
Redes de Computadores

Introduction

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Introduction to the Course

RCOM – Professors, Information, Language

- ♦ Prof. Manuel Ricardo
 - mricardo@fe.up.pt
 - <http://www.fe.up.pt/~mricardo>
 - Tel.: 22 209 4200
 - Room at INESC Porto (3rd floor)
- ♦ Information about RCOM
 - available at 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 to the fundamentals; the 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 - » Examples on outdated networks

- ♦ **Alberto Leon-Garcia, Indra Widjaja, Communications Networks – Fundamental Concepts and Key Architectures, 2nd Edition, 2004, McGRAW-HILL**
 - » Excellent book
 - » Could be the main book of RCOM ...

- ♦ **Larry L. Peterson, Bruce S. Davie, Computer Networks - A Systems Approach, 4th Edition, 2007, Morgan Kaufmann**
 - » Less generic than Tanenbaum and Leon-Garcia; oriented to TCP/IP and implementation aspects
 - » 3^a edition can be used

- ♦ **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 ($FQ < 8,0$) $FQ = \text{“Reprovado por Falta de Frequência”}$

se ($E < 8,0$) $CF = E$

Learning objectives

- ◆ 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

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} ?

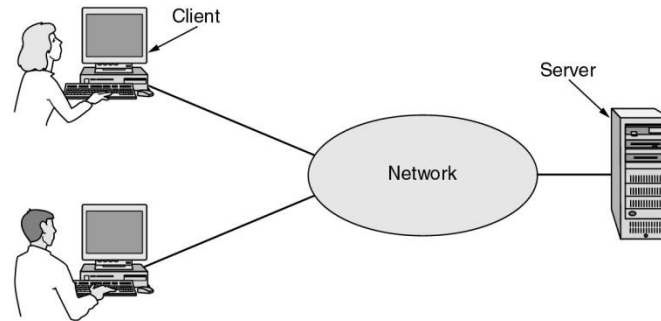
Uses of Computer Networks

Some Applications Using the Networks

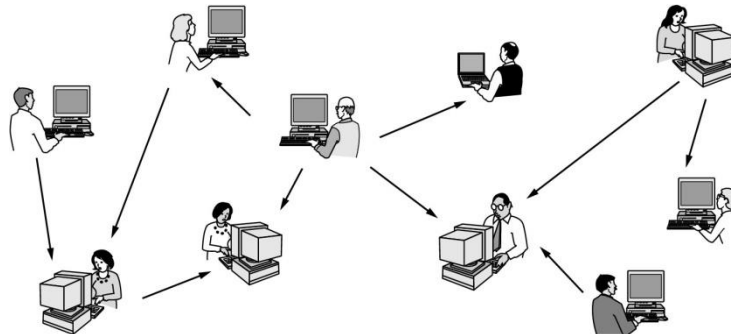
- ♦ E-mail
- ♦ Web
- ♦ Remote login
- ♦ P2P file sharing
- ♦ Multi-user network games
- ♦ Video retrieval
- ♦ Voice over IP
- ♦ Video streaming
- ♦ Real-time video conferencing
- ♦ ...

Application Architectures

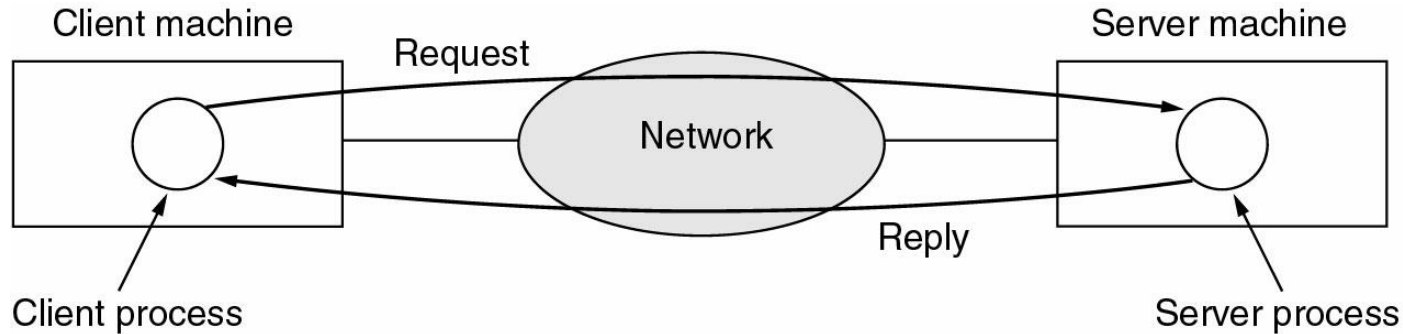
◆ Client-server



◆ Peer-to-peer (P2P)



Client-server Architecture



◆ Server

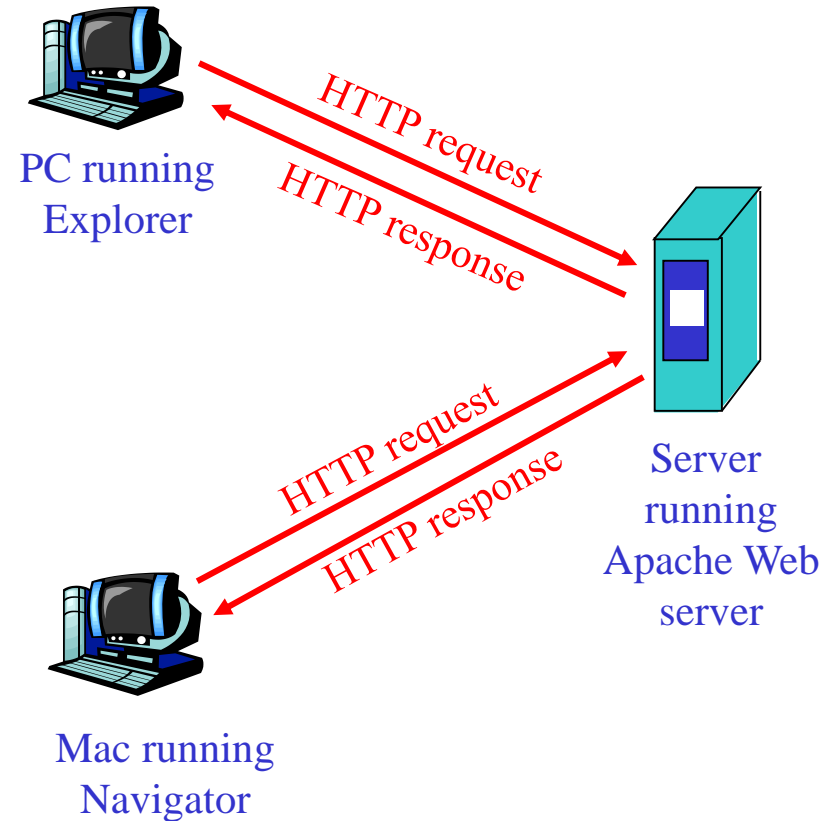
- » always-on computer
- » permanent IP address, well-known name

