

Reti Internet Multimediali

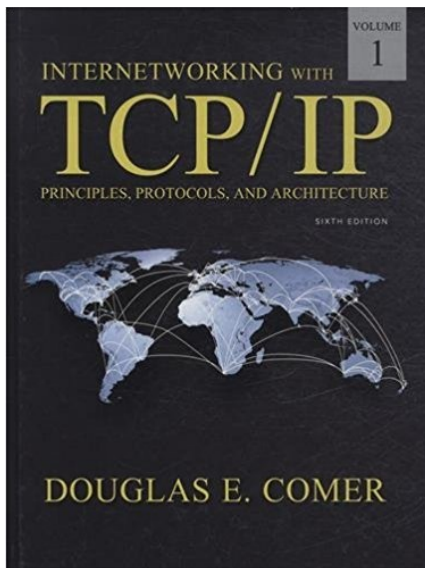
Prof. Fabio Martignon

Professore

- **Prof. Fabio Martignon**
- **Ufficio:**
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- **Tel: (035205) 2358**
- **E-mail: fabio.martignon@unibg.it**
- **Orario di ricevimento**
(previo appuntamento via mail):
 - Lunedì 13:30-15:30

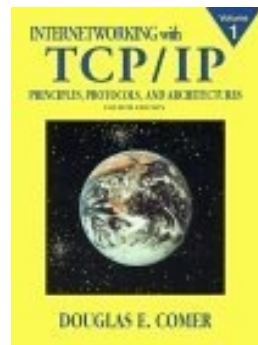
Teaching material

- **Book :**
- **Douglas E. Comer, *Internetworking with TCP/IP*, volume 1, Prentice Hall.**



6th edition

... but previous editions work as well (for example the 5th)



Teaching material

- Slides on the website
- Other documents signaled during the course on the course Web page
- Internet (RFCs ...)

- Web page:

<http://cs.unibg.it/martignon/indexRIM.html>

<http://193.204.253.55/martignon/indexRIM.html>

Course Agenda

- **Recap on the topics studied in FRT**
- **Access Technologies**
 - LAN protocols and devices
 - Multiplexing/Multiple Access techniques
 - ✓ Focus on: Cellular (Mobile) Networks
 - ✓ STP protocol
- **The Network Layer (Internet Protocol, IP)**
 - Routing in IP networks
 - Algorithms and protocols for routing (DV, Link State, RIP, OSPF, BGP)
- **Internet Evolution and Organization**

..Course Agenda..

- **The Transport Layer**
 - **Unreliable Transport, UDP**
 - **Reliable Transport, TCP**

- **Application Layer**
 - **Domain Name System (DNS)**
 - **File Transfer (FTP)**
 - **Web Browsing (HTTP)**
 - **E-mail (SMTP)**
 - **Peer to Peer Systems**

...Course Agenda

- **Wireless networks**
- **Internet of Things (IoT)**

- **Quality of Service**
- **Content Delivery Networks/Information Centric Networks (CDN/ICN)**
- **Voice Over IP**

Target

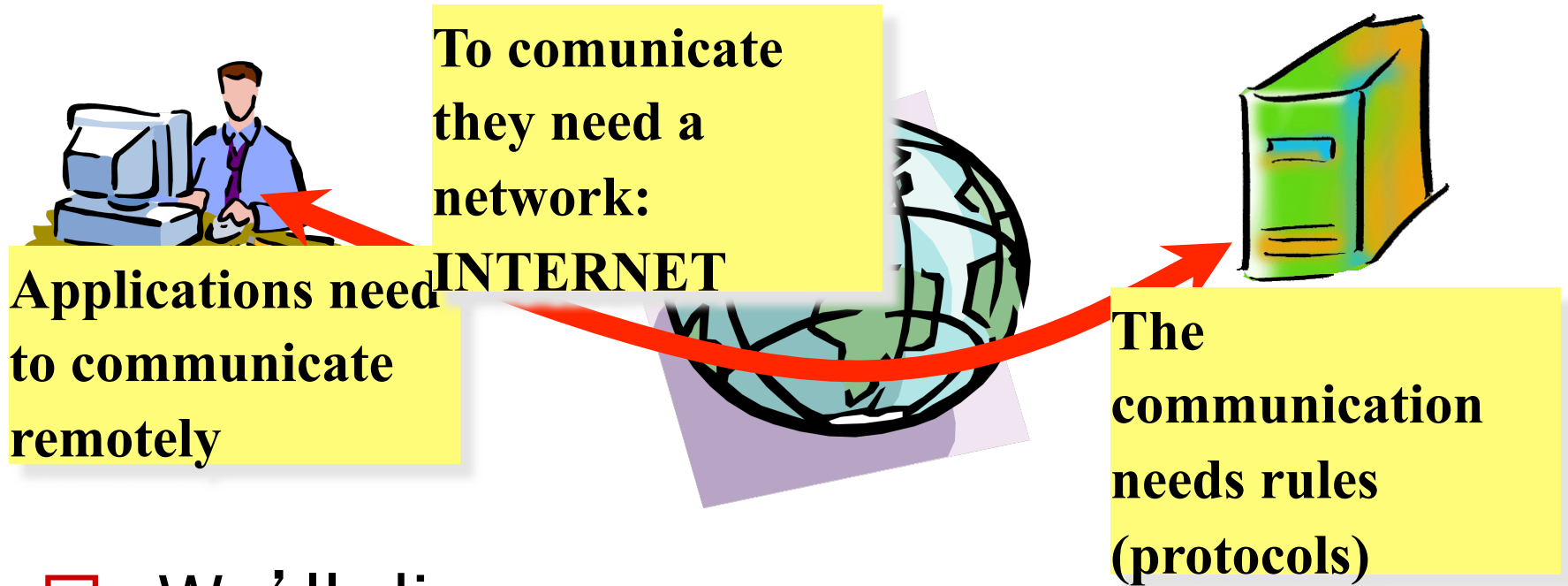
- To give you the basics of the

INTERNET



*Any ICT Engineer **MUST**
know the **INTERNET***

Background

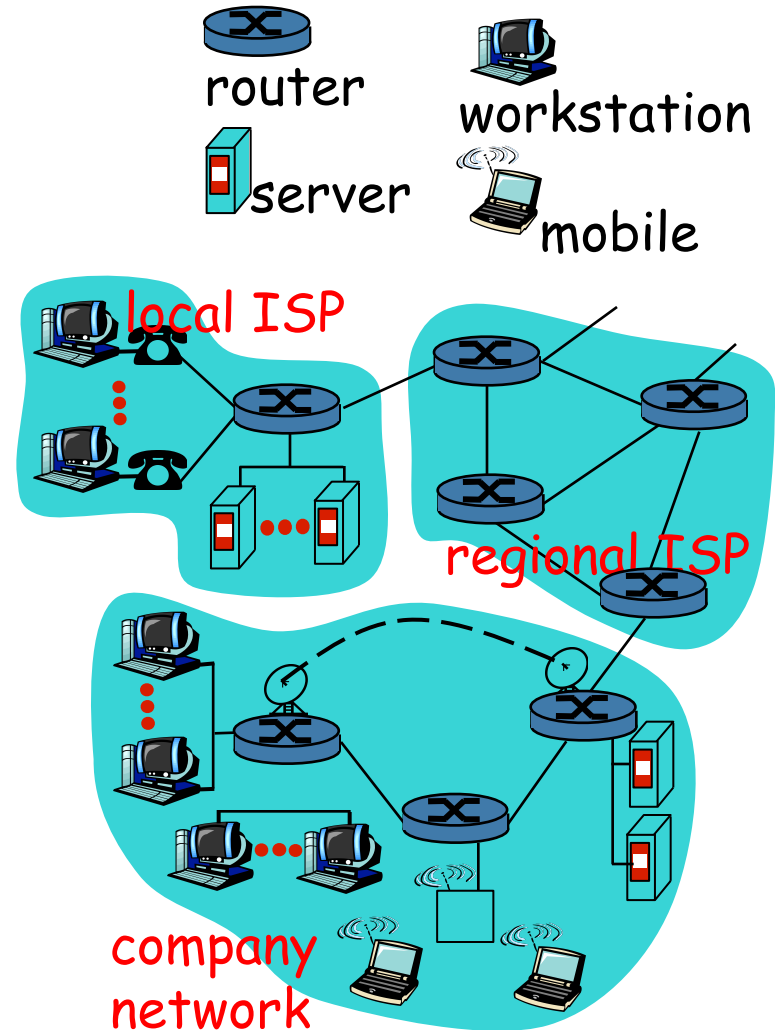


- We'll discuss on:
 - Communication Protocols
 - Internet Network infrastructures and devices

What is The Net?

