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 (links through SIFEUP)
- 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 fundaments; 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  - » Examples on outdated networks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 – Fudamental 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
  - » 3ª 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

Tipos de Aulas

- ***Aulas teóricas*** (2ª feira)
  - » 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 = "Sem 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
  - » Planning of a simple network

Introduction to Computer Networks

- *What are the main uses of computer networks?*
- *What are the common architectures of network applications?*
- *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 communication layers of the OSI 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

To think

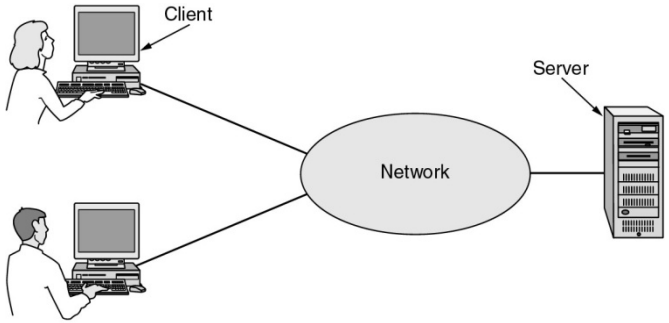
- What do computer networks transport?

Some Applications Using the Networks

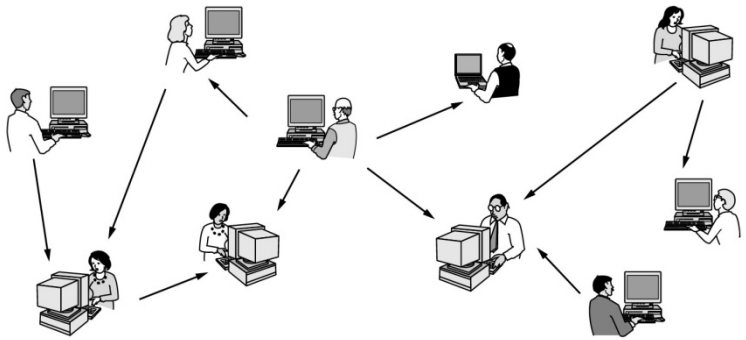
- E-mail
- Web
- Instant messaging
- Remote login
- P2P file sharing
- Multi-user network games
- Video clips retrieval
- Voice over IP
- Video streaming
- Real-time video conferencing
- Grid computing

Application Architectures

- Client-server

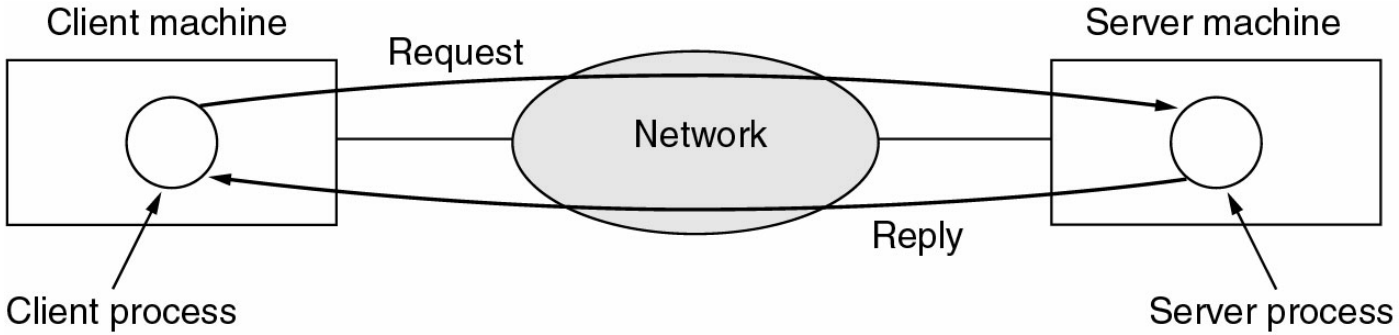


- Peer-to-peer (P2P)



- Hybrid client-server / P2P

Client-server Architecture



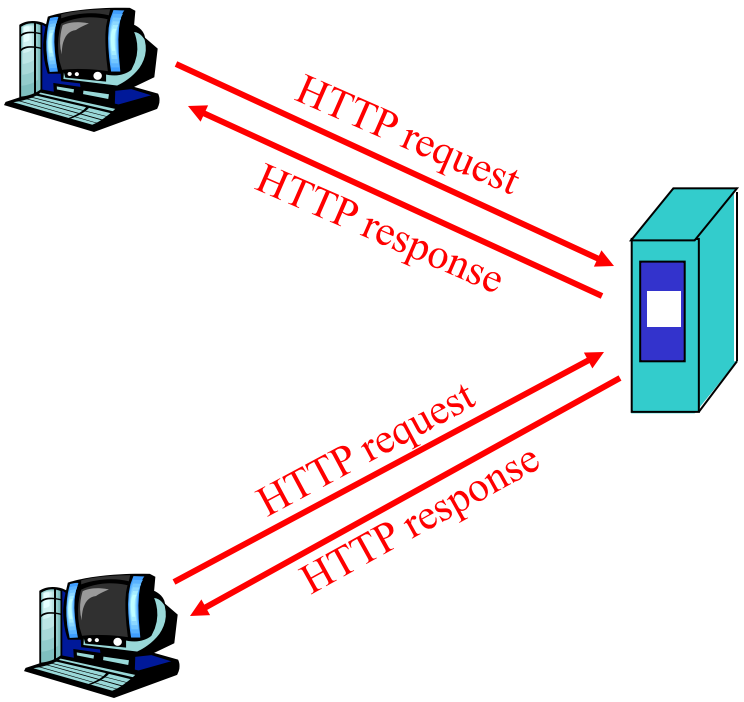
- Server
  - » always-on host
  - » permanent IP address
- Clients
  - » communicate with server
  - » may be intermittently connected
  - » do not communicate directly with other clients