◆ Clients

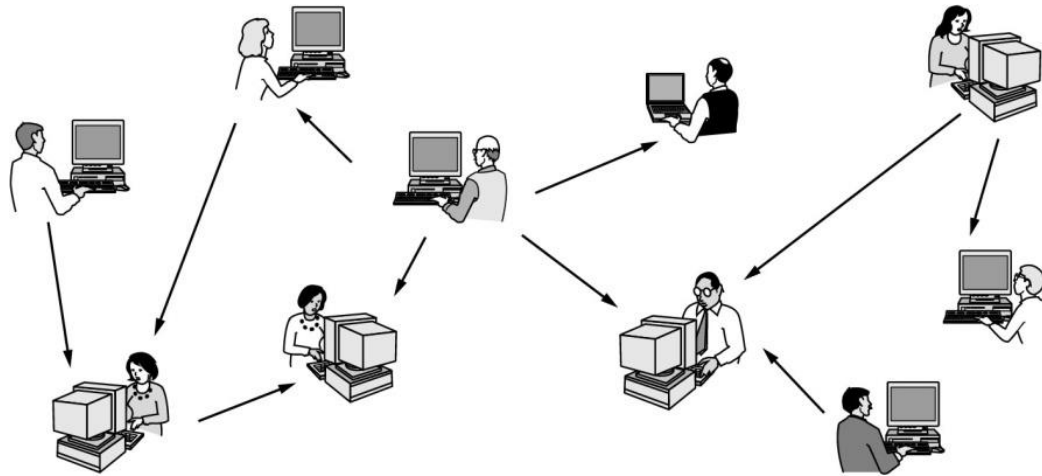
- » communicate with server
- » may be intermittently connected
- » do not communicate directly with other clients

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



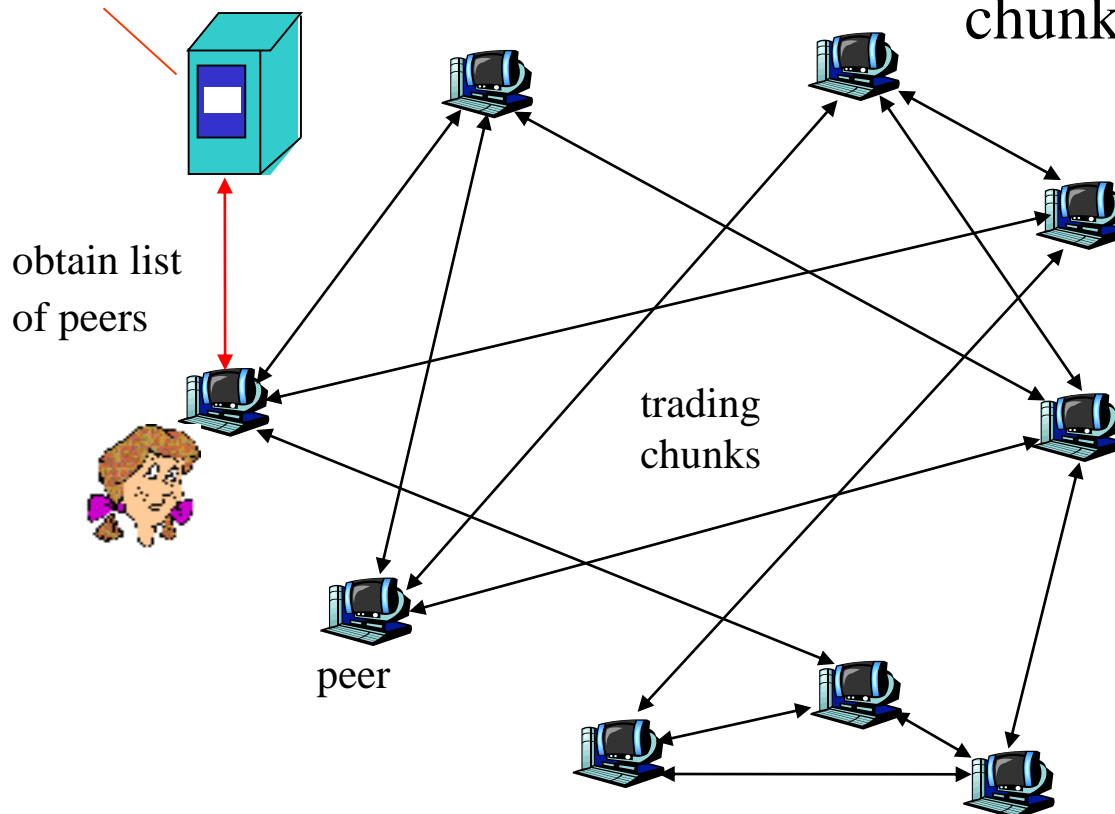
- ◆ No always-on server
- ◆ Arbitrary end systems communicate directly
- ◆ Peers are intermittently connected and may change IP addresses