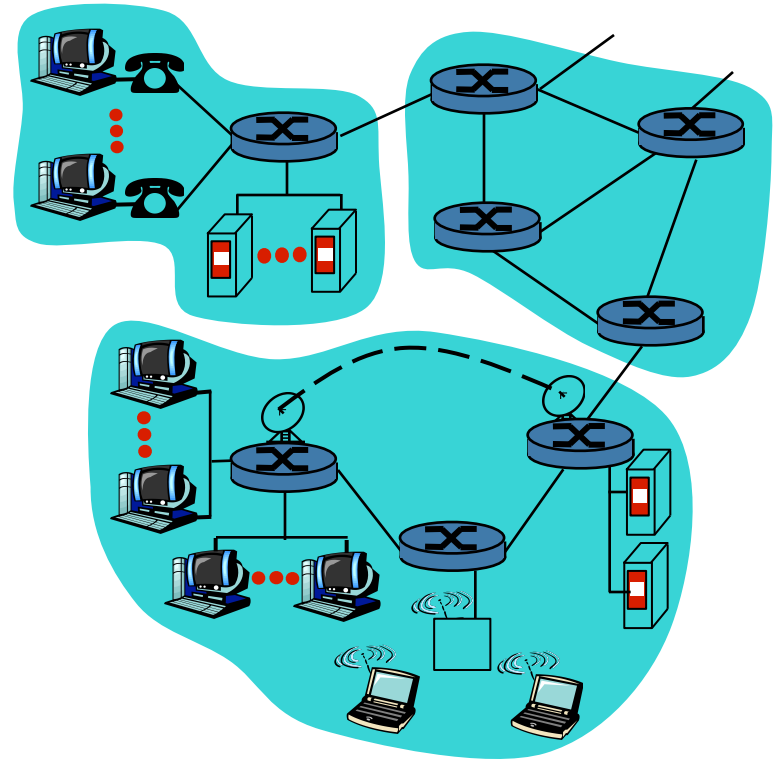
What's Internet?

- Millions of computers connected named *hosts* = terminals
- Applications running on hosts
- Links (fibers, cables, wireless, satellite)
- Network devices, named *routers*



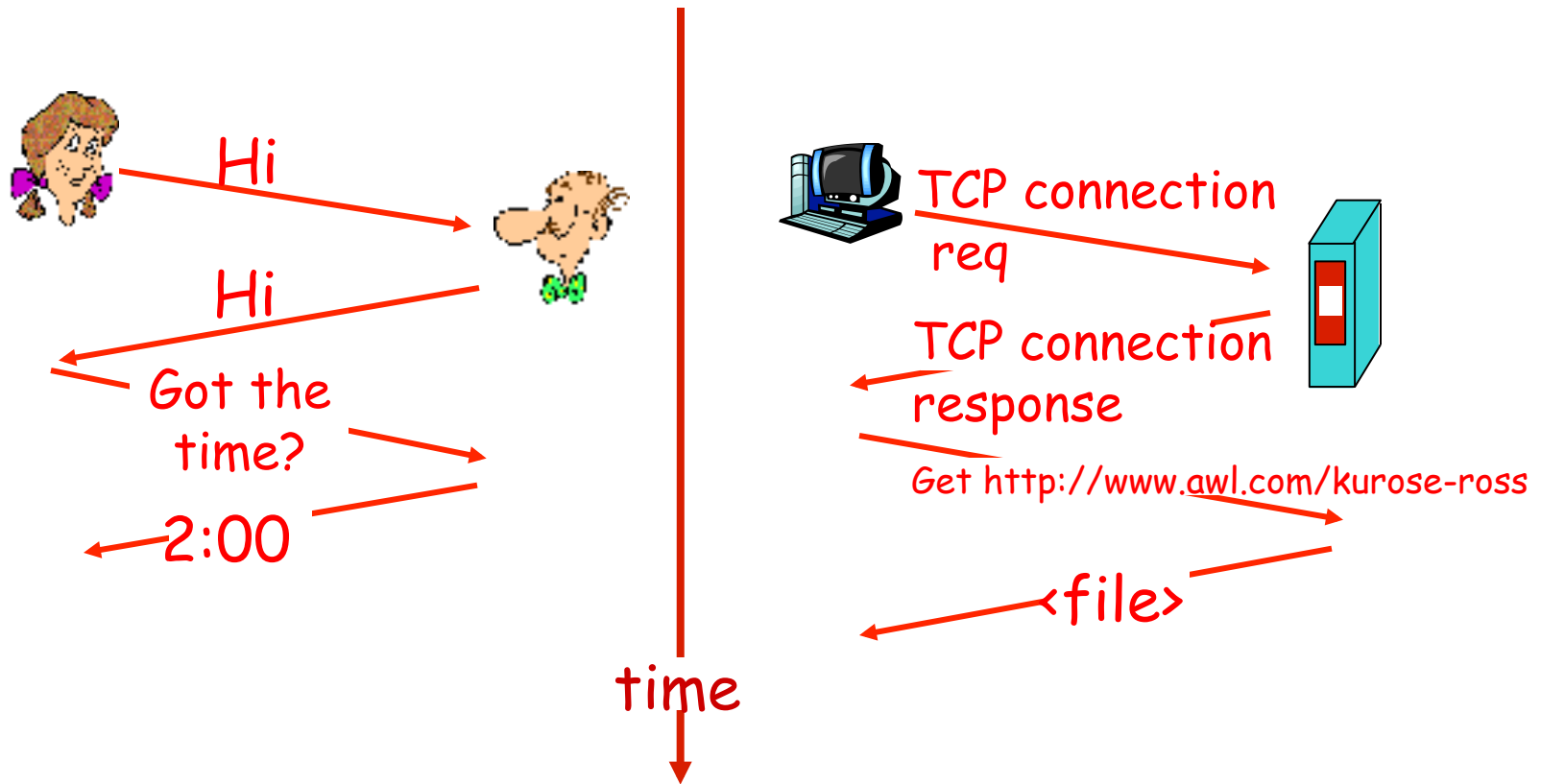
What's Internet?

- Communication Infrastructure to let applications talk
 - Web, email, games, e-commerce, file sharing
- Communication protocols to send/receive messages



What's a protocol?

a human protocol and a computer network protocol:

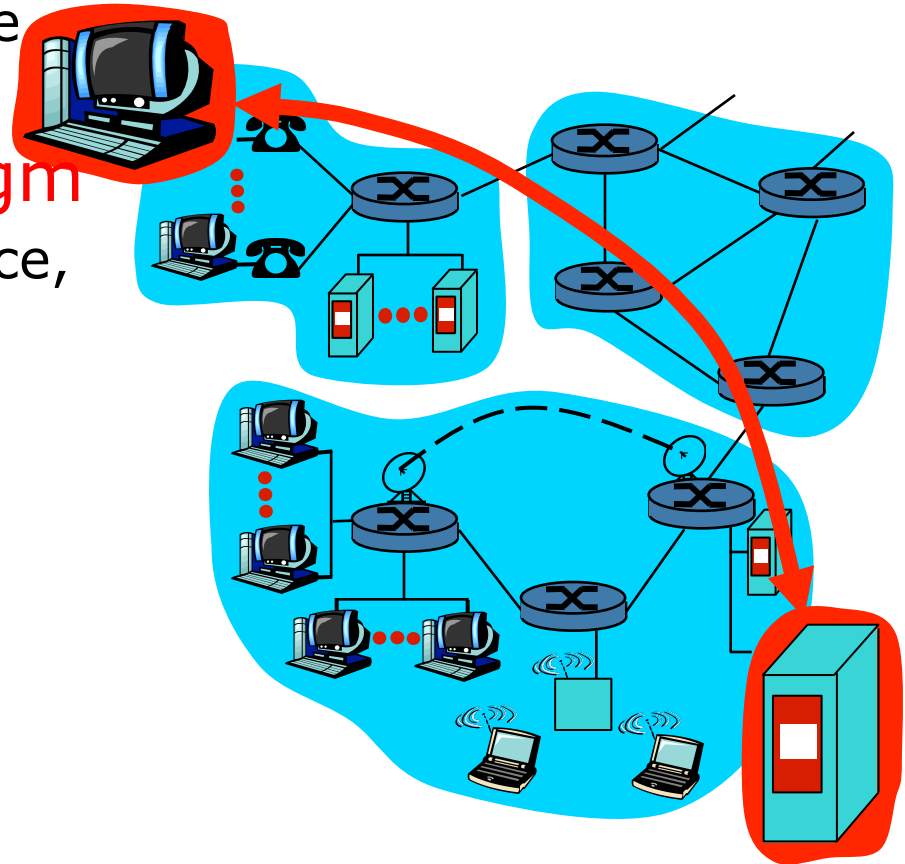


Source: **Computer Networking: A Top Down Approach Featuring the Internet**, Jim Kurose, Keith Ross, Addison-Wesley, July 2004.