Client-server Example – The Web

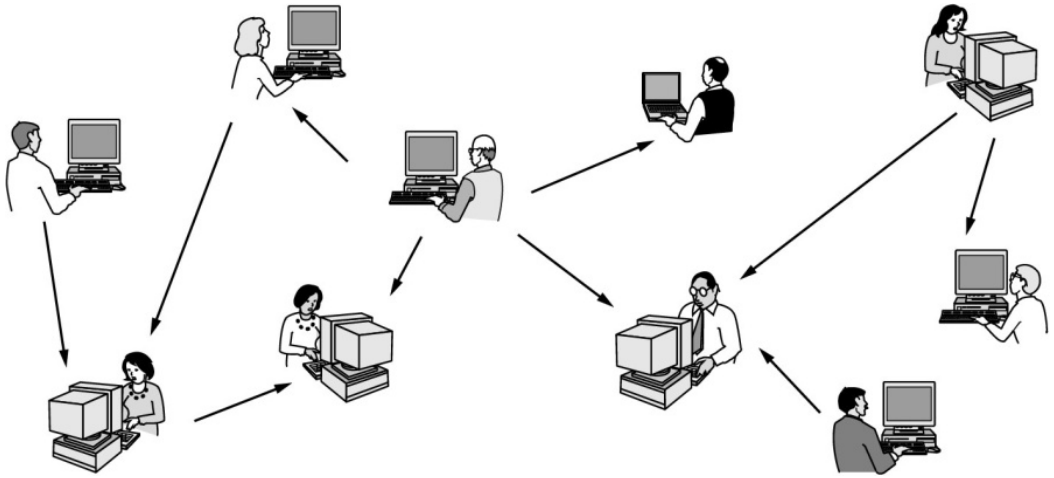
- Client/server model
- Client: browser

  requests, receives, and "displays" Web objects
- Server: Web server

  sends objects in response to requests



P2P Architecture



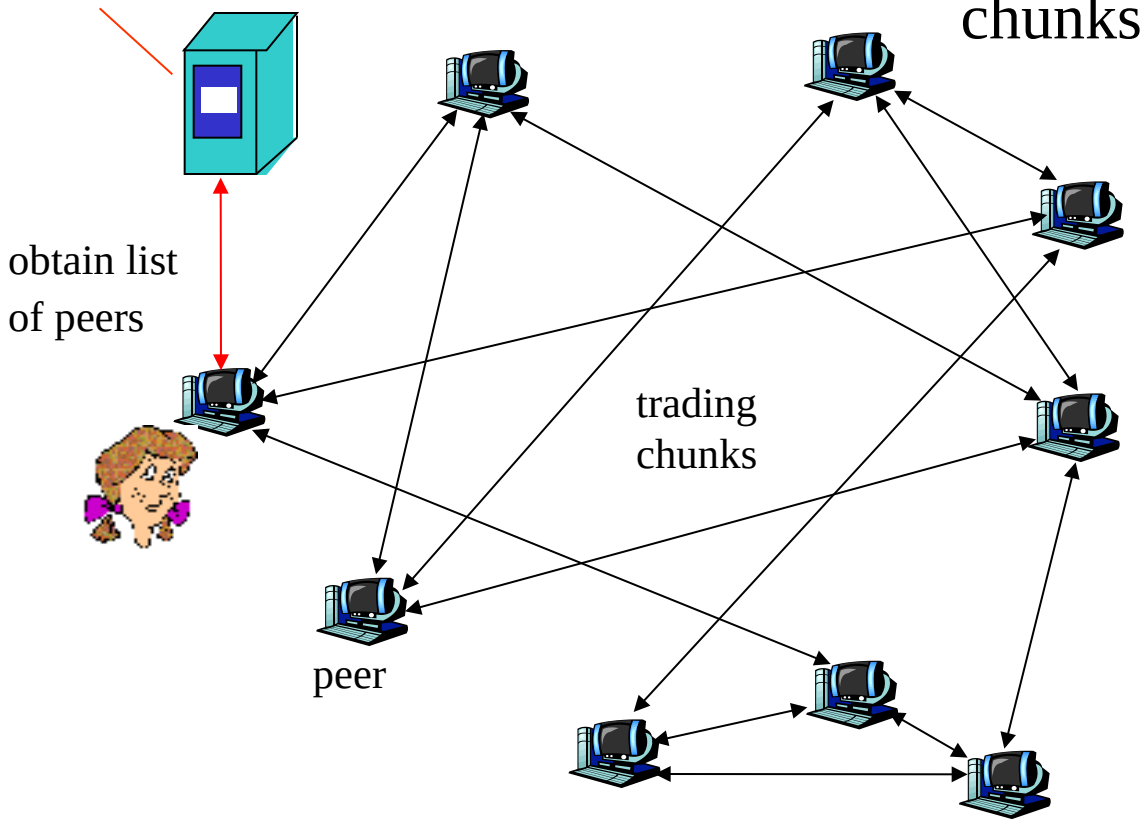
- No always-on server
- Arbitrary end systems directly communicate
- Peers are intermittently connected and may change IP addresses

P2P Example - BitTorrent

P2P file distribution

tracker: tracks peers participating in torrent

torrent: group of peers exchanging chunks of a file



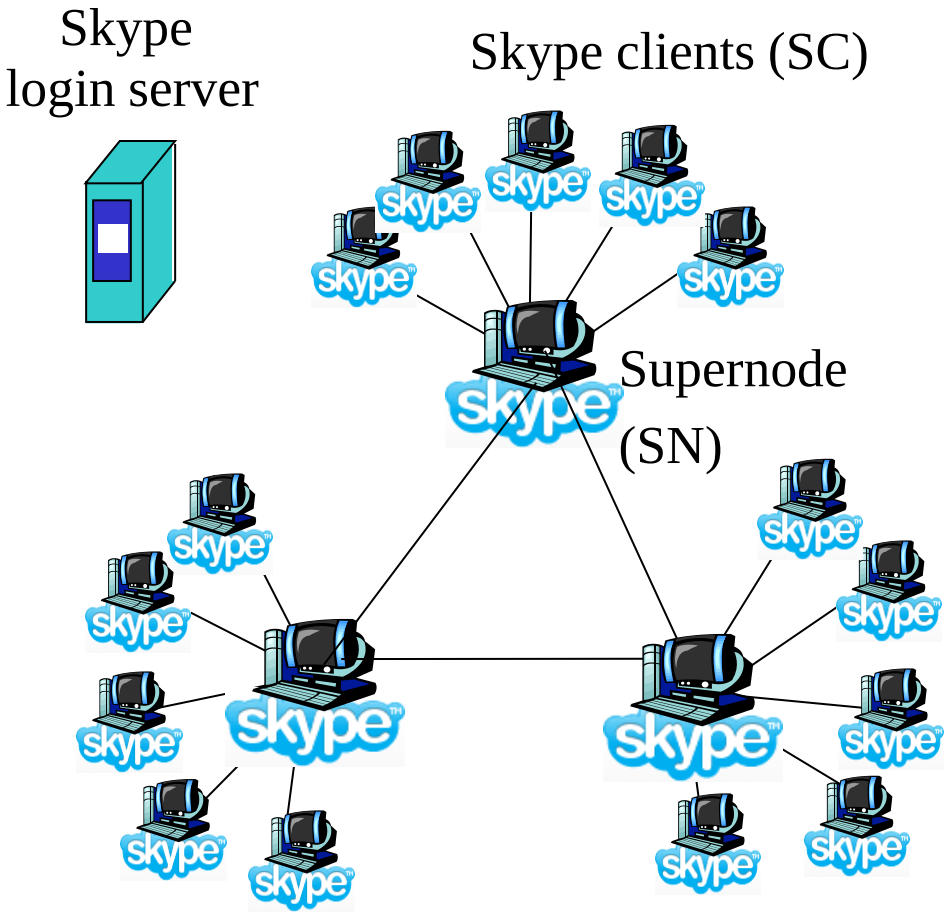
To Think

How does Skype work?

Hybrid of Client-server and P2P - Example

Skype

- » voice-over-IP P2P application
- » centralized server
  - finding address of remote party
- » client-client connection
  - direct (not through server)



Topology of Networks

Classification of Networks

- By transmission technology
  - » Broadcast links

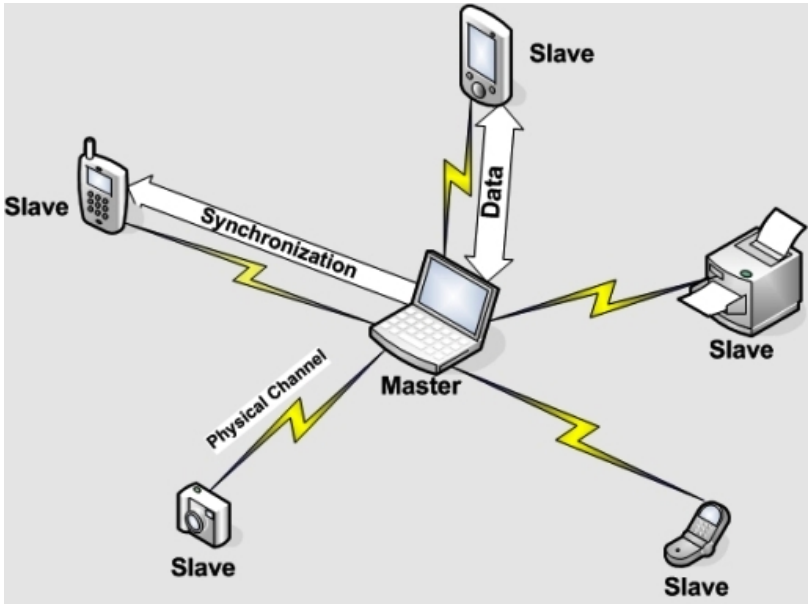
  - » Point-to-point links

- By scale (distance between processors)
  - » PAN – Personal Area Network
  - » LAN - Local Area Network
  - » MAN - Metropolitan Area Network
  - » WAN - Wide Area Networks
  - » 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