P2P Example - BitTorrent

P2P file distribution

tracker: tracks peers
participating in torrent

torrent: group of
peers exchanging
chunks of a file



Types of Networks

Classification of Networks

- ◆ By scale

- » distance between processors

- ◆ PAN - Personal Area Network

- ◆ LAN - Local Area Network

- ◆ MAN - Metropolitan Area Network

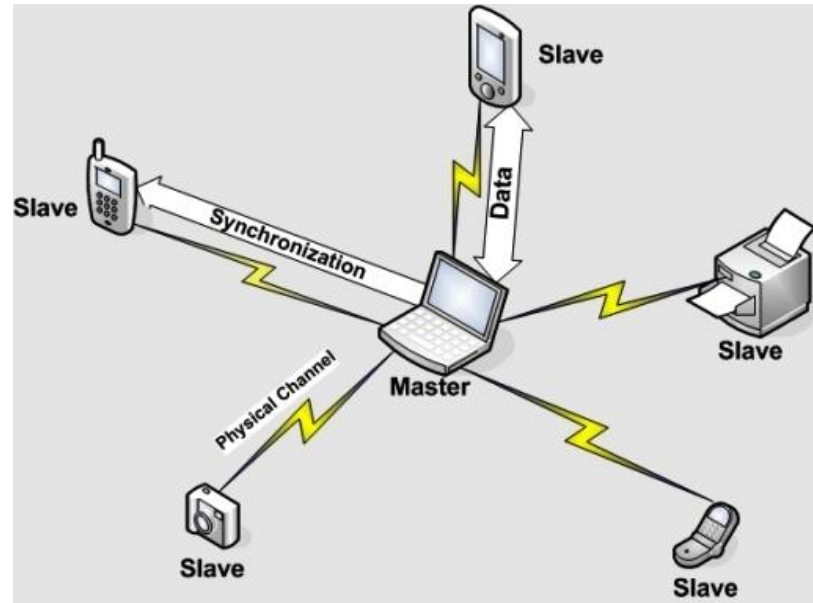
- ◆ WAN - Wide Area Network

- ◆ 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

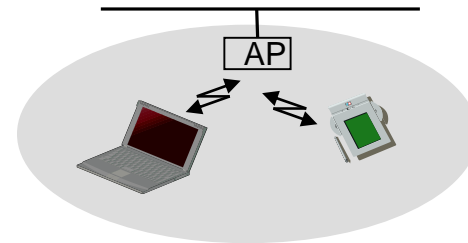
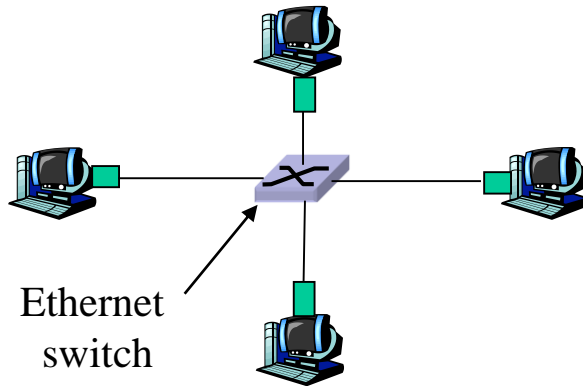
Personal Area Networks