All material copyright 1996-2004. J.F Kurose and K.W. Ross, All Rights Reserved

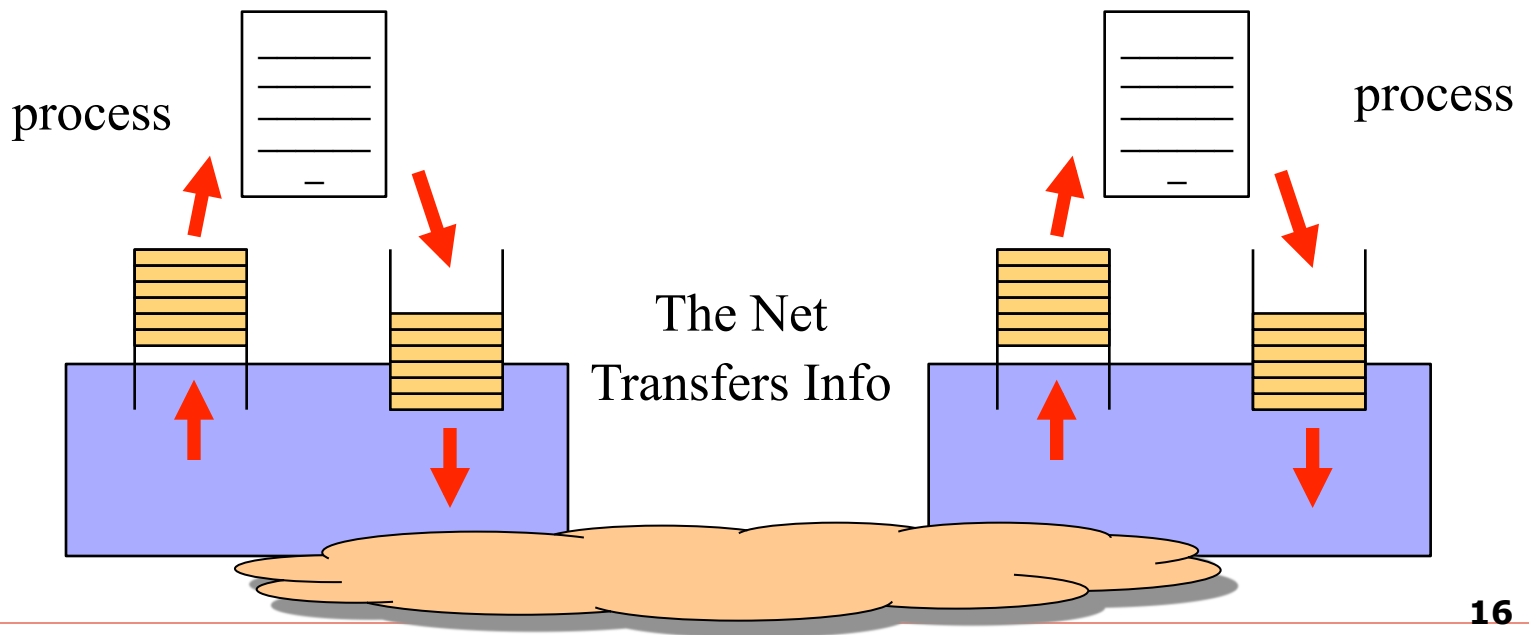
At the Edges of The Internet

- **Terminals (hosts):**
 - Run application software (Web, email, ecc.).
- **Client/server Paradigm**
 - clients request for service, servers provide it
 - Clients issue requests, servers issue responses
- **Peer-to-peer:**
 - No strict distinctions
 - Flat architecture



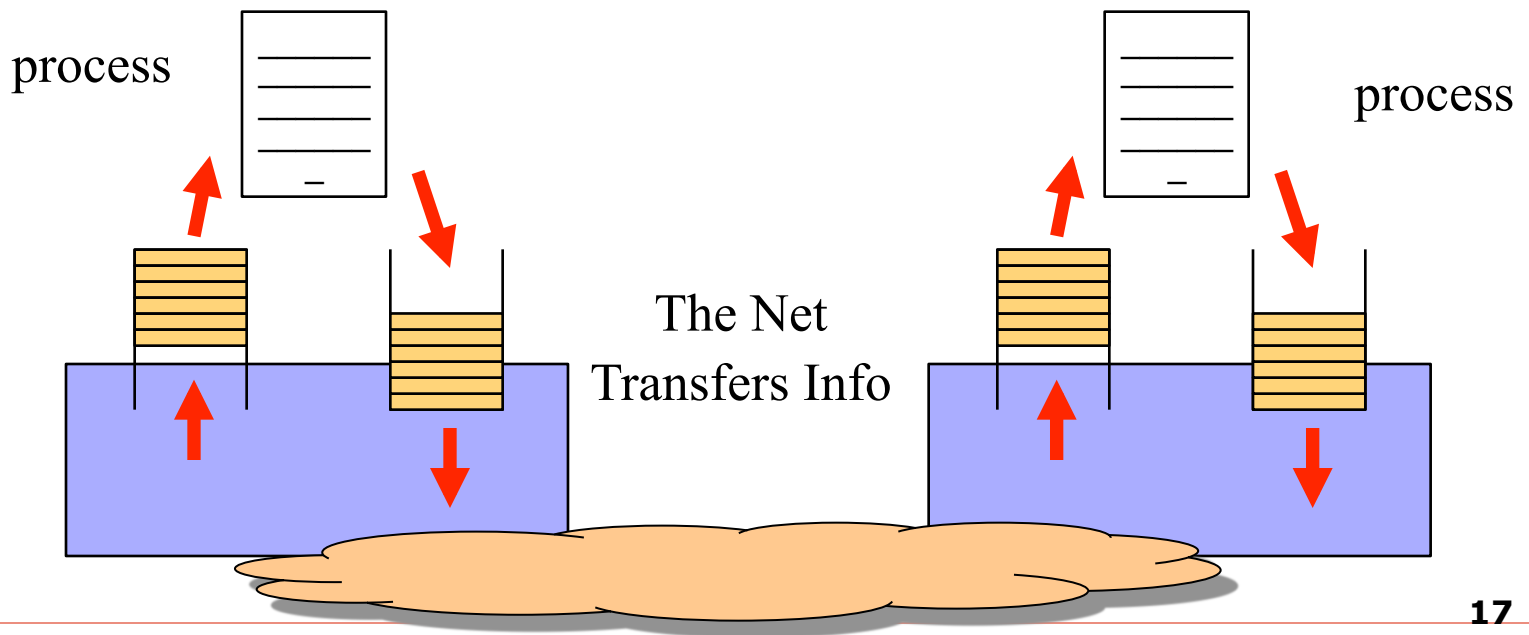
Applications over The Net

- The Net provides a *communication service* to *transport* information among remote processes
- The type of transfer provided by The Net may be of various kinds



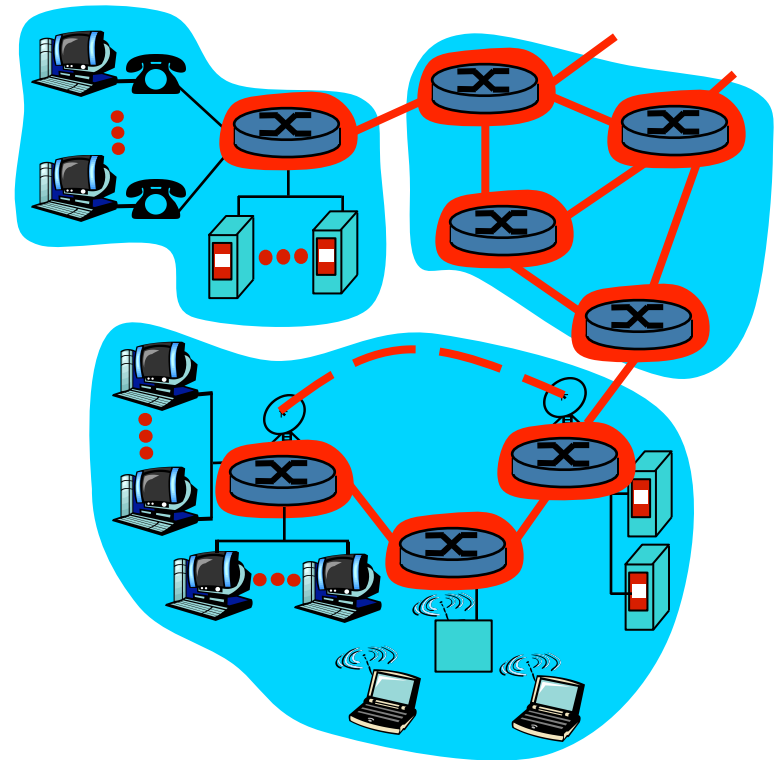
Types of Transport

- Short messages, unreliable (e.g. DNS, signaling, etc.)
- Reliable byte streaming (web, email, file transfer, etc.)



Network Core

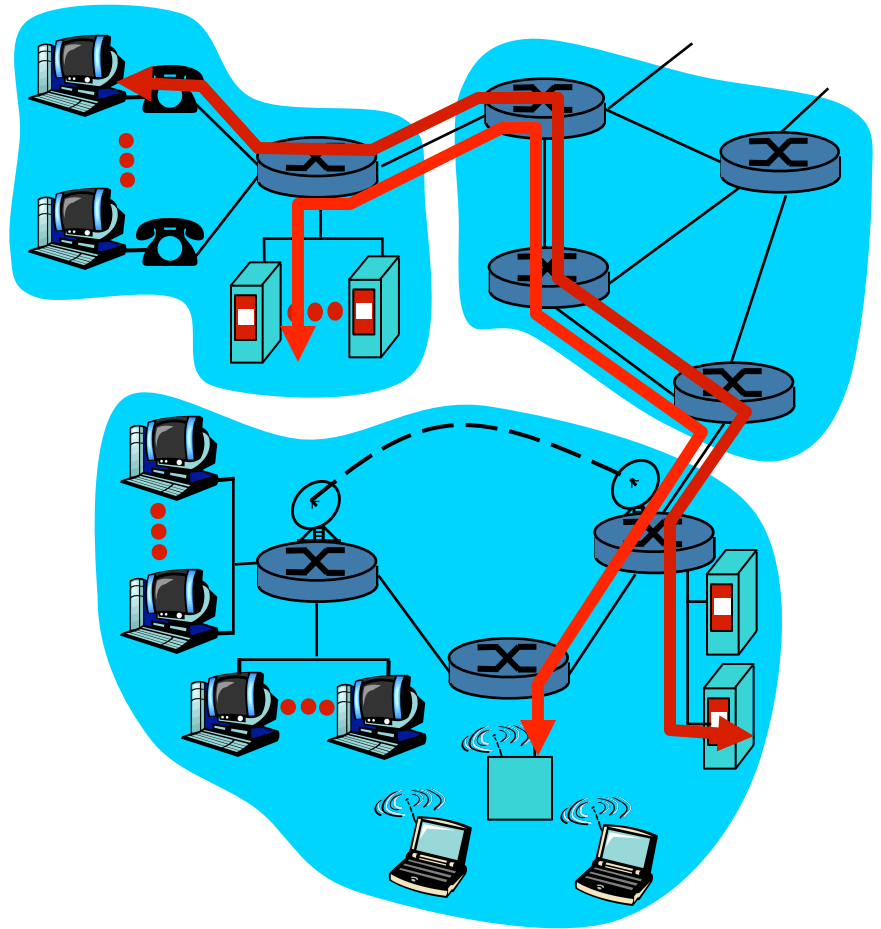
- Bunch of Interconnected routers
- How to transfer information?
 - **Circuit Switched communication:** each call is assigned a circuit
 - **Packet Switched communication:** info divided into messages