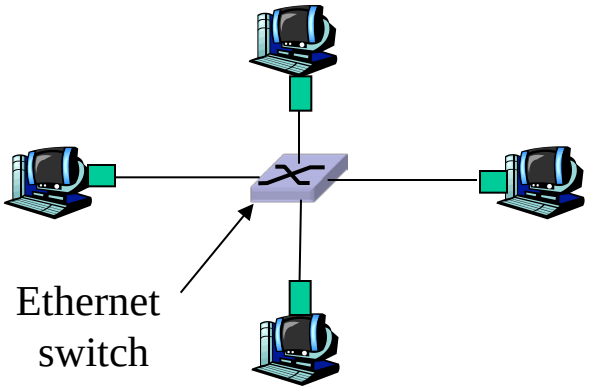
Personal Area Networks

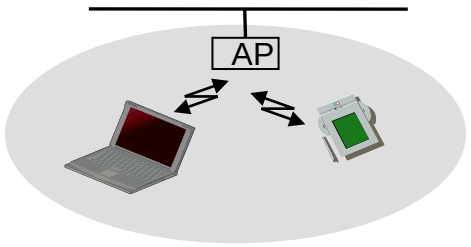
Bluetooth network



Local Area Networks

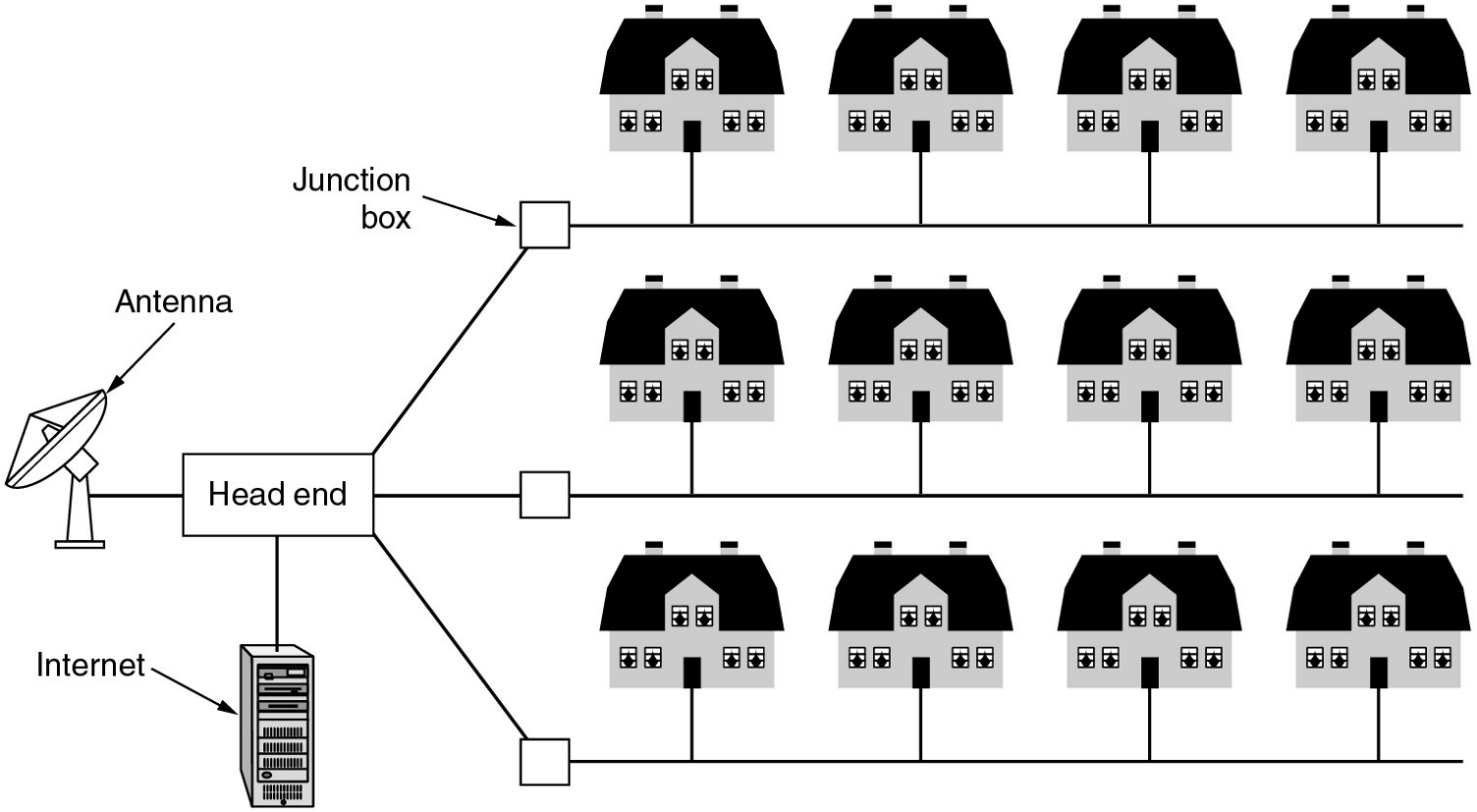
- Common Local Area Networks





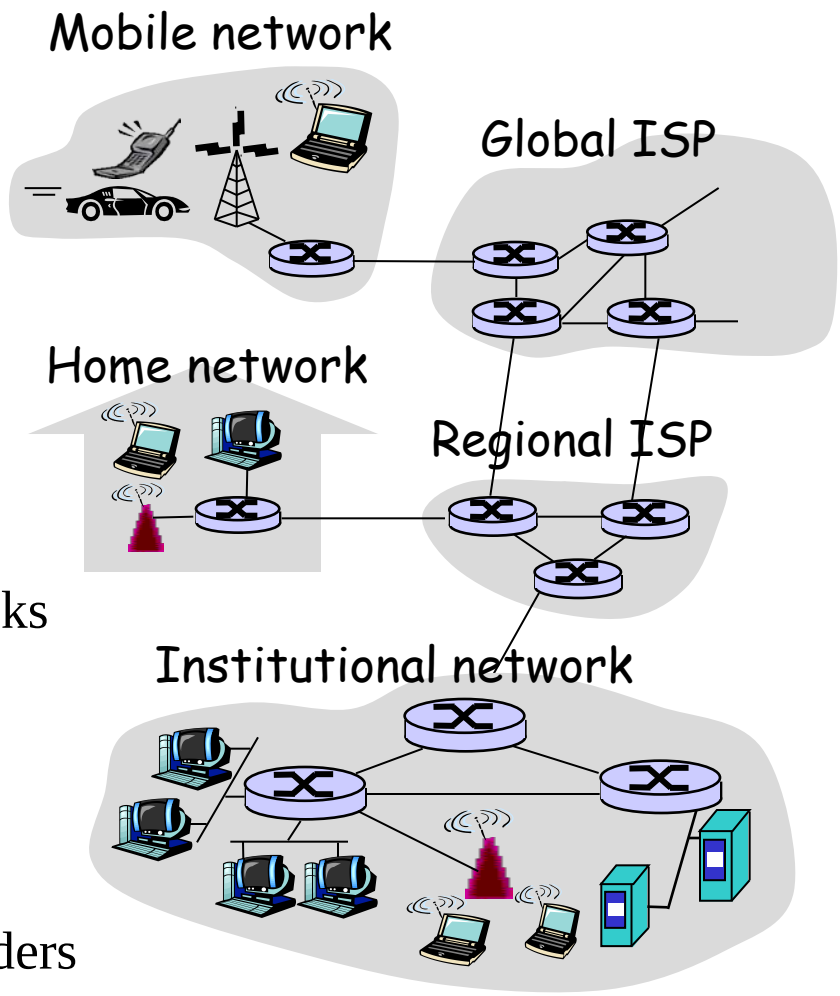
Metropolitan Area Networks

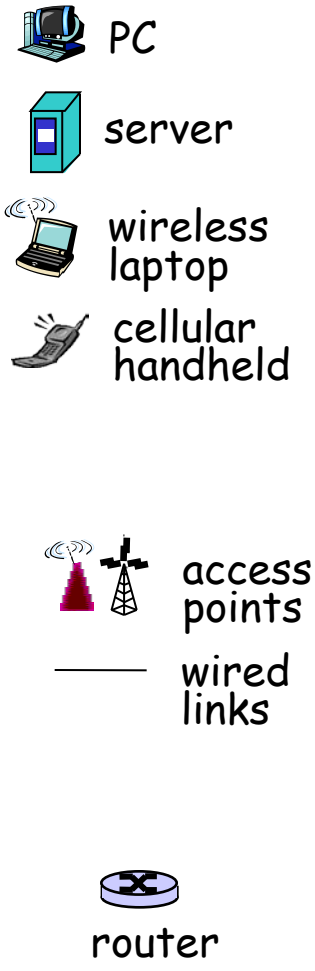
A metropolitan area network based on cable TV



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

To Think

- How do you proceed to develop a complex program?