Bluetooth network



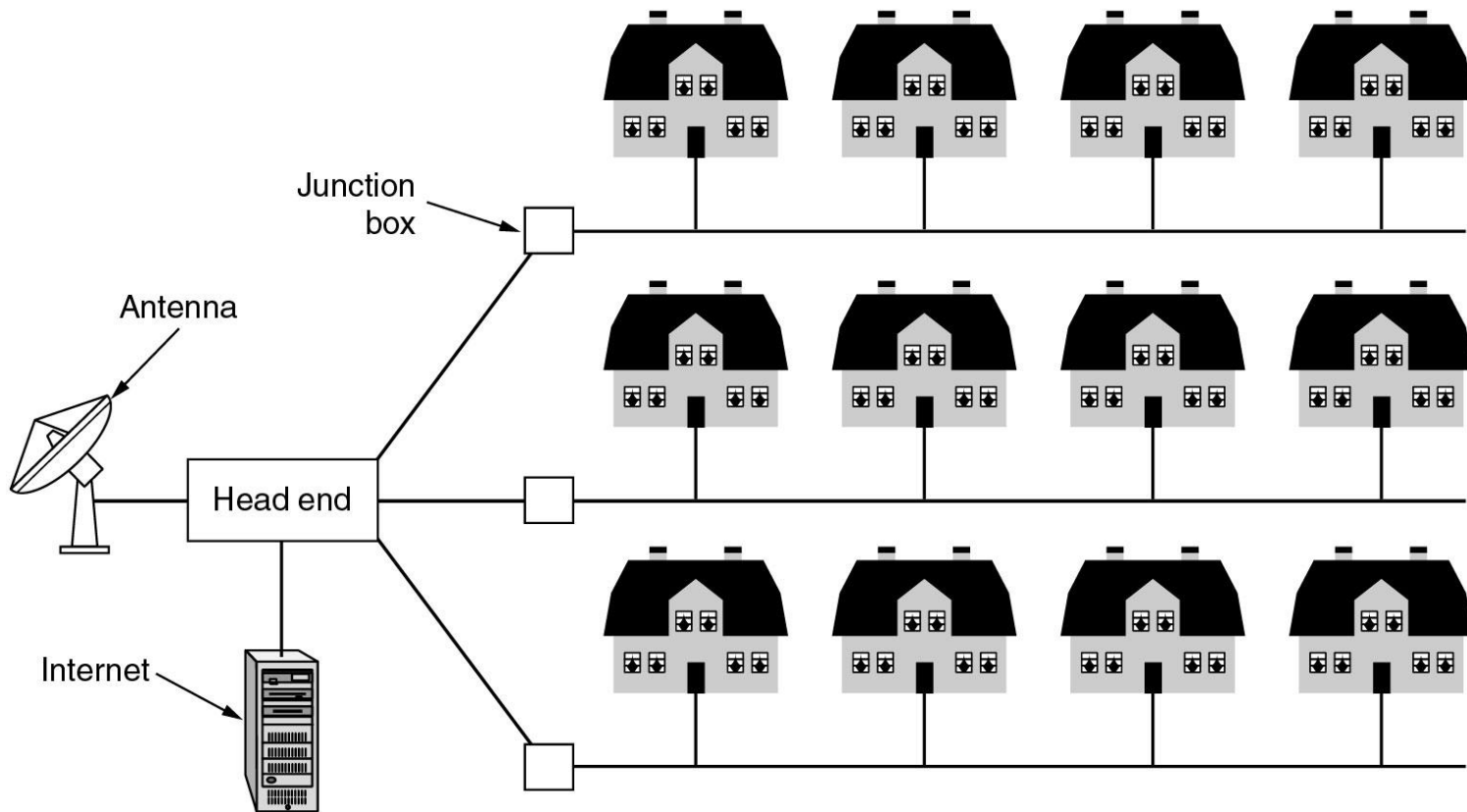
Local Area Networks

◆ Local Area Networks



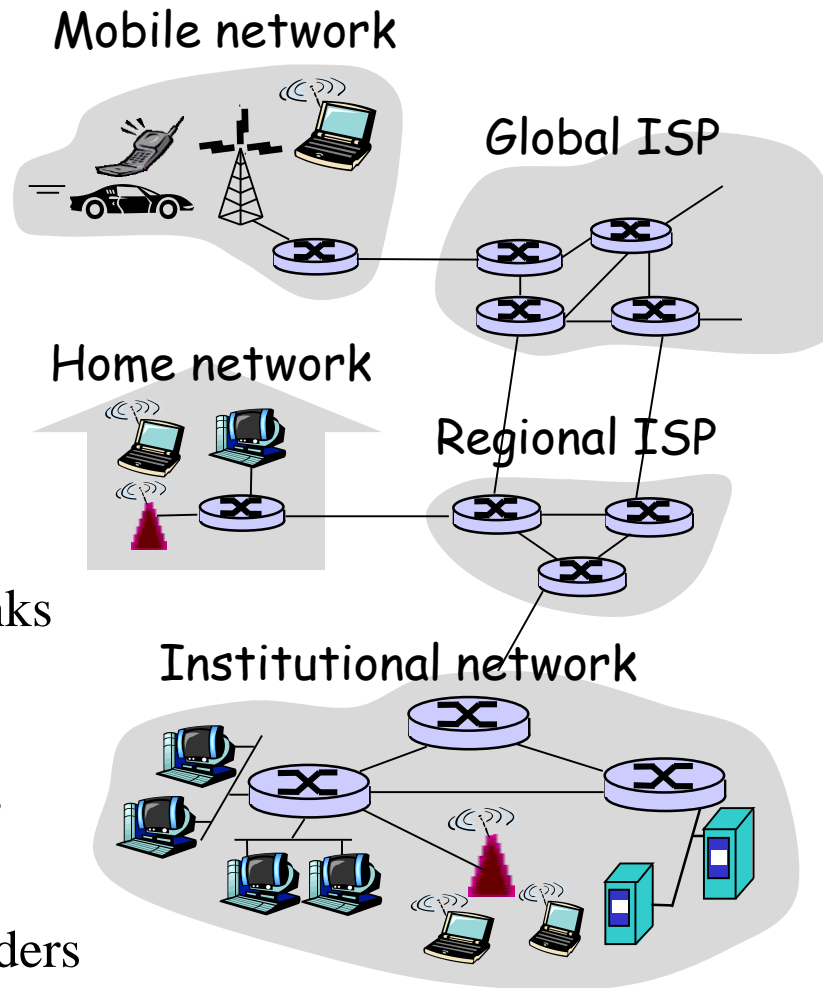