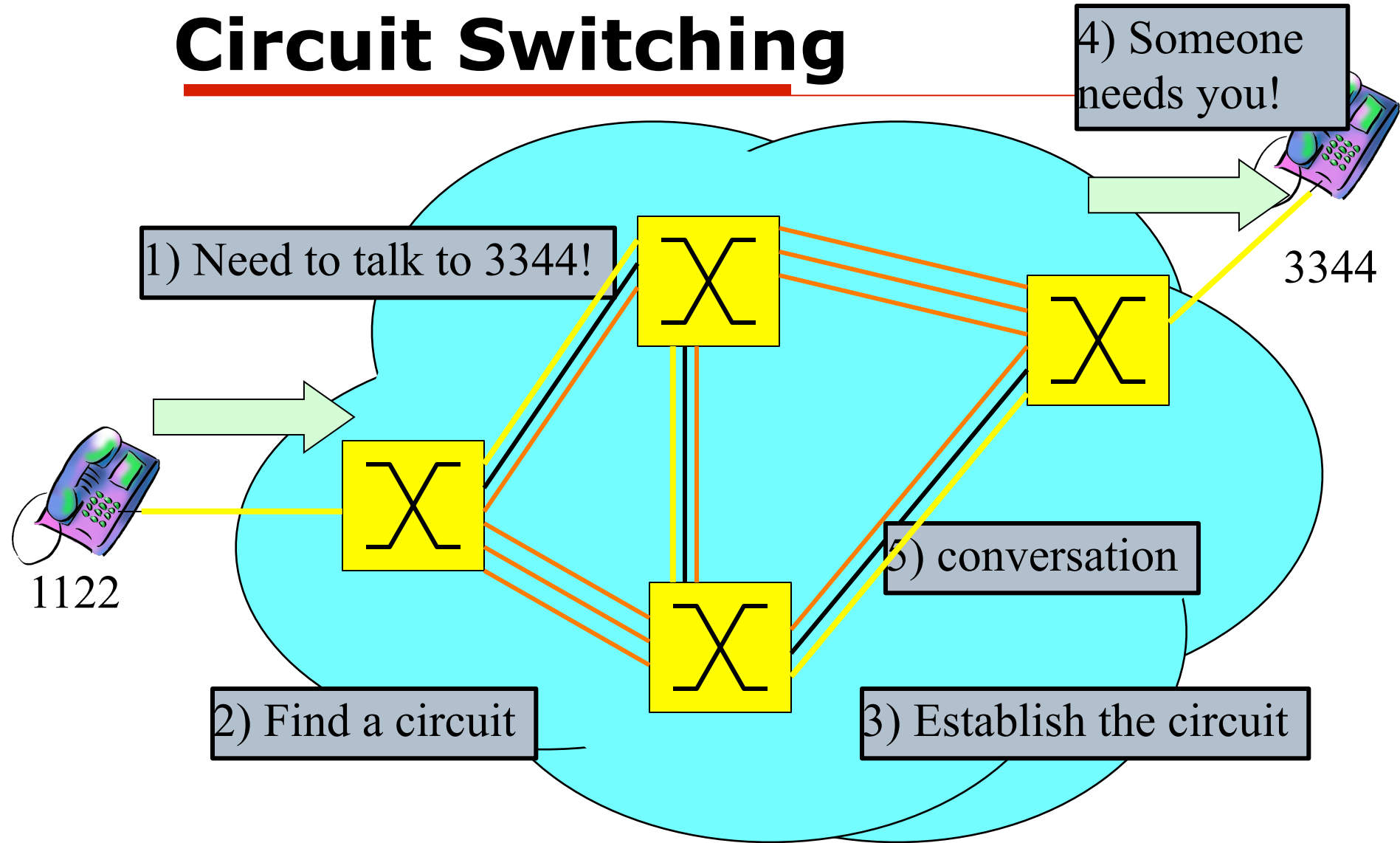
Circuit Switching

Communication resources are reserved on call basis

□ E.g. PSTN



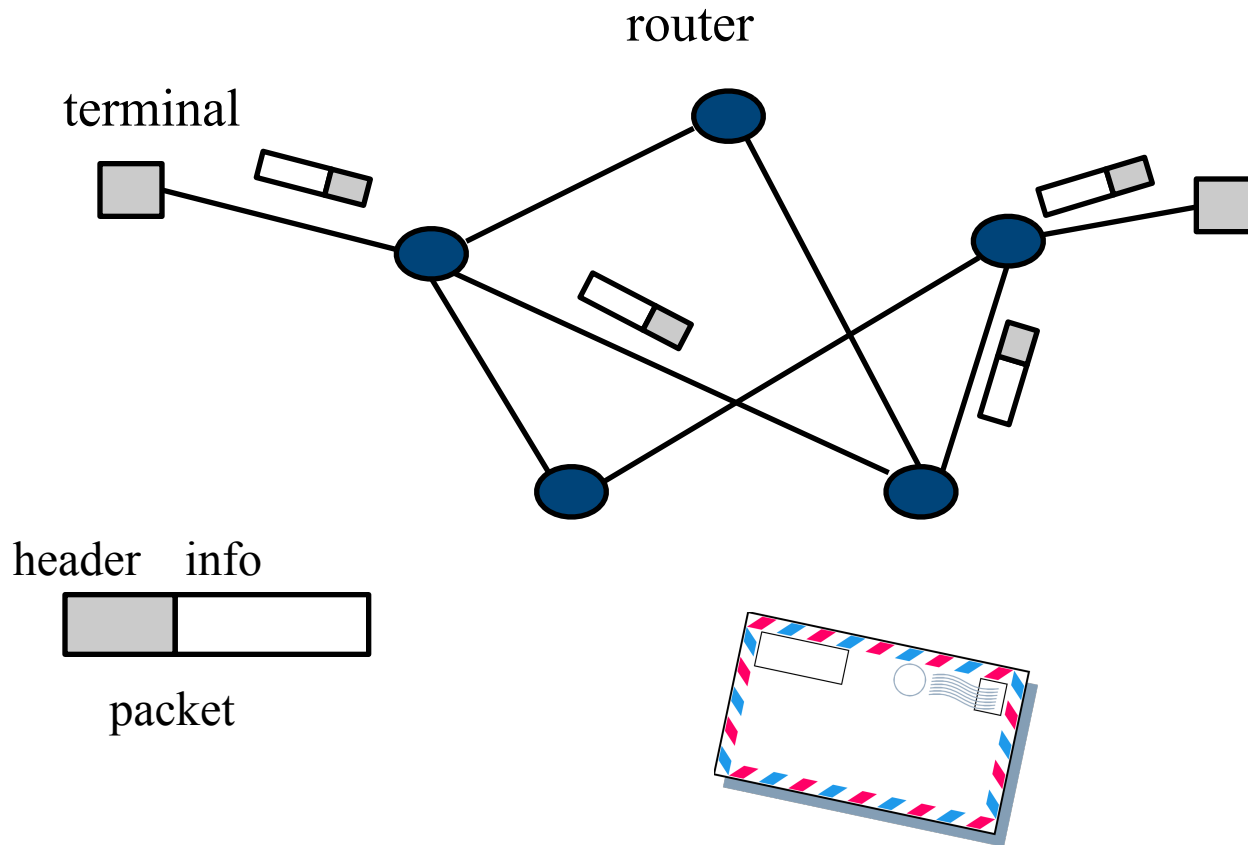
Circuit Switching



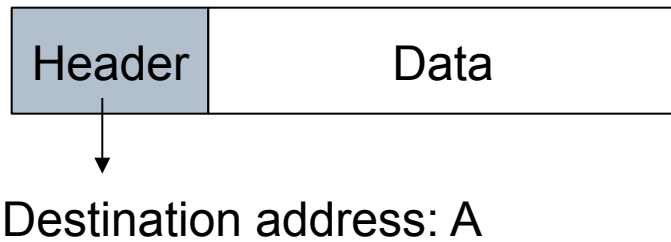
Circuit Switching

- Network resources **divided into “circuits”**
- each circuit is statically assigned to communications
- Assigned circuit stays idle if not used (*lack of sharing*)
- Circuits can be built through:
 - Time division
 - Frequency division
 - Code division