Software Organized in Black Boxes

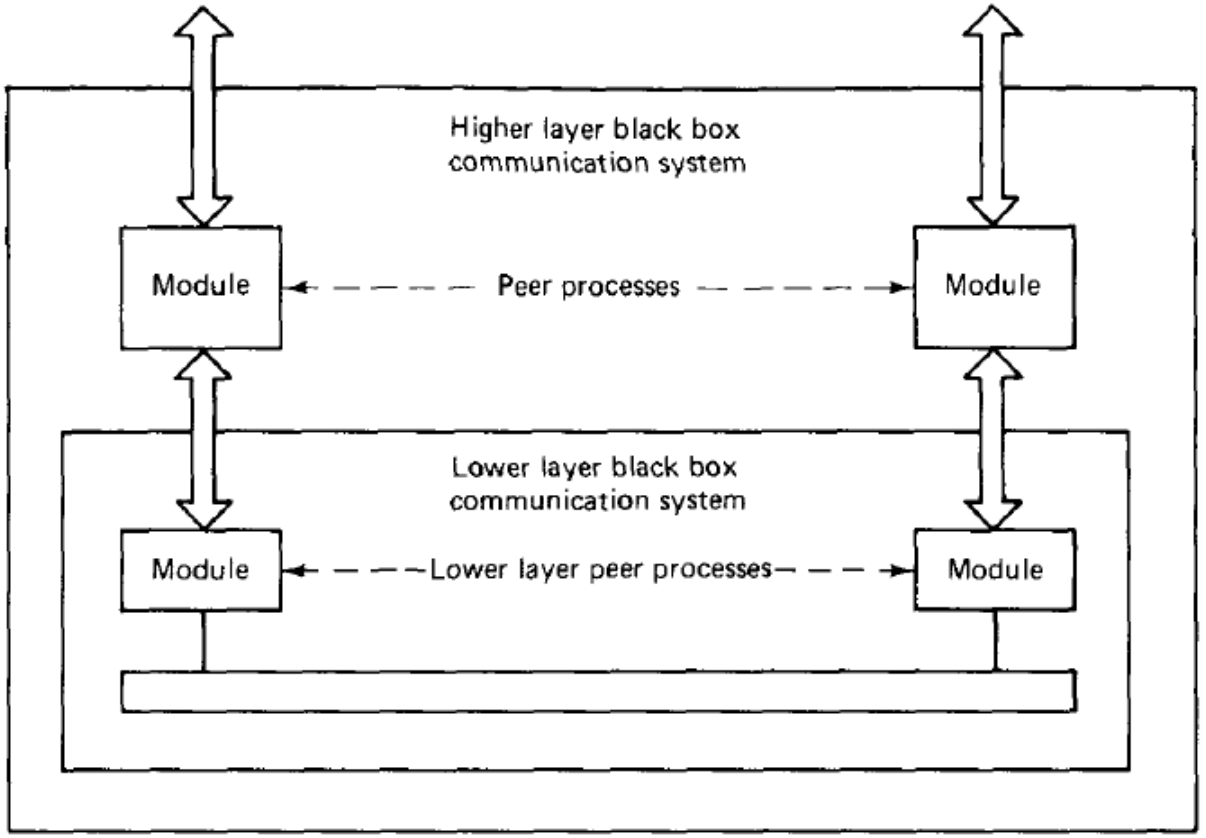
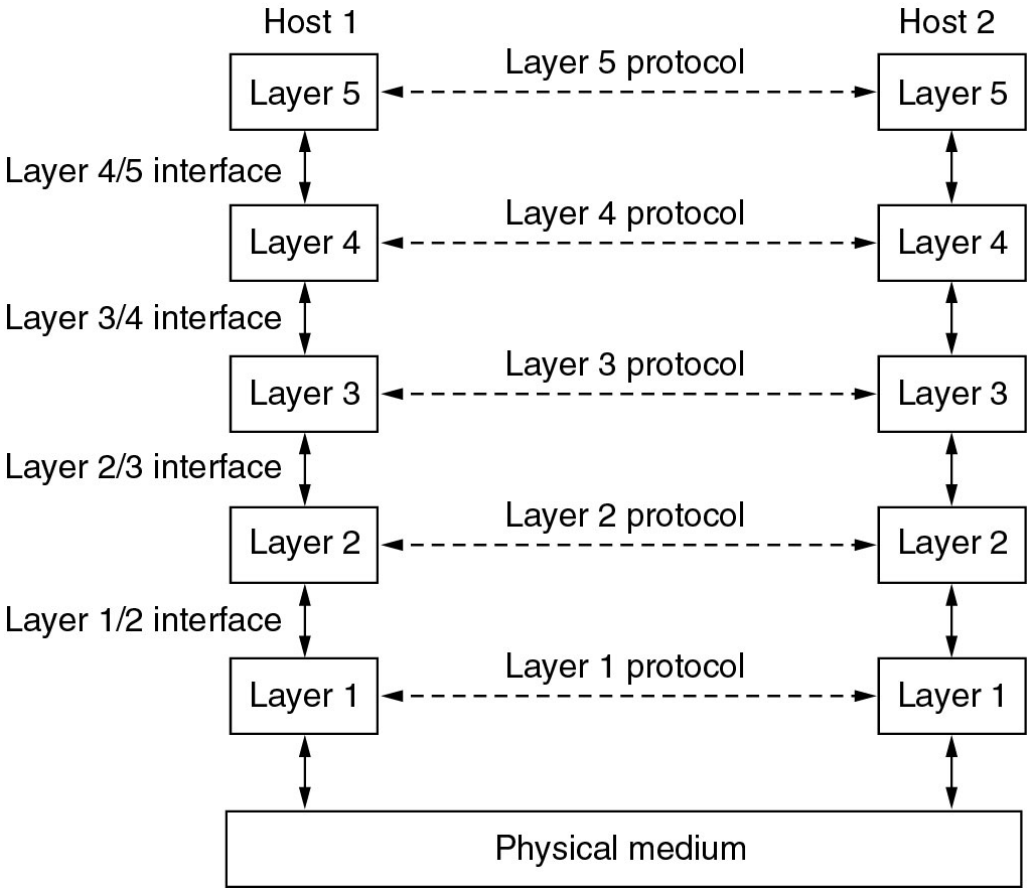


Figure 1.7 Peer processes within a black box communication system. The peer processes communicate through a lower-layer black box communication system that itself contains lower-layer peer processes.

