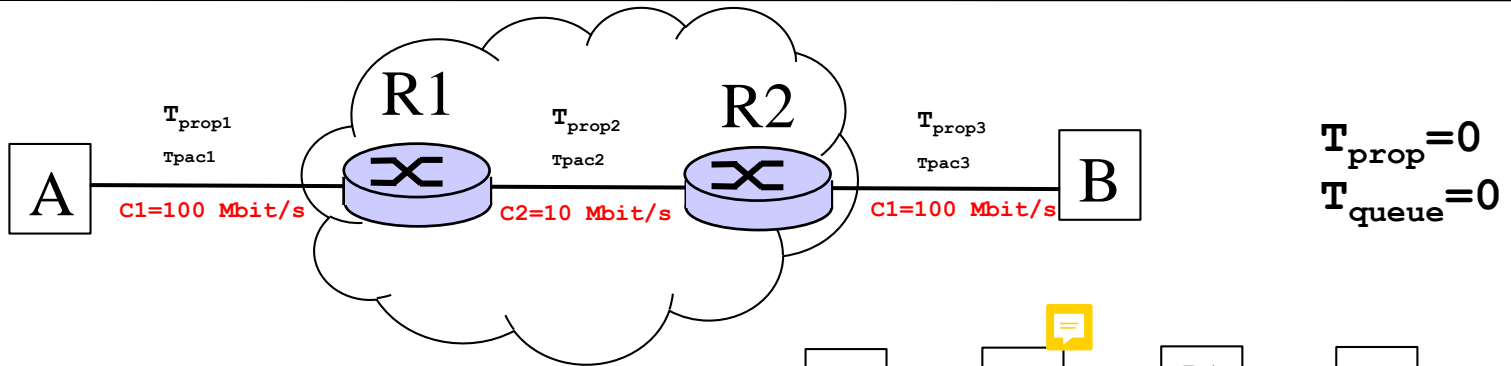
# *Packet Switching – Numerical Example*

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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  $T_{\text{prop}} \sim 0$  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



## ♦ Answer:

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

# *Homework*

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1. Review slides
2. Read from Tanenbaum
  - » Chapter 1 - Introduction
  - » Section 2.6.5 – Switching
3. Answer questions at moodle