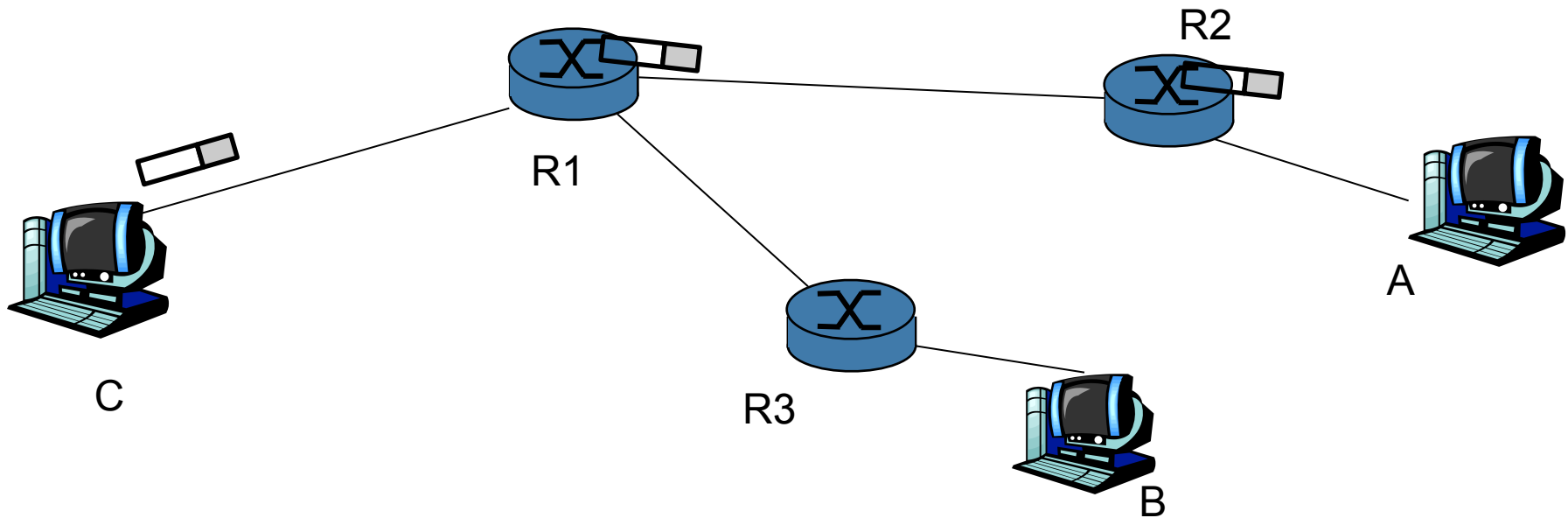
Packet Switching



Packet Switching



Routing Table	
dest.	Next router
A	R2
B	R3



Packet Switching

Data Flow split up in packets

- Packets from different flows share the network resources
- Each packet fully utilizes the channel
- Network resources are used according to current needs

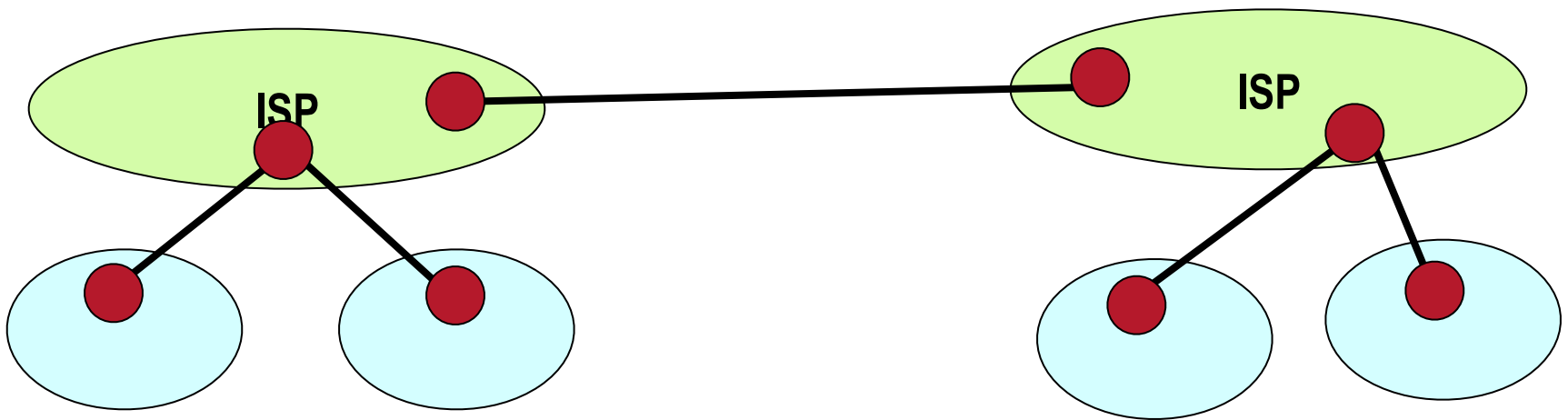
Resource Contention

- **store and forward:** each packet must be completely received before starting the transmission on the outgoing link
- **Statistical Multiplexing:** packet queuing, waiting time to use the link

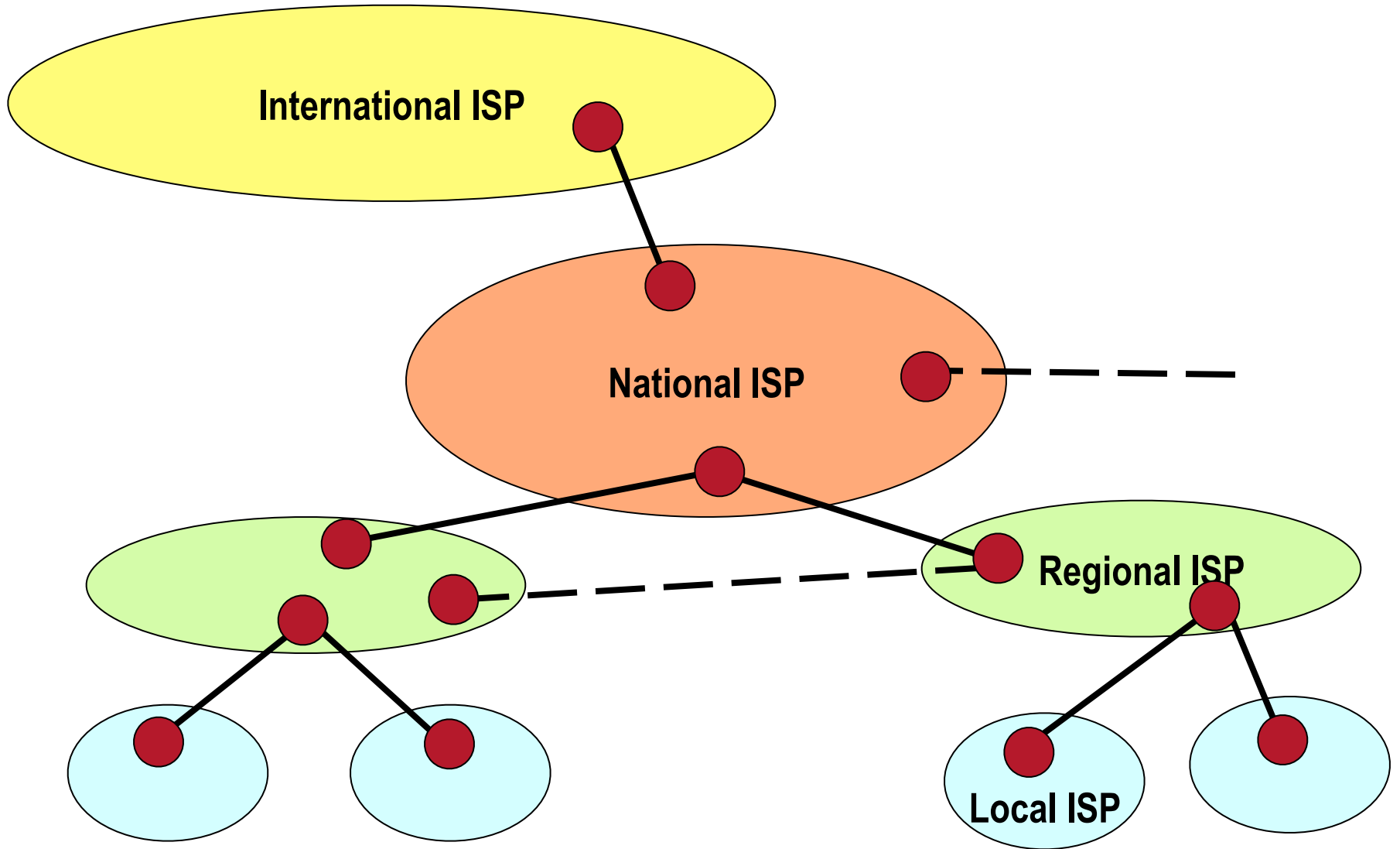
Internet Architecture and Access Technologies

General Architecture

- *Internet Service Providers (ISP)* provide connectivity (AOL, Orange, Free, etc.)
- ISPs share a common backbone