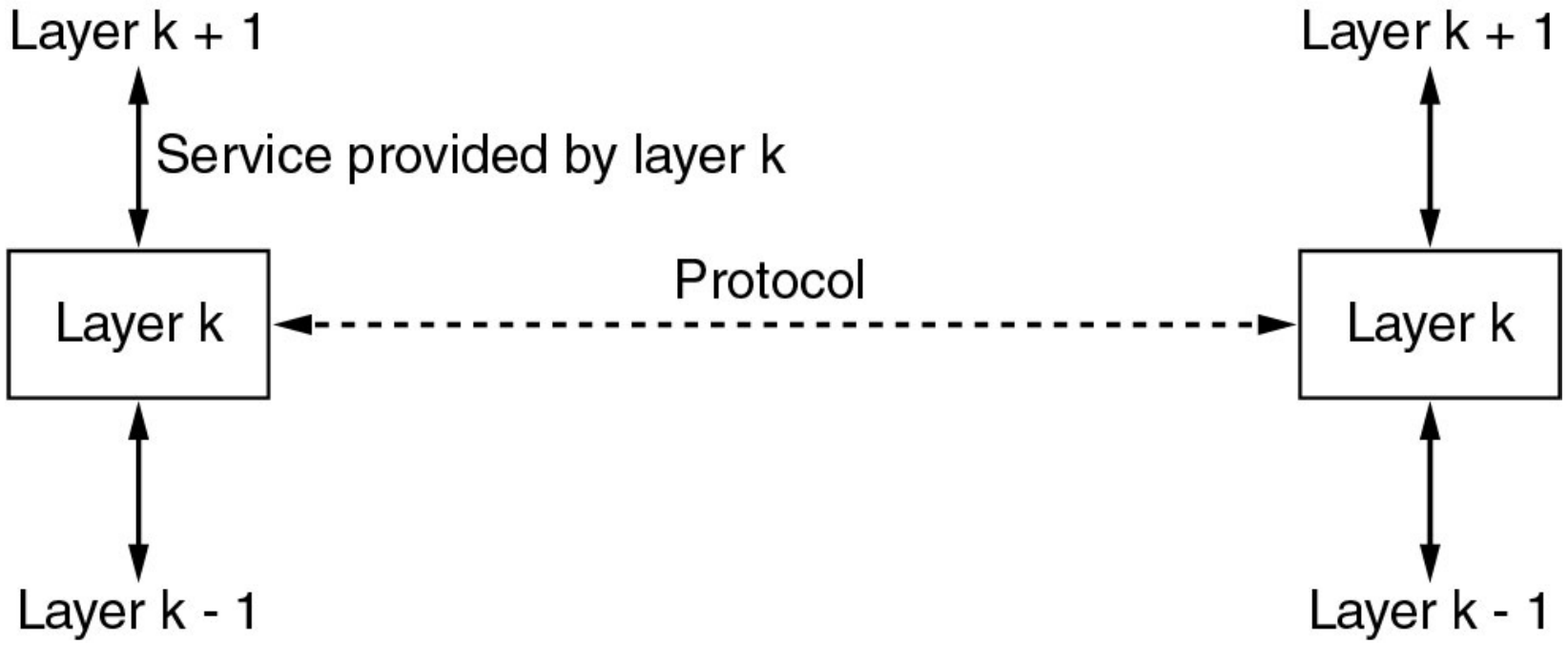
Protocol Hierarchies

Layers, protocols, and interfaces



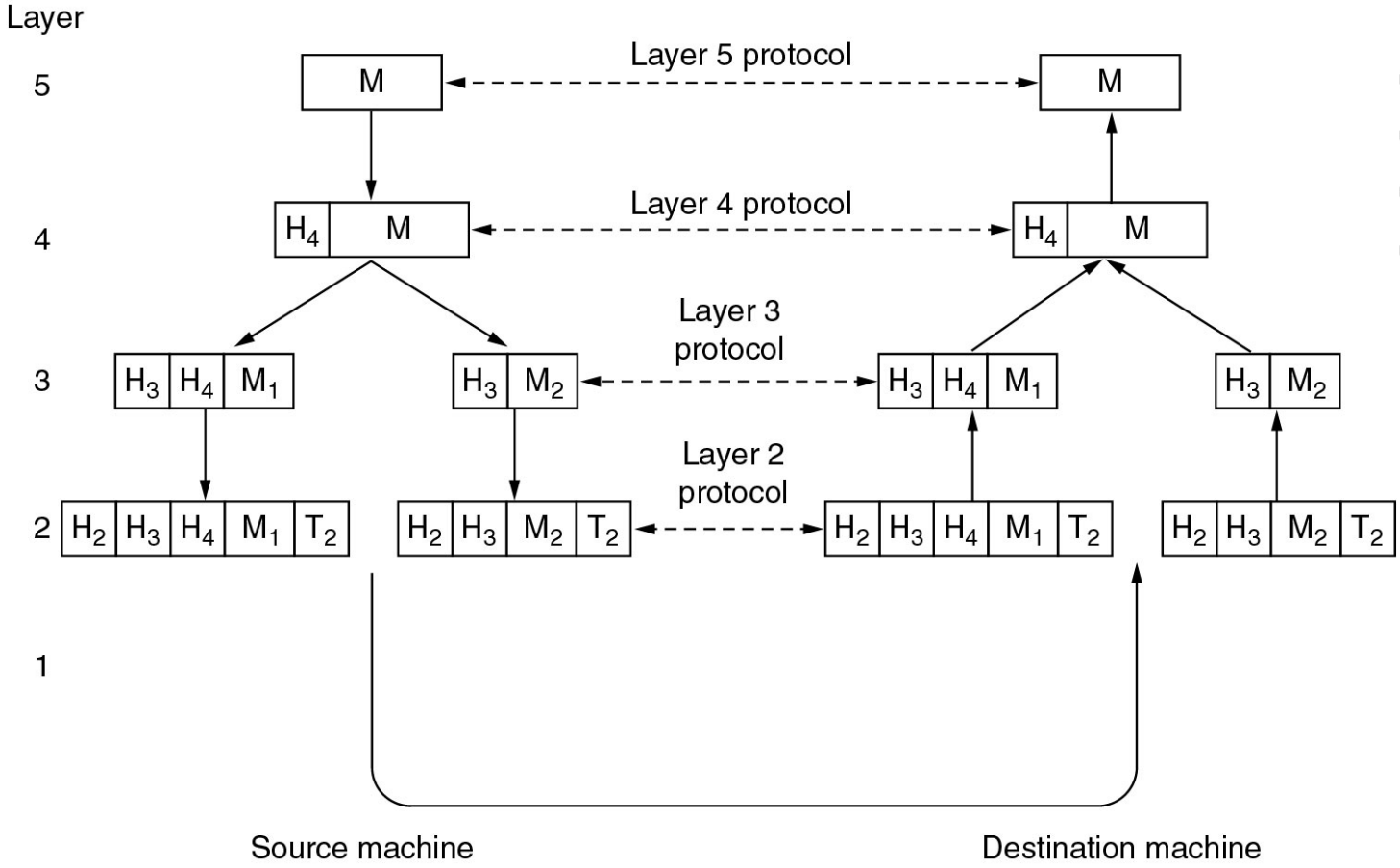
Services to Protocols Relationship

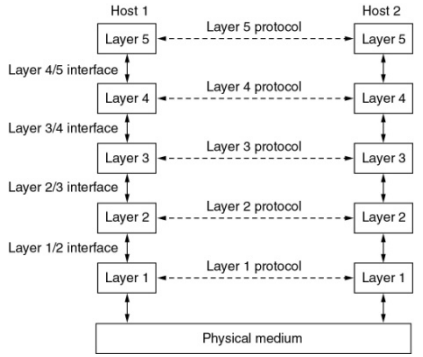
The relationship between a service and a protocol



Transference of Information

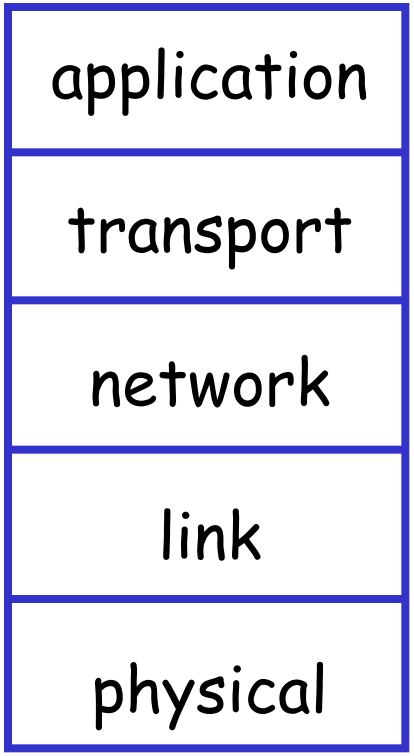
Information flow supporting virtual communication in layer 5



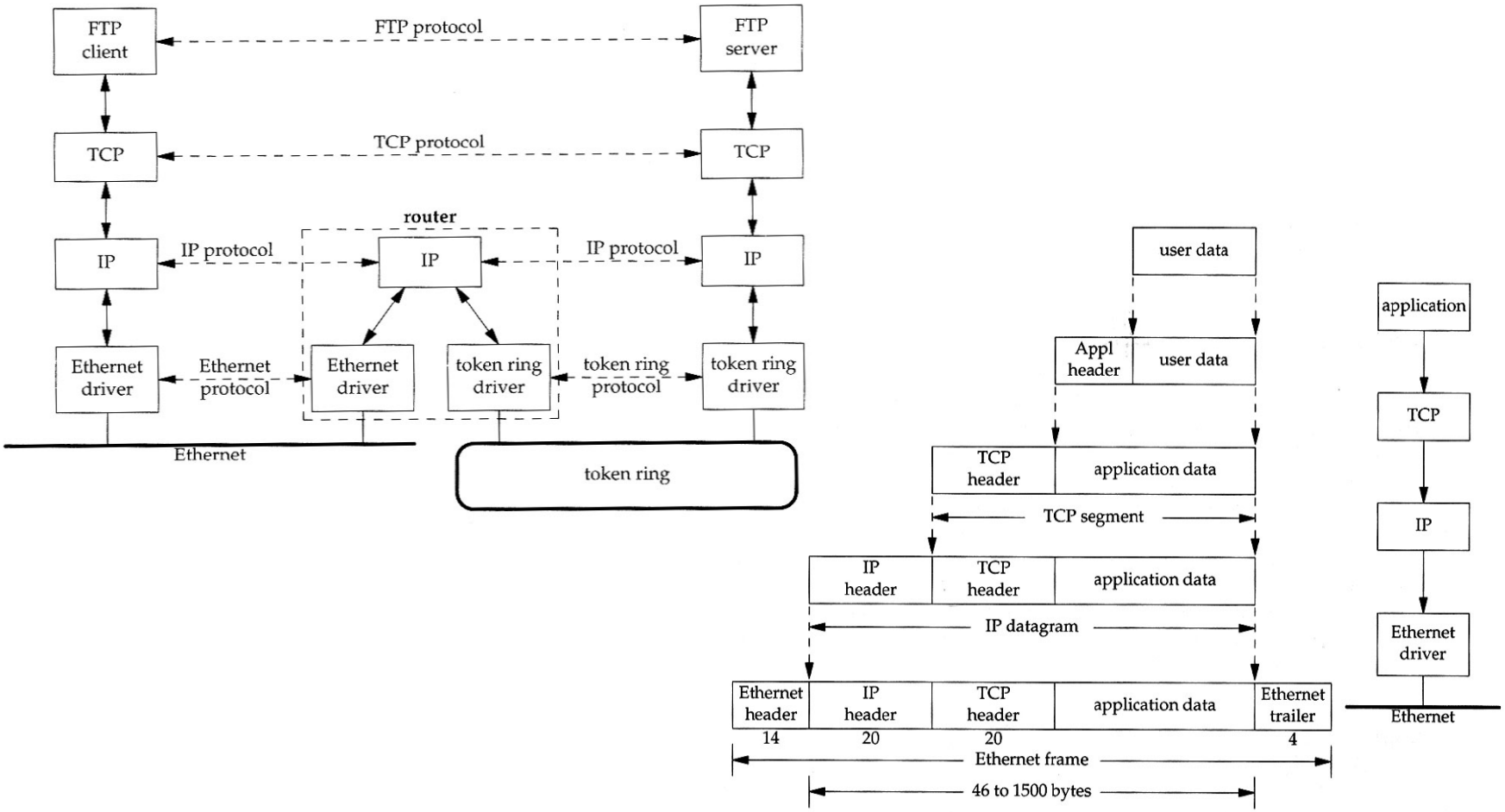


Internet (TCP/IP) Reference Model

- 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
- Link layer
  - » data transfer between neighboring network elements
  - » PPP, Ethernet, WLAN
- Physical layer
  - » bits sent “on the wire”