Metropolitan Area Networks

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

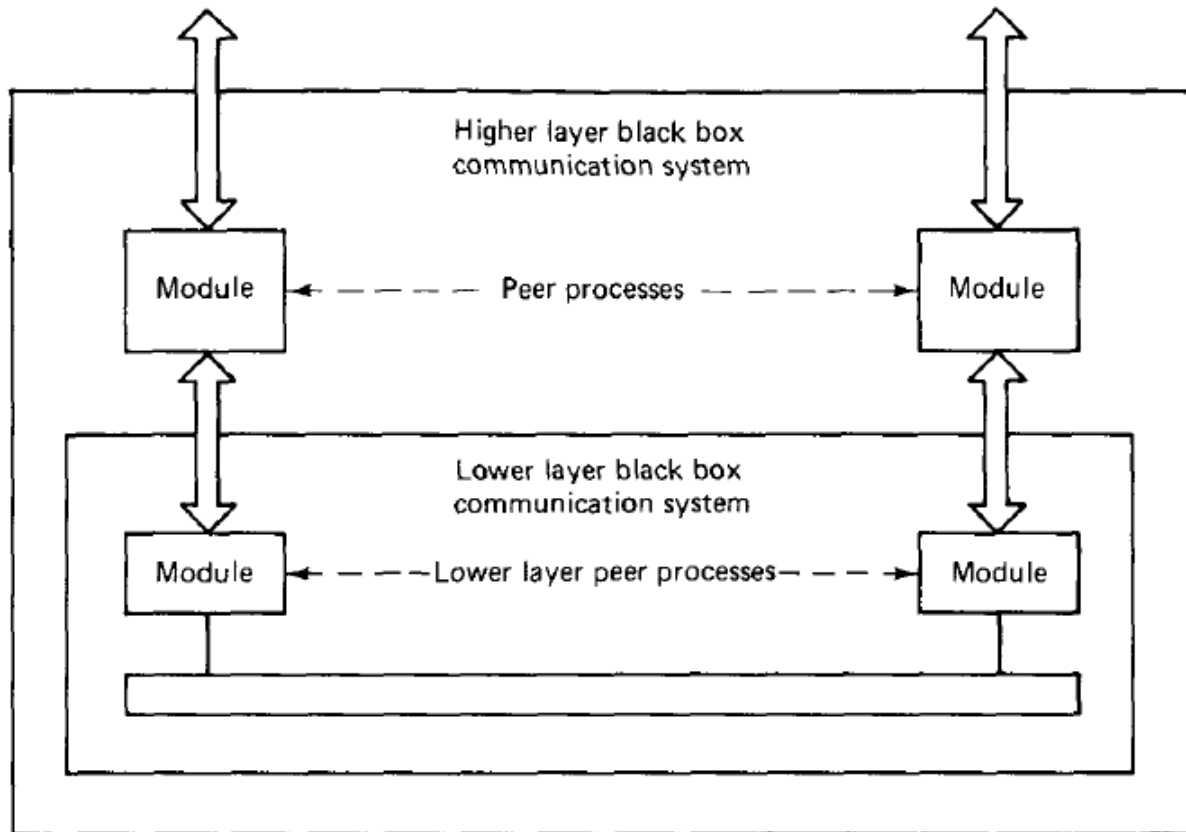
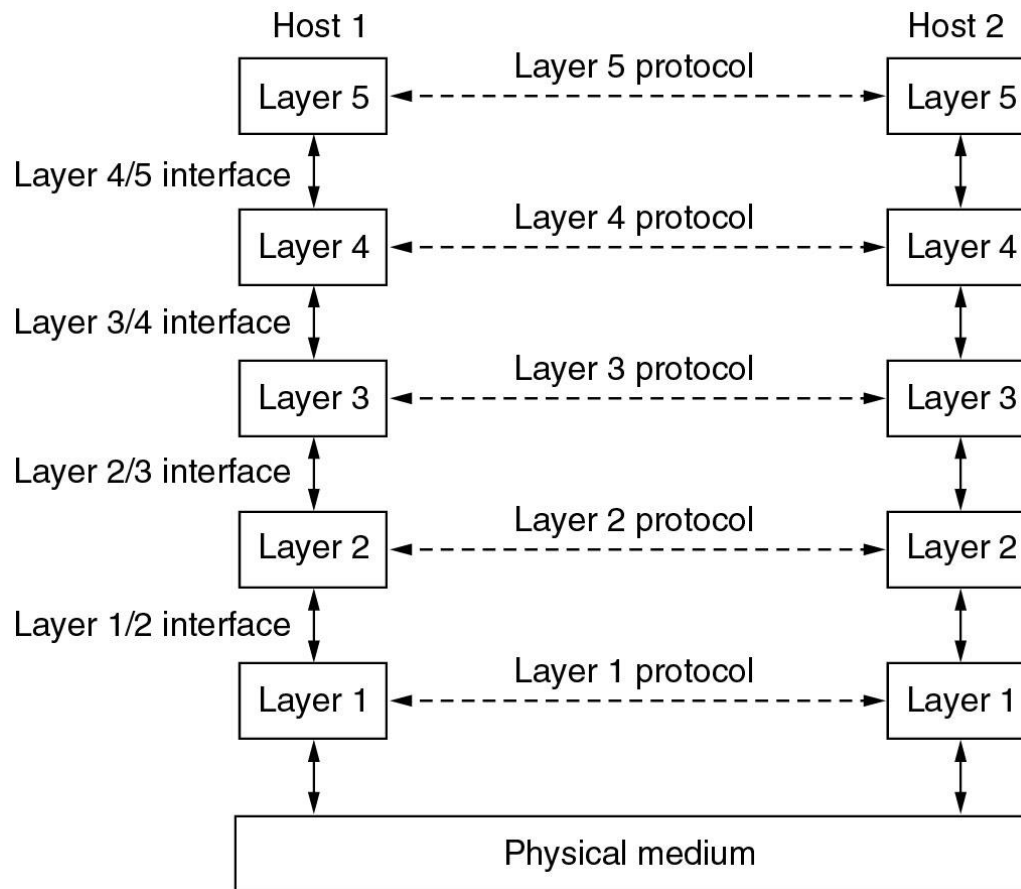