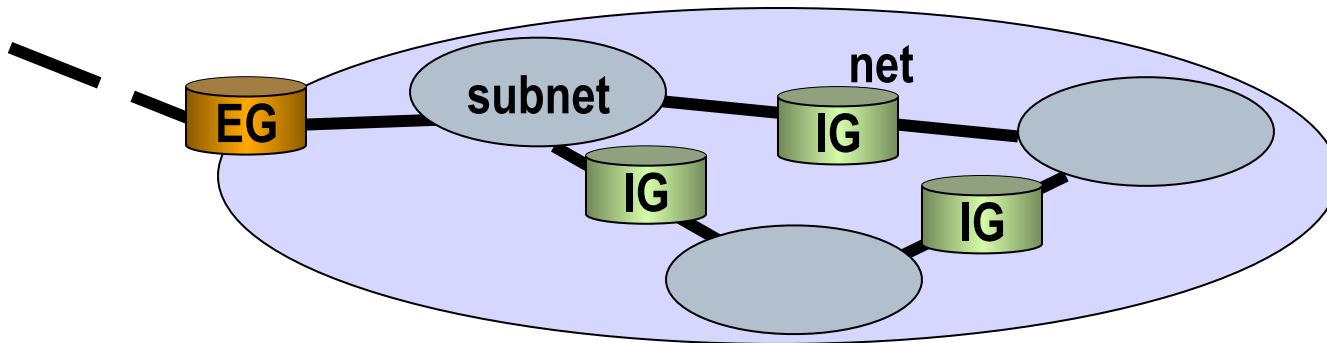


Internet Hierarchy



Internet Taxonomy

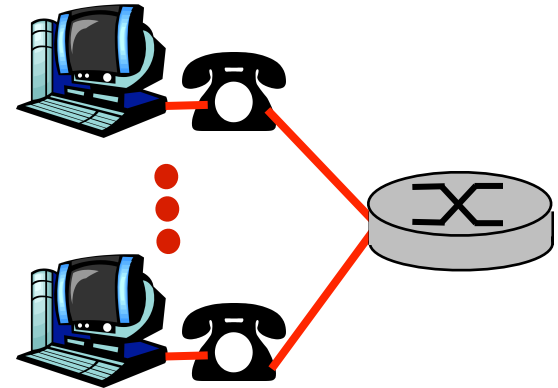
- The IP Network managed by a single organization is called *Autonomous System (AS)*
- TCP/IP are often used even in private networks (companies, campus nets, etc.) called *Intranets*
- The routers belonging to a given AS are *Interior Gateway (IG)*, whereas the routers connecting different ASs are *Exterior Gateway (EG)*



Access to the Internet

□ Dialup

- Direct access to ISP router through PSTN

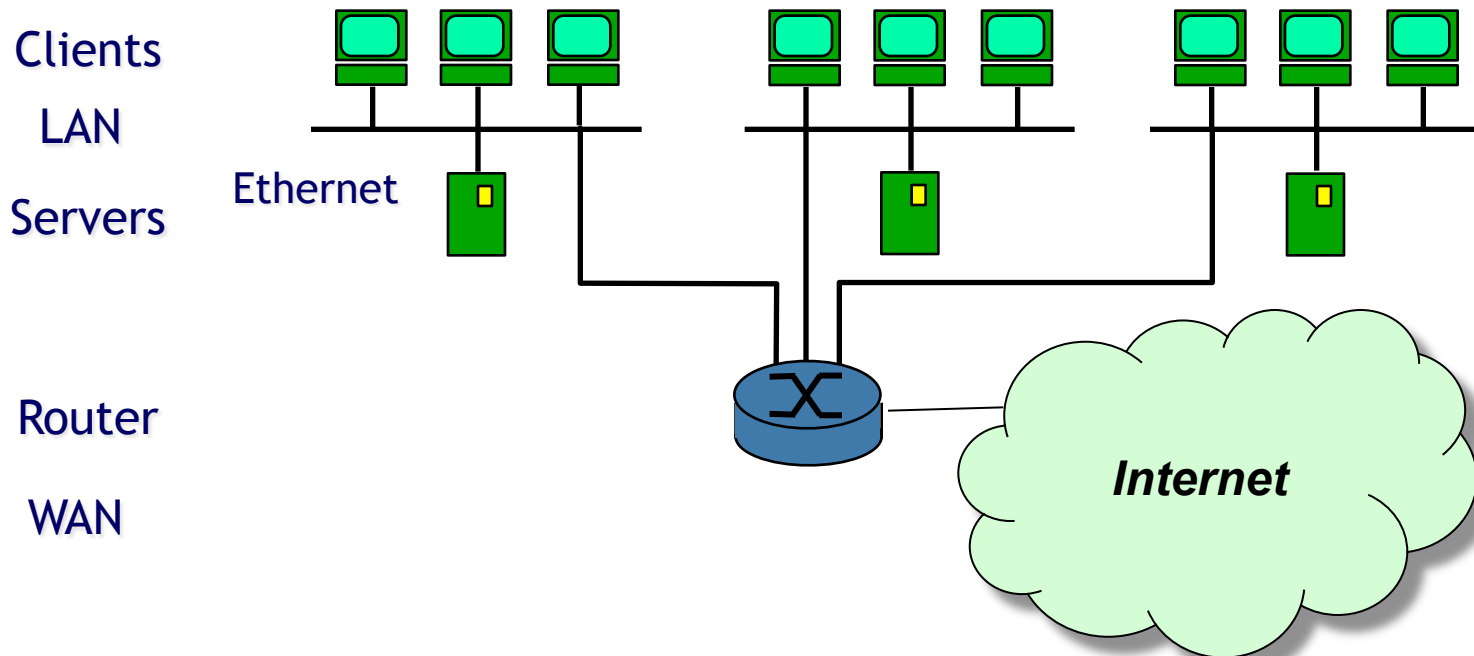


□ ADSL: asymmetric digital subscriber line

- UTP shared with PSTN till the first Switching Point (frequency division)
- Access to ISP router through fast data network

Access to the Internet

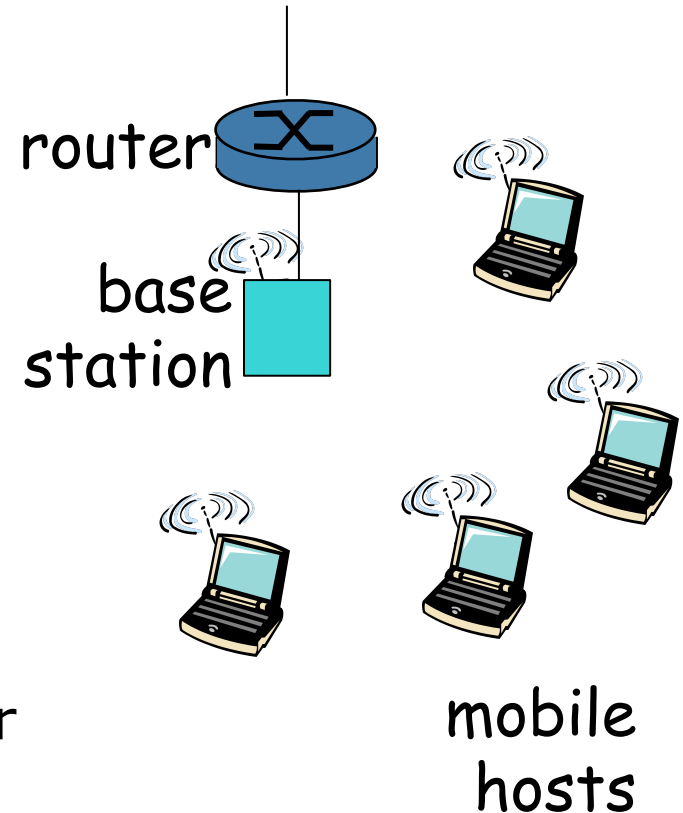
- Local Networks
 - Local Area Network (LAN) link between terminals and routers
 - Ethernet: 10 Mbs, 100Mbps, Gigabit Ethernet