TCP/IP – Interworking and Encapsulation



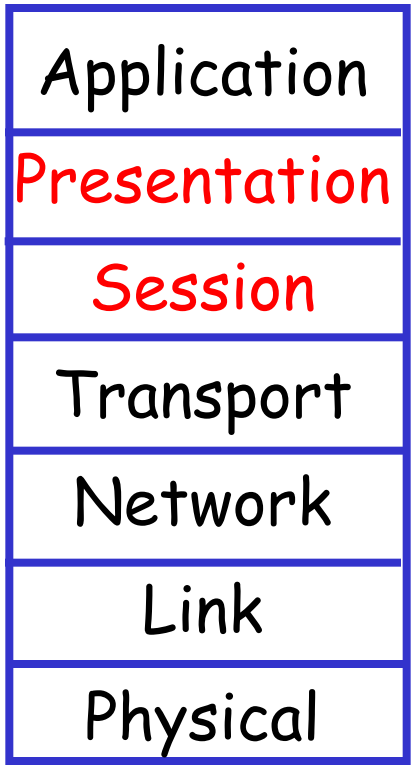
7 Layer OSI Reference Model

- Presentation layer
  - allow applications to interpret meaning of data
  - (e.g., encryption, compression, machine-specific conventions)
- Session layer

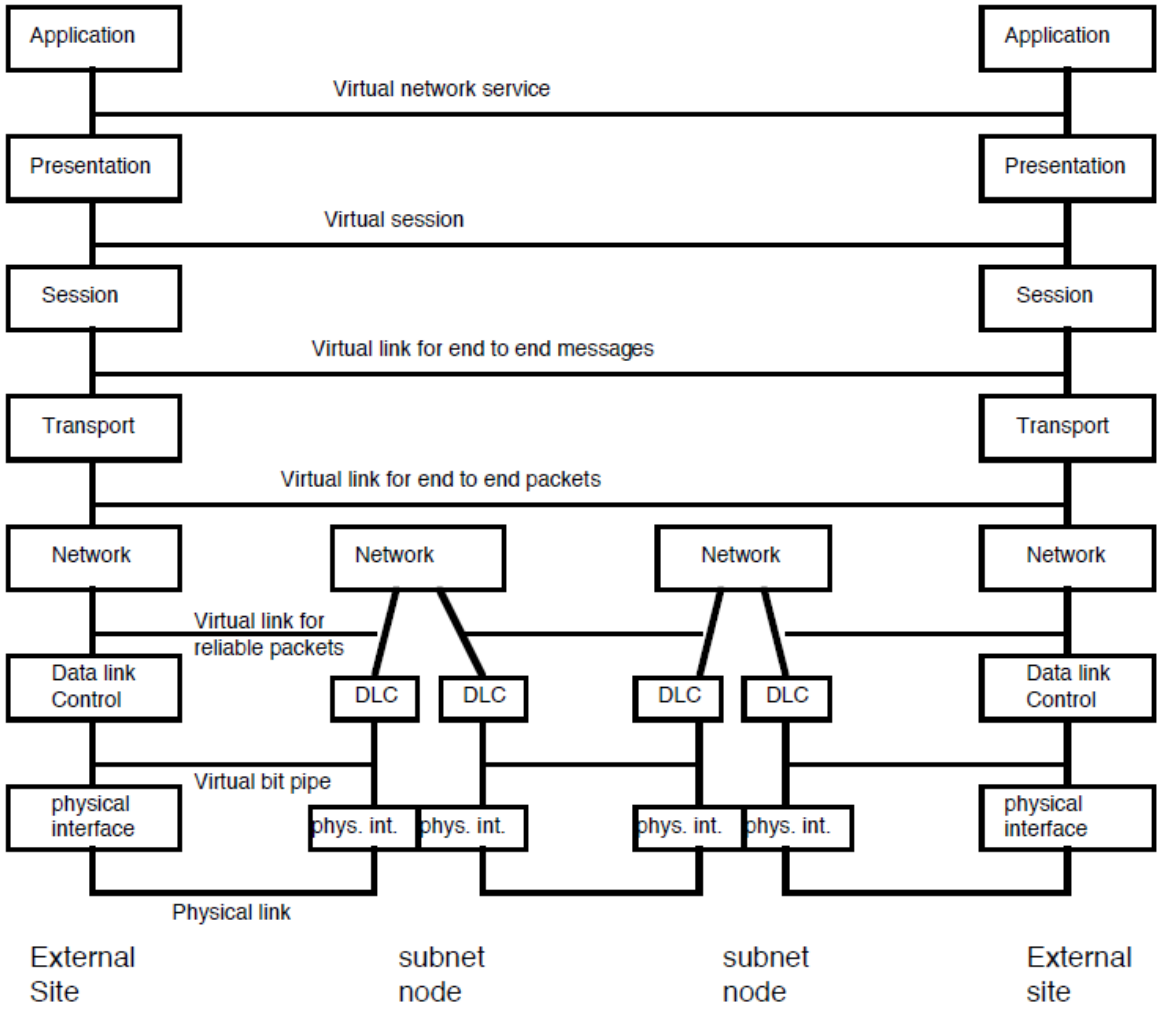
  synchronization, checkpointing, recovery of data exchange

- Internet stack "missing" these layers!

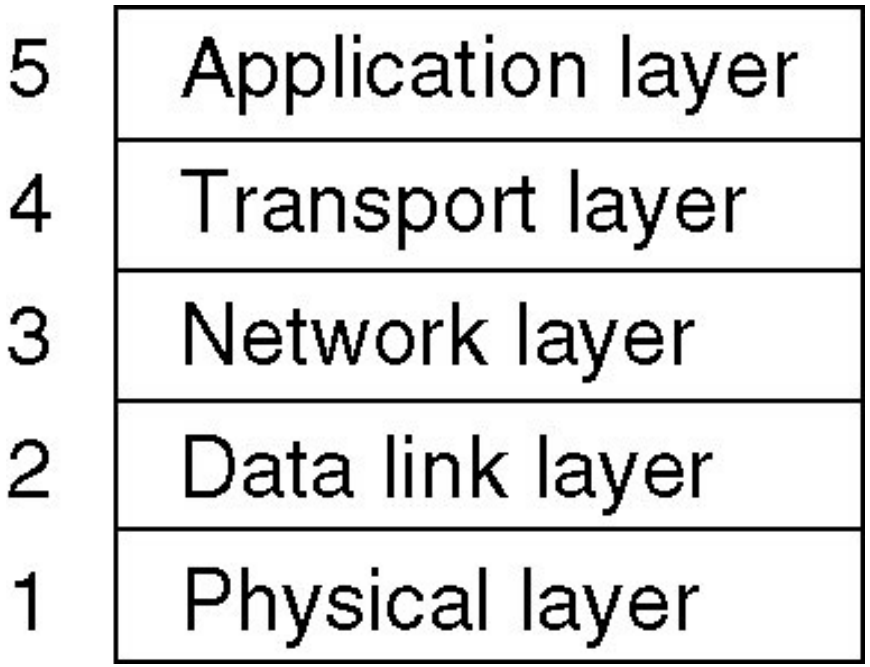
  if needed, must be implemented in the Application Layer