Figure 1.7 Peer processes within a black box communication system. The peer processes communicate through a lower-layer black box communication system that itself contains lower-layer peer processes.

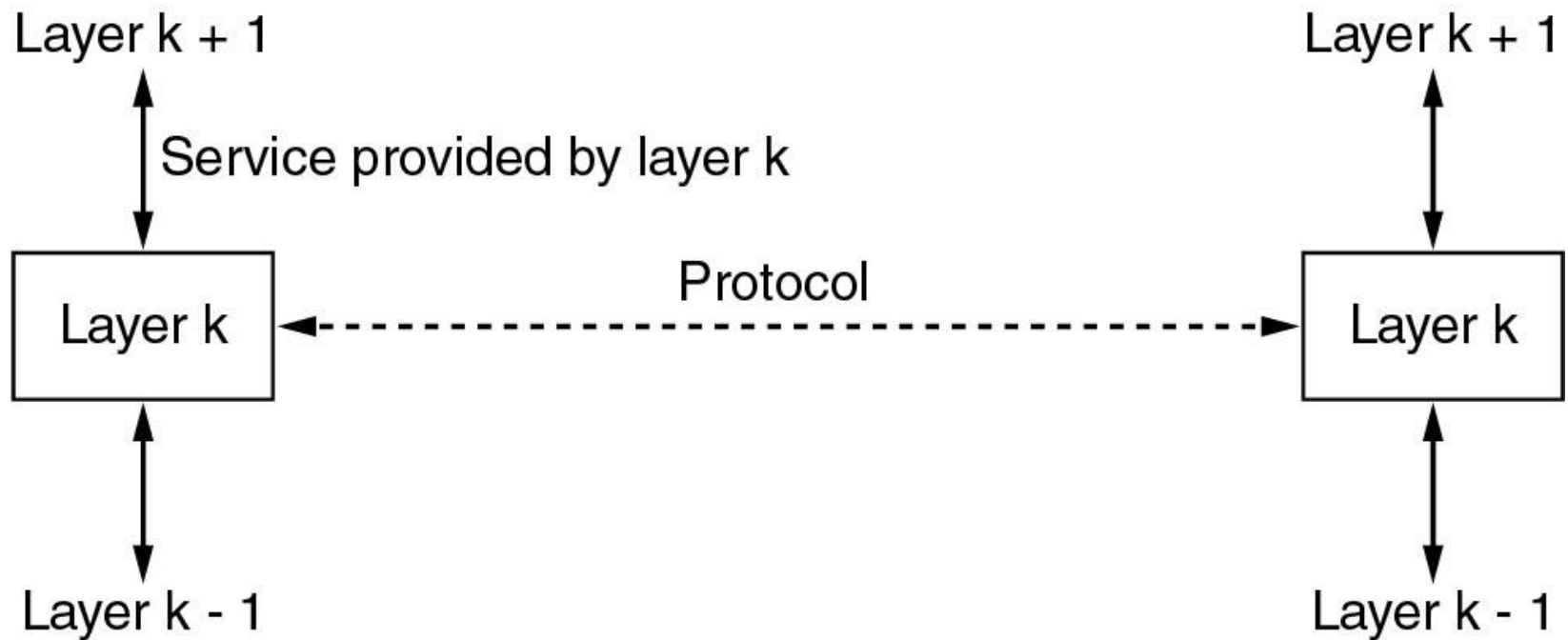
Protocol Hierarchies

Layers, protocols, and interfaces



Services to Protocols Relationship

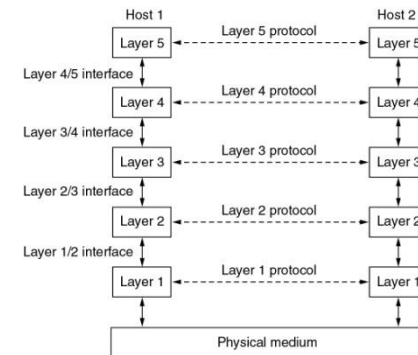
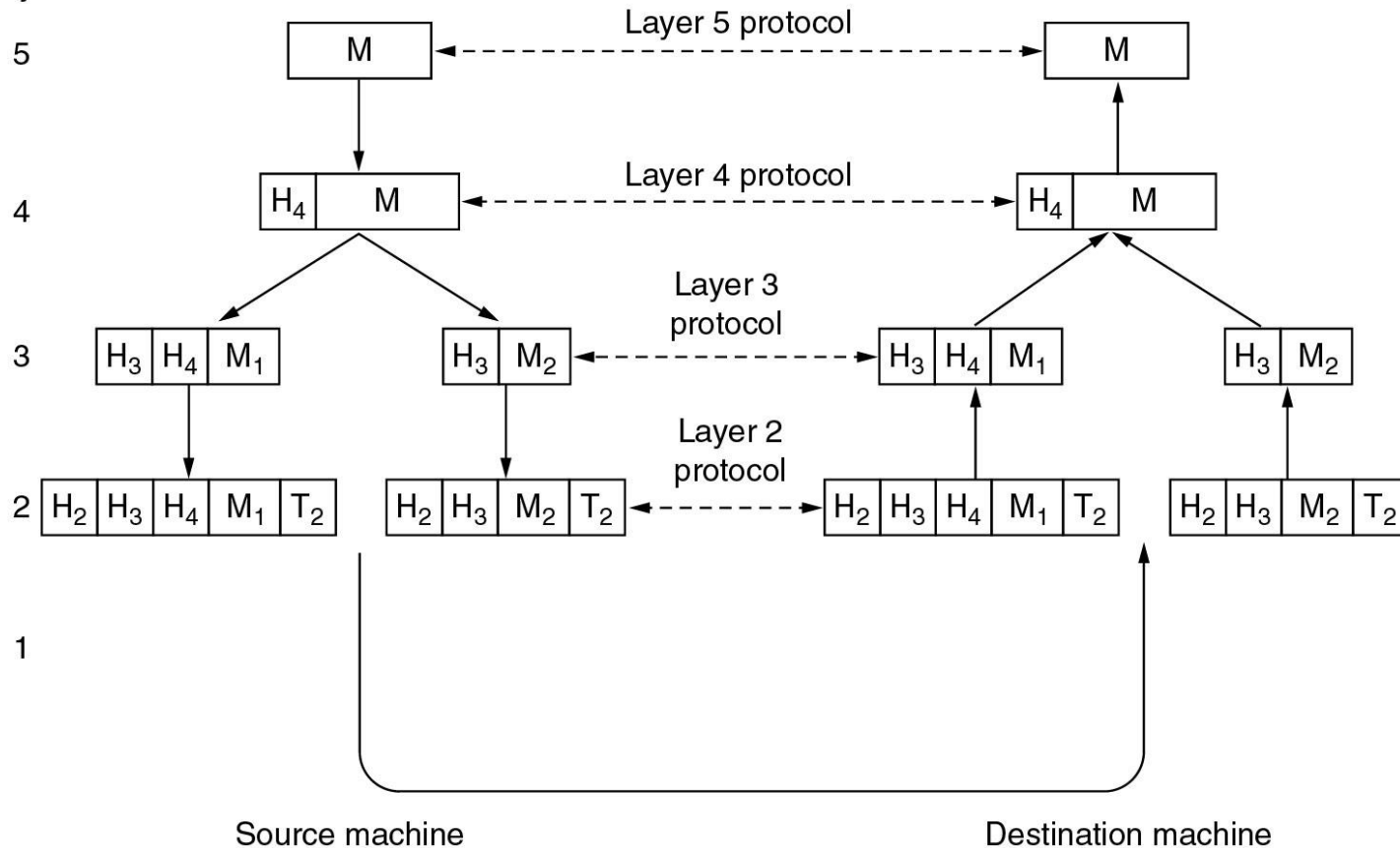
The relationship between a service and a protocol



Transference of Information

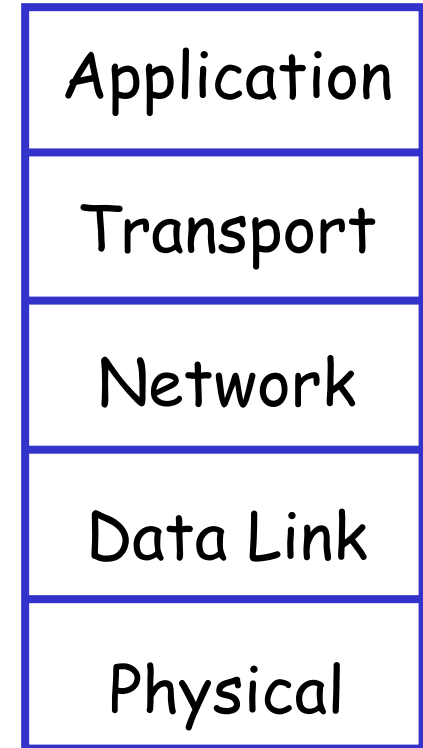
Information flow supporting virtual communication in layer 5

Layer



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

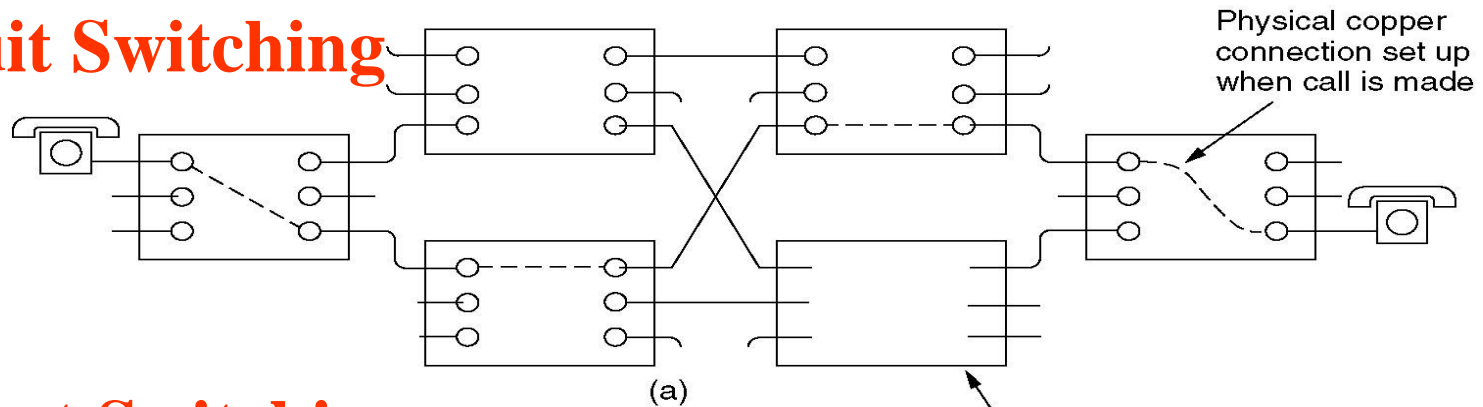
- » 0110110001010....
- » 1 Byte = 1 octet = 8 bits
- » 1 kbit = 10^3 bit; 1 Mbit = 10^6 bit; 1 Gbit = 10^9 bit