Access to the Internet

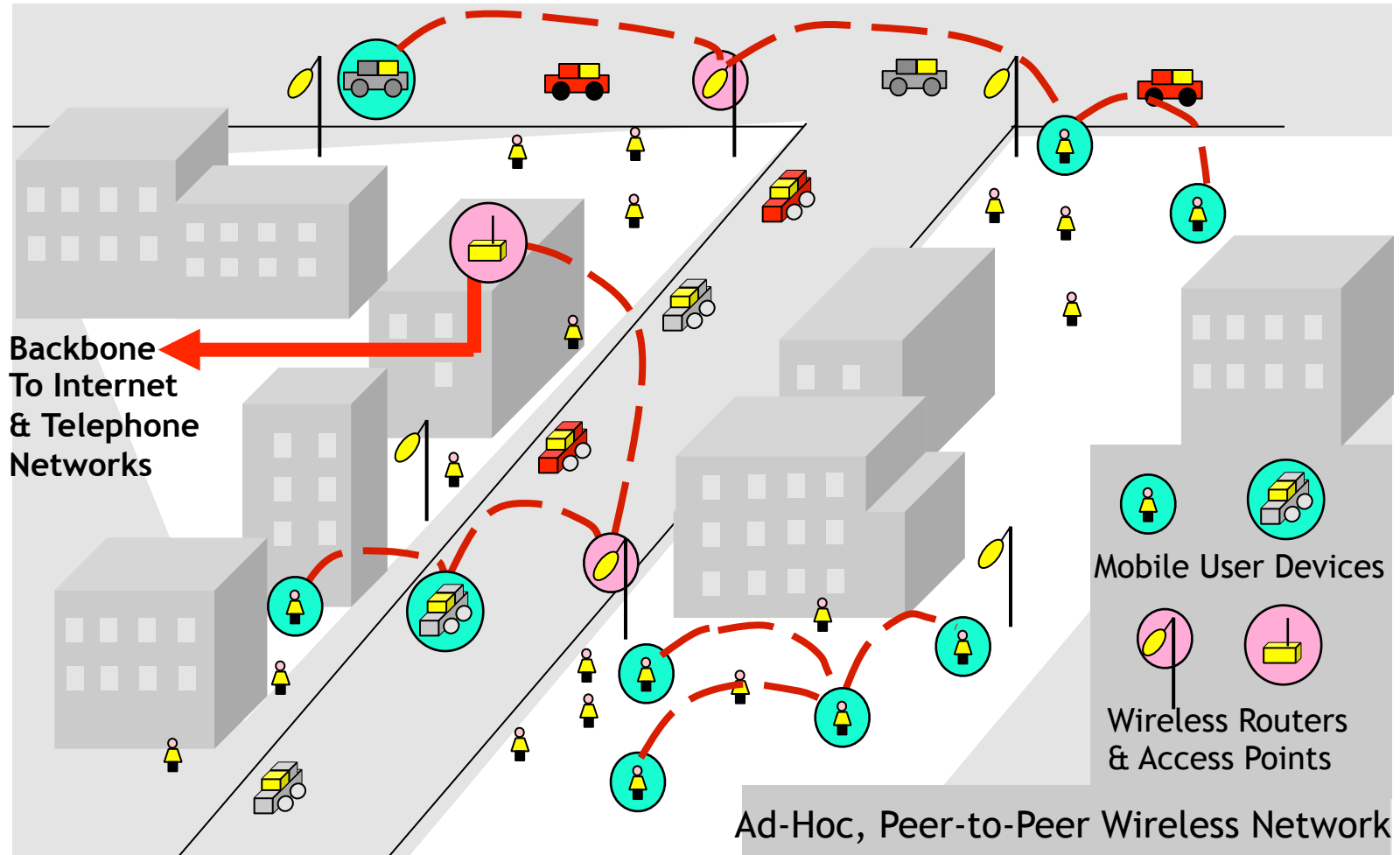
- Wireless Access
 - Wireless LAN:
 - Cellular Systems
 - GSM
 - GPRS
 - EDGE
 - UMTS
 - WiMAX
 - LTE ...

Access through a base station or access point



Pervasive Internet

Mesh & Ad hoc Networks



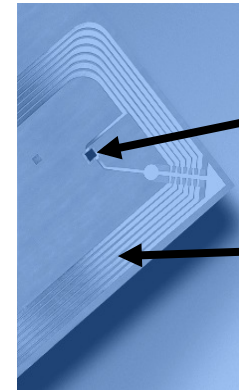
Distributed Networking

Pervasive Internet

Wireless Sensor Networks

- Small, light, cheap network nodes able to:
 - Measure
 - Communicate
 - Act

- Applications
 - Embedded computing: e.g. home appliances
 - wearable computing: e.g. mp3 players, PDAs
 - Ambient intelligence: e.g. sensors/actuators

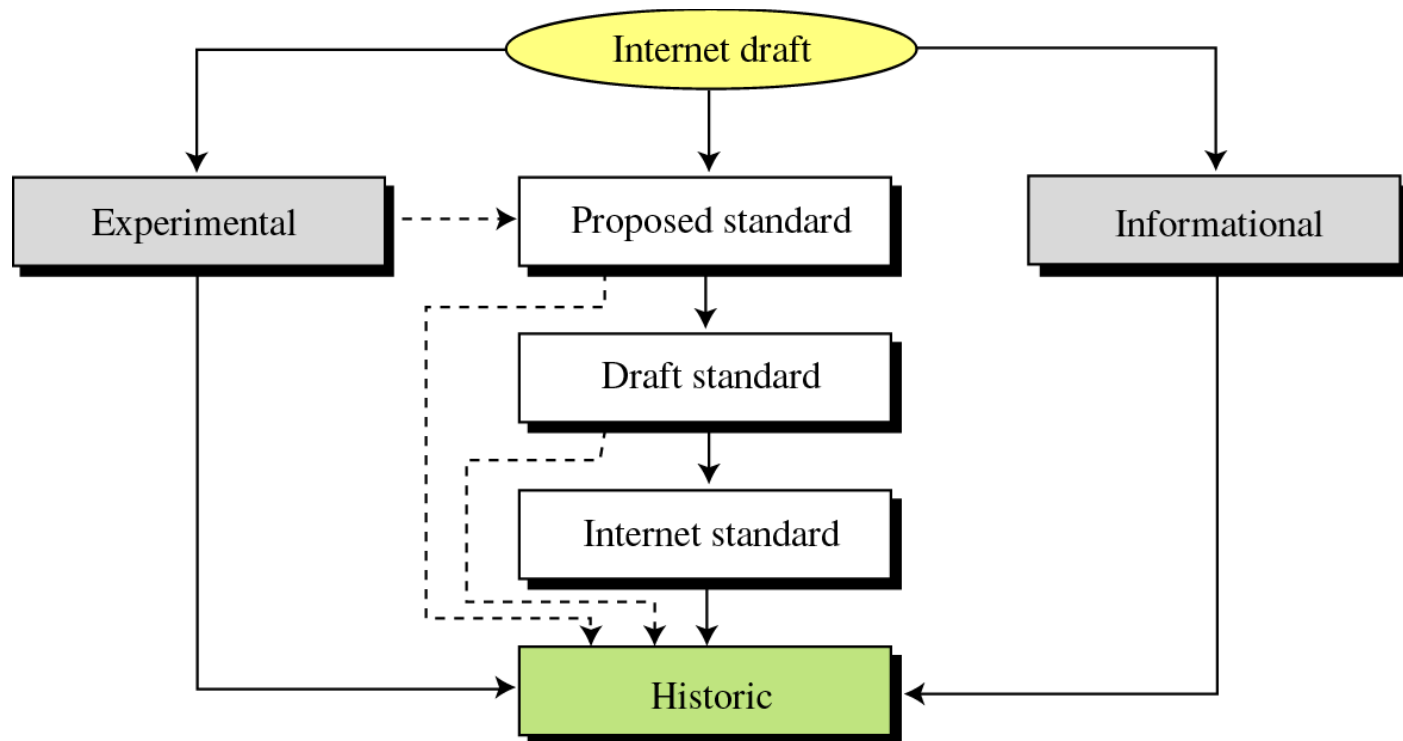


Chip

Antenna

Internet Standardization

- ❑ Internet Standards are public documents called **RFC** (*Request For Comments*)
- ❑ The *Internet Engineering Task Force* (IETF) coordinates the RFC publication



How to Get a Standard



The screenshot shows the IETF Home Page in Mozilla Firefox. The browser window title is "IETF Home Page - Mozilla Firefox". The address bar shows "http://www.ietf.org/index". The page features a search bar with a "Go" button and a link to "IETF Mirror Sites". The IETF logo is prominently displayed, consisting of a stylized yellow and grey graphic above the letters "I E T F". Below the logo, the text "The Internet Engineering Task Force" is centered. A list of links is provided, including "Overview of the IETF", "The Internet Standards Process", "IETF Working Groups", "WG Chairs Web Page", "Internet-Drafts", "RFC Pages", "Educational Materials", "IESG Activities/Actions", "Meetings", "65th IETF - Dallas, TX, USA (March 19-24, 2006)", "Proceedings", "IETF Liaison Activities", "IETF IPR Disclosure Page", and "The NomCom".

IETF Home Page - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.ietf.org/index

Search Teaching Papers Research projects Technical topics News Personals My pages Useful links Other links PC & PDA

IETF Search:

Go

[IETF Mirror Sites](#)



I E T F

The Internet Engineering Task Force

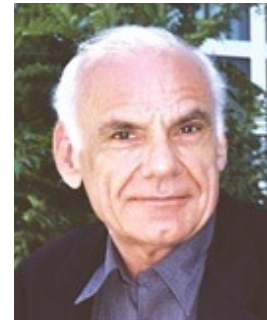
- [Overview of the IETF](#)
- [The Internet Standards Process](#)
- [IETF Working Groups](#)
- [WG Chairs Web Page](#)
- [Internet-Drafts](#)
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 - ★ [65th IETF - Dallas, TX, USA](#)
(March 19-24, 2006)
- [Proceedings](#)
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- [IETF IPR Disclosure Page](#)
- [The NomCom](#)