7 Layer OSI Reference Model



Reference Model Adopted in RCOM



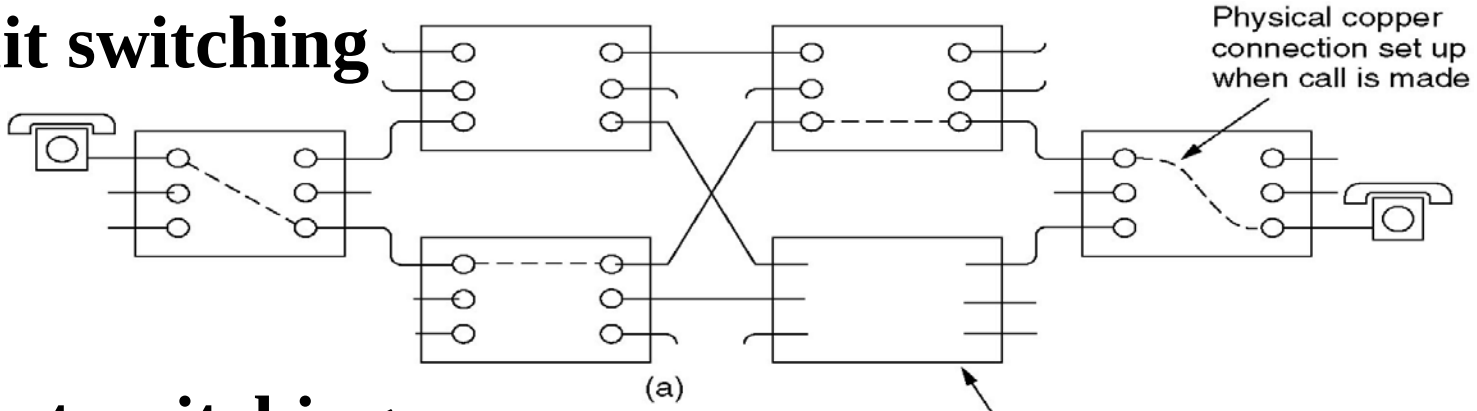
Transferring Data Through a Network

Information and Data

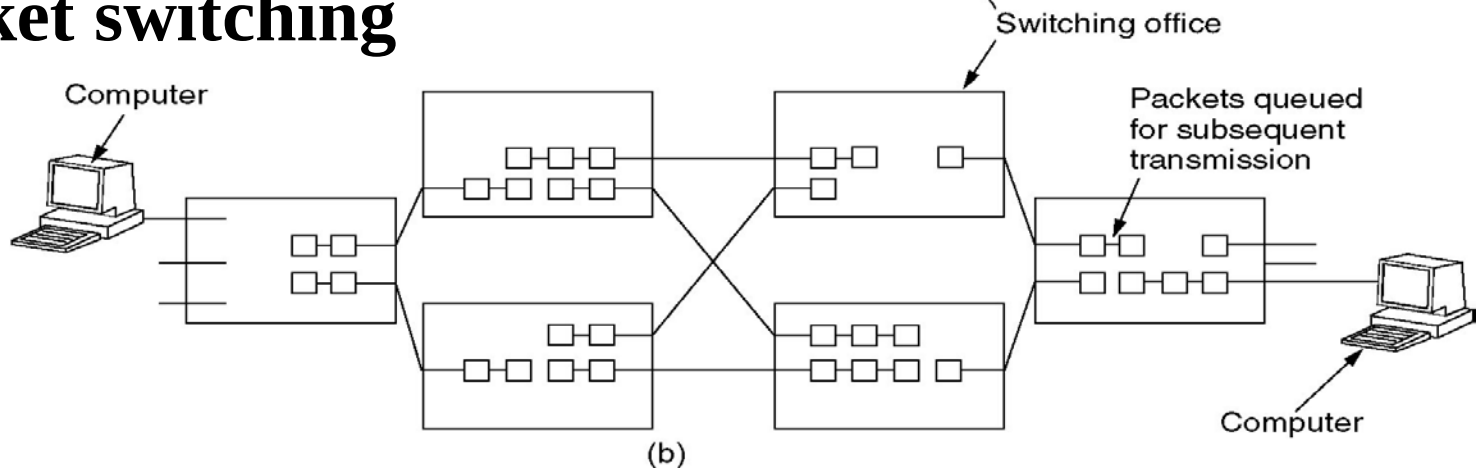
- Data
  - » term used to represent ***information***
  - » e.g. text, voice, video, image, graphics
- Information represented as a sequence of bits
  - » 0110110001010....
  - » 1 Byte = 1 octet = 8 bits
  - » 1 kbit = 10^3 bit; 1 Mbit = 10^6 bit; 1 Gbit= 10^9 bit
- Computer Networks
  - » aimed to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