♦ Computer Networks

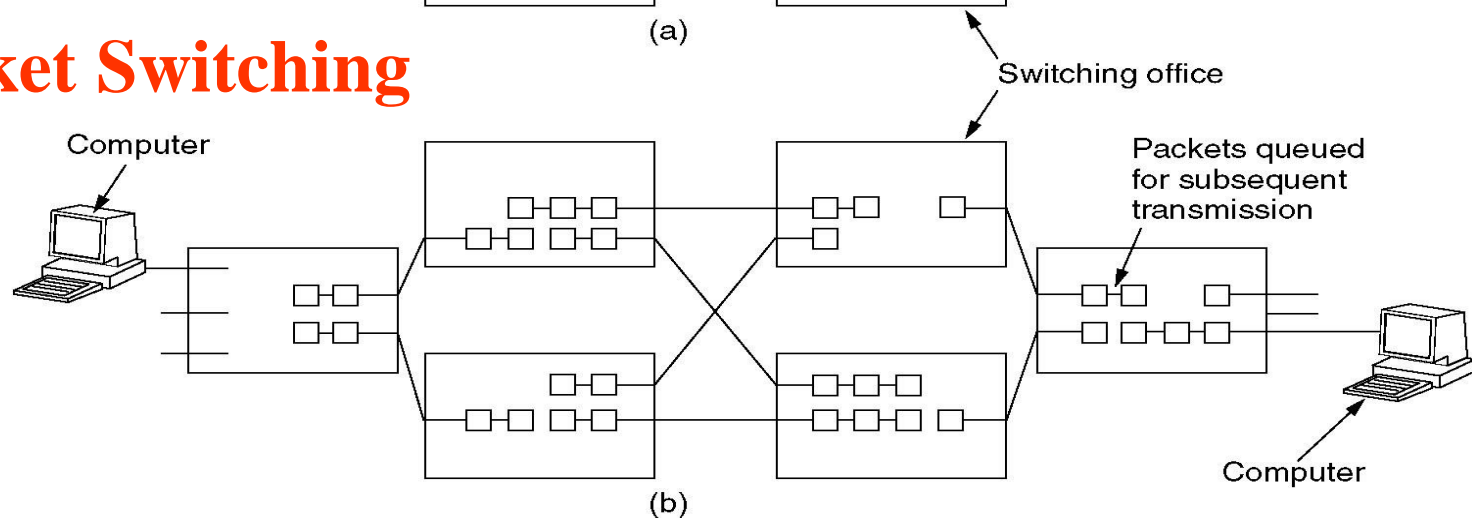
- » transport information, from source to destination
- » Information flow, capacity of a link → Byte/s; bit/s

Circuit Switching, Packet Switching

Circuit Switching

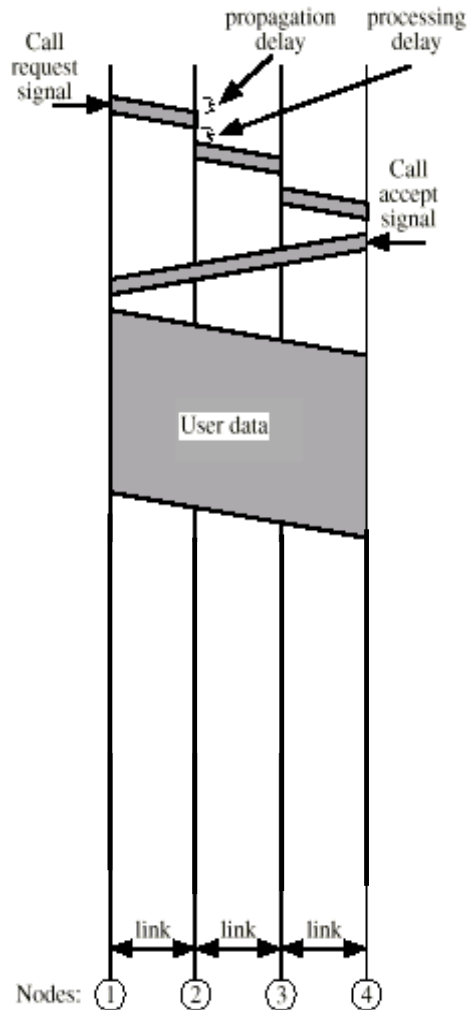


Packet Switching

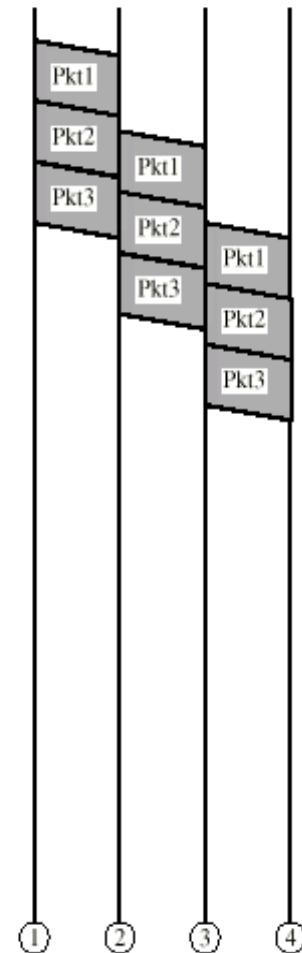


Circuit Switching, Packet Switching

Circuit Switching

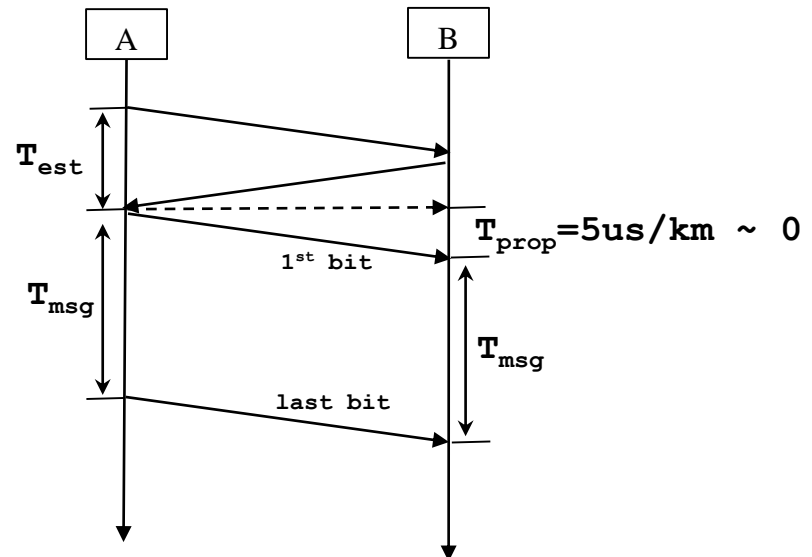
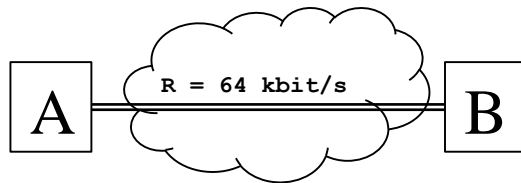