Circuit Switching vs Packet Switching

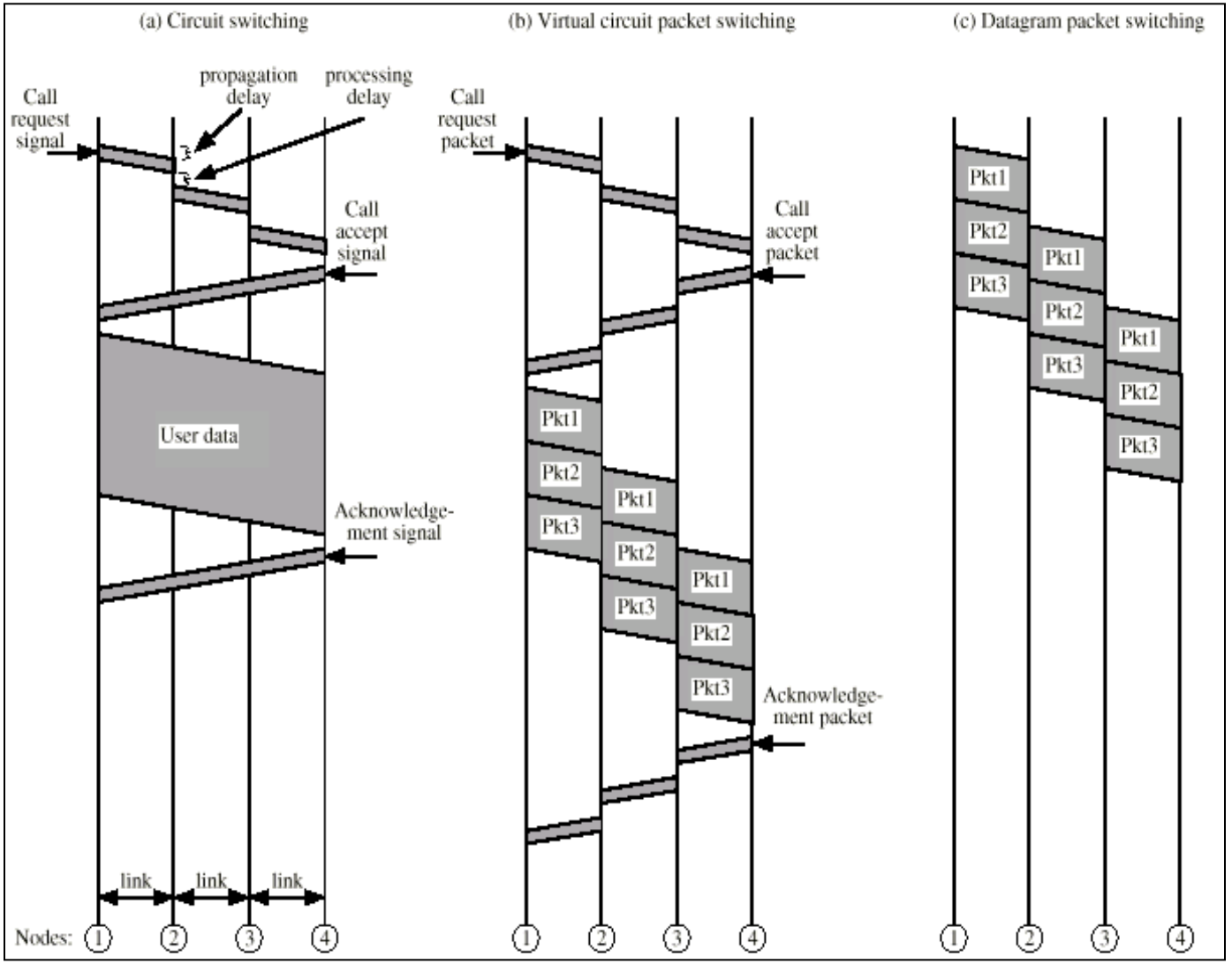
Circuit switching



Packet switching

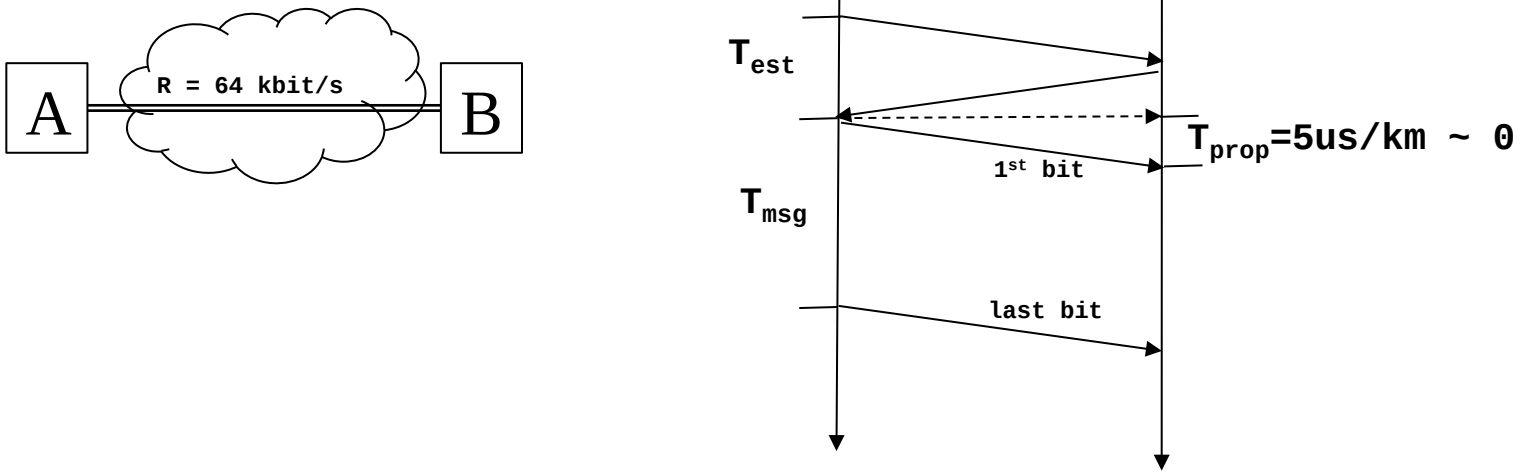


Switching: Circuits, Virtual Circuits, Packets



Circuit Switching – Numerical Example

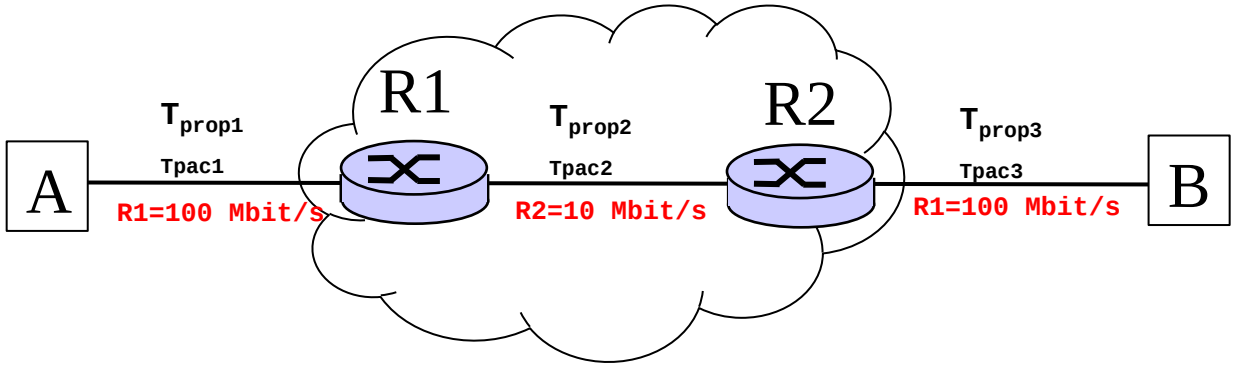
Host A needs to send a file of length **L=640 kbit** to Host B through a circuit offering a bitrate of **R= 64 kbit/s**. Assuming a delay for establishing the circuit **T_{est}=500 ms,** *how long does it take to transmit the file?*



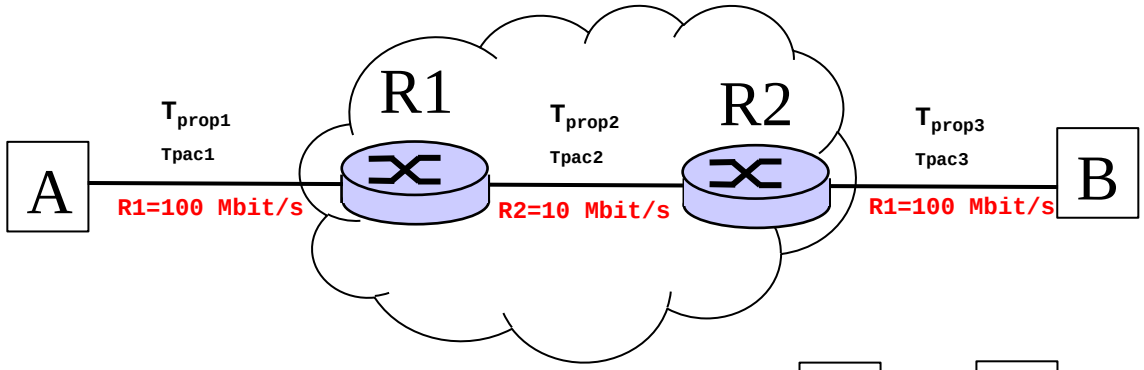
- **Answer:**
  - » **T_{msg}=L/R=640/64= 10s**
  - » **T_{tot}=T_{est}+T_{prop}+T_{msg}=0.5+0+10=10.5 s**

Packet Switching – Numerical Example

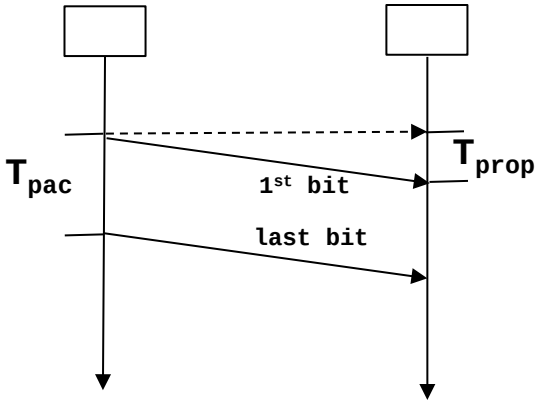
Host A sends a packet of length **L=10 kbit** to Host B through routers R1 and R2. Not considering the propagation delay through the 3 links nor the queuing delays at the network elements (A, R1 and R2), how long does it take for the packet to arrive to Host B?

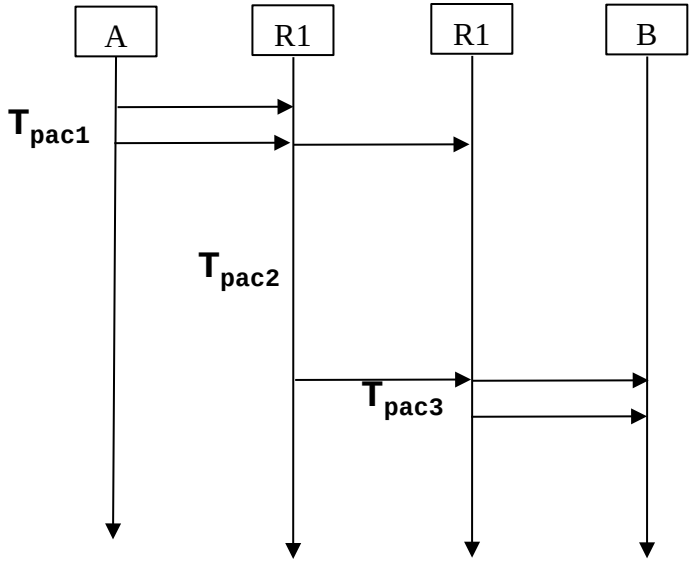


Packet Switching – Numerical Example



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





- **Answer:**
  - $T_{pac1}=T_{pac3}=L/R1=0.1$ ms
  - $T_{pac2}=L/R2=1$ ms
  - $T_{tot}=T_{pac1}+T_{prop1}+T_{pac2}+T_{prop2}+T_{pac3}+T_{prop3}=1.2$ ms

To Play

- How many routers are there from my computer to:
  - » www.up.pt →
  - » www.bbc.com (UK) →

  `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 →
  - » www.bbc.com →

  `ping www.up.pt`

Homework

1. Review slides

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

3. Answer questions at moodle