Packet Switching



Circuit Switching – Numerical Example

A file of length $L=640$ kbit is transferred from Host A to Host B through a circuit offering a bitrate of $R=64$ 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?**



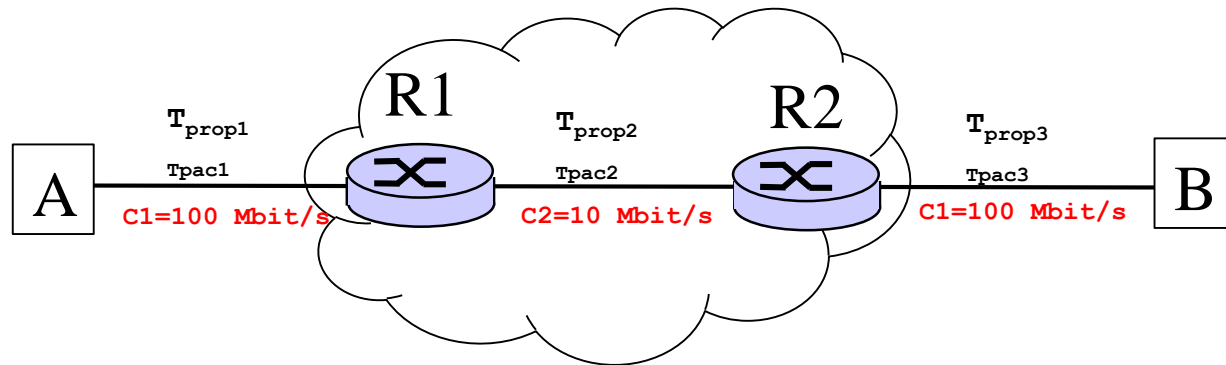
♦ Answer:

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

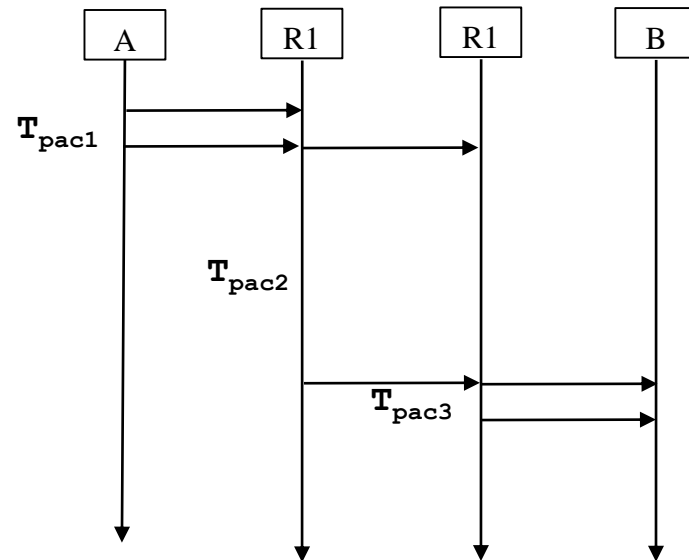
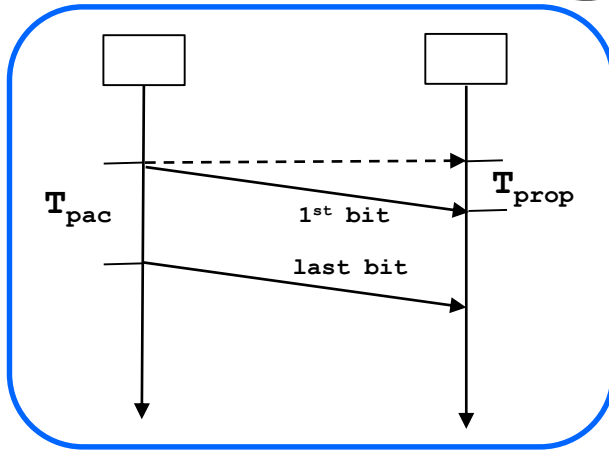
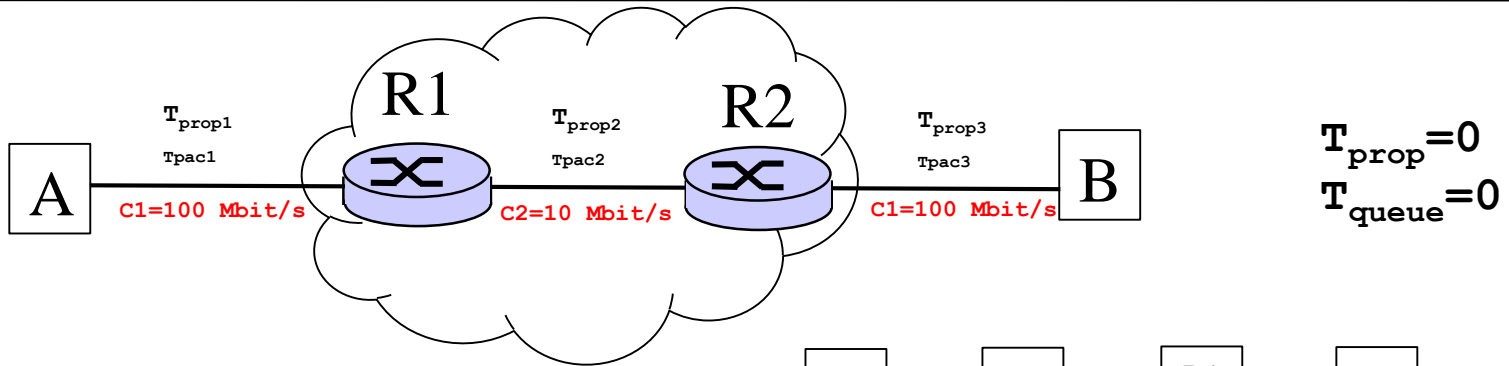
$$\gg T_{\text{tot}} = T_{\text{est}} + T_{\text{prop}} + T_{\text{msg}} = 0.5 + 0 + 10 = 10.5 \text{ s}$$

Packet Switching – Numerical Example

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 packet end-to-end delay?**



Packet Switching – Numerical Example



♦ Answer:

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

To Play

- ◆ How many routers are there from my computer to **www.up.pt** ?

traceroute www.up.pt (Unix) or **tracert www.up.pt** (Windows)

- ◆ How long does it take for a packet to go and come back (Round Trip Time) from my computer to **www.up.pt** ?

ping www.up.pt

- ◆ Do it at home and at FEUP (use VPN)

Homework

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