Done

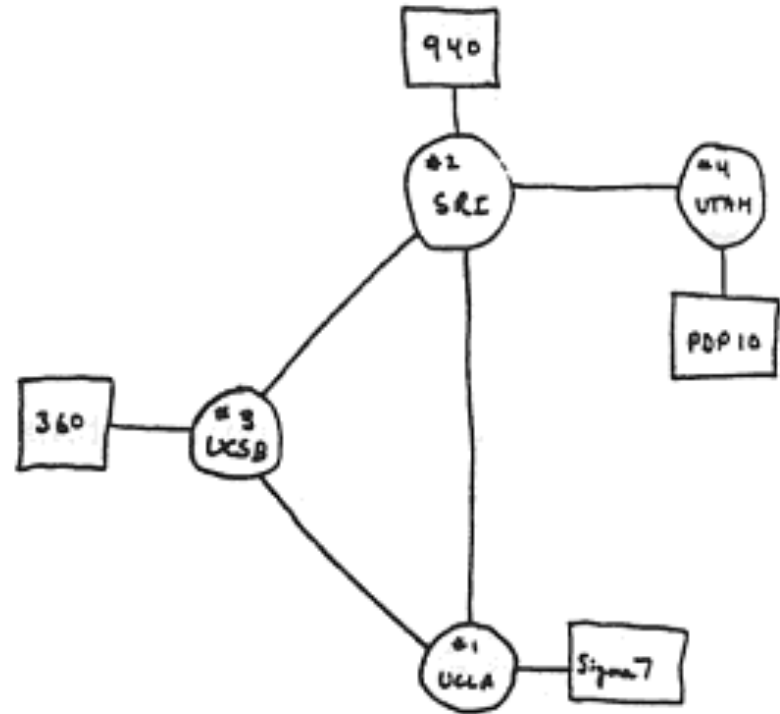
Internet Evolution

Internet Birth Days: The '60s

- **1961:** Kleinrock – applies queuing theory to packet switched networks proving its efficiency
- **1967:** Lawrence Roberts designs ARPAnet (Advanced Research Projects Agency)
- **1969:** first ARPAnet node IMP (Interface Message Processor) deployed at UCLA



A Bit of History

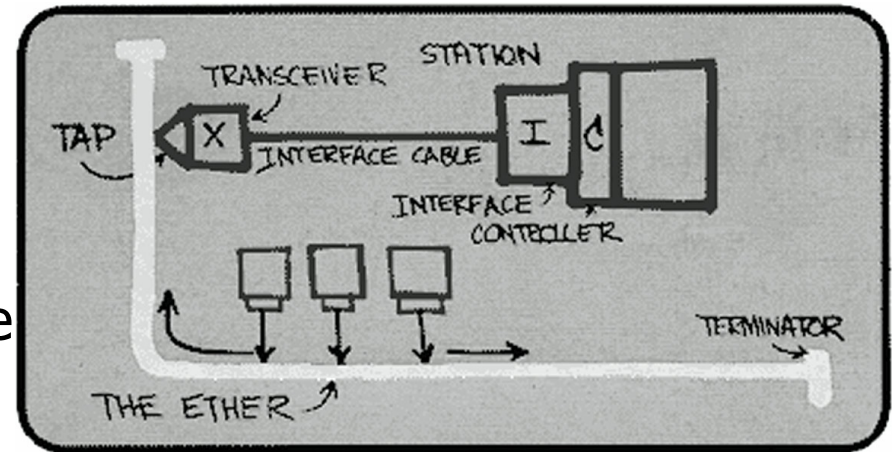


THE ARPA NETWORK

DEC 1969

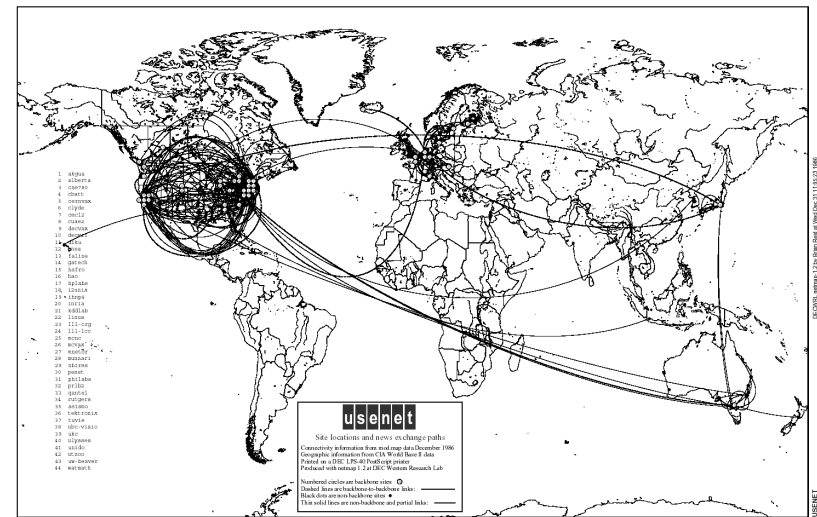
Internet Birth Days: The '70s

- **1972:**
 - NCP (Network Control Protocol) first internet protocol
 - First email application
 - ARPAnet has 15 nodes
- **1970:**
 - ALOHAnet packet switched network at Univ. of Hawaii
- **1974:**
 - Cerf and Kahn -study the internetworking principles (Network of Networks)
- **1976:**
 - Ethernet birth at Xerox
- **1979:**
 - ARPAnet has 200 nodes



Internet Birth Days: The ' 80s

- **1982:** SMTP protocol definition
- **1983:** TCP/IP replace NCP
- **1983:** DNS definition
- **1985:** FTP definition
- **1988:** TCP congestion control
- New national nets: Csetnet, BITnet, NSFnet, Minitel
- 100.000 hosts worldwide



The First Applications

□ Telnet

□ Email

The screenshot shows a Telnet session window titled 'TELNETPM.EXE' and an email message window titled 'PINE 4.64 MESSAGE TEXT'. The Telnet session shows a login for 'laizitse' on a 'UNIX(r) System V Release 4.0' machine. The email message is from Chase Venters to Tim Tassonis, with the subject 'Re: State of the Union: Wireless'. The email content discusses a management style document and a 'right' direction. The screenshot also shows a PuTTY window titled 'pinky.notnet.co.uk - PuTTY' connected to 'dante.ukc.ac.uk', displaying a welcome message and instructions for using the FTP gateway. The PuTTY window shows the prompt 'Name (ftp-gw.ukc.ac.uk:ph2):' with a cursor.

TELNETPM.EXE
Connection Edit Commands Opt

UNIX(r) System V Release 4.0 (sununx.iscs.nus.sg)
login: laizitse
Password:
Last login: Tue Jun 20 23:3

PINE 4.64 MESSAGE TEXT <Baythorne> lists.1-k Msg 3,804 of 3,818 44% NEW

Date: Tue, 10 Jan 2006 08:16:26 -0600
From: Chase Venters <chase.venters@clientec.com>
To: Tim Tassonis <timtas@cubic.ch>
Cc: linux-kernel@vger.kernel.org
Subject: Re: State of the Union: Wireless

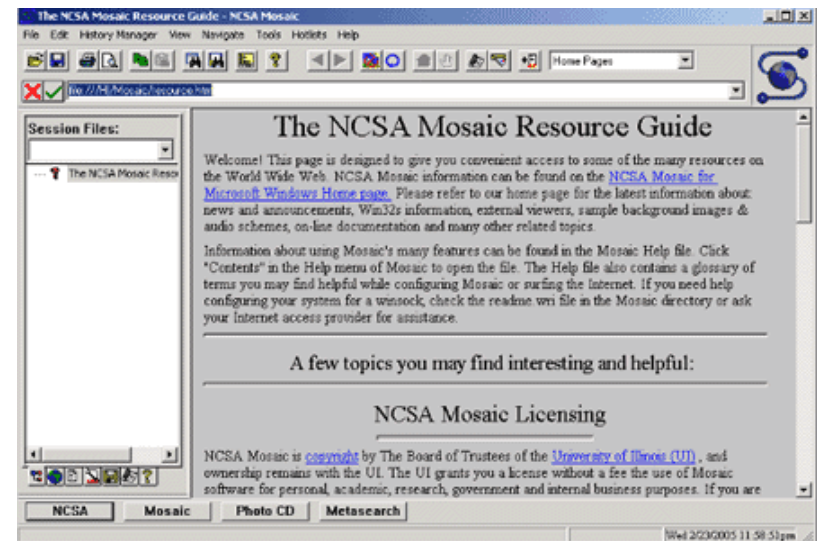
On Tuesday 10 January 2006 06:38, Tim Tassonis wrote:
> This is exactly the opposite of what Linus proposes in his management
> style document: "Avoid making decisions". At the moment, nobody seems to
> know what the "right" direction is, because the right direction is the
the one that
at some point),
ere.
whine "can't
f it's not
t out. The
lete R Reply
delete F Forward

pinky.notnet.co.uk - PuTTY
Connected to dante.ukc.ac.uk.
220-*****
220-* Welcome to the University of Kent FTP gateway *
220-*****
220-
220-Unauthorized access is a criminal offence under the
Computer Misuse Act 1990
220- If you are not an authorised user, disconnect NOW
220-
220-To connect to a server use username@site as a login
name in response to the 'Name:' prompt, eg. -
(anonymous@ftp.somewhere.ac.uk)
220-
220 *****
Name (ftp-gw.ukc.ac.uk:ph2):

□ FTP

Internet Birth Days: The '90s

- **1990**: ARPAnet discontinued
- **1991**: NSFnet to be used for commercial purposes also
- Early 90s: Tim Berners-Lee invents the web (Cern, Geneve)
- **1994**: Mosaic, and Netscape
- Late 90s : Web is invaded by commercials



Internet Today

2000 – today:

- ❑ New “killer applications”: messaging, file sharing, IP Telephony
- ❑ Network security
- ❑ Hundreds of Millions of host, Billions of users
- ❑ Fastest Backbones [Gb/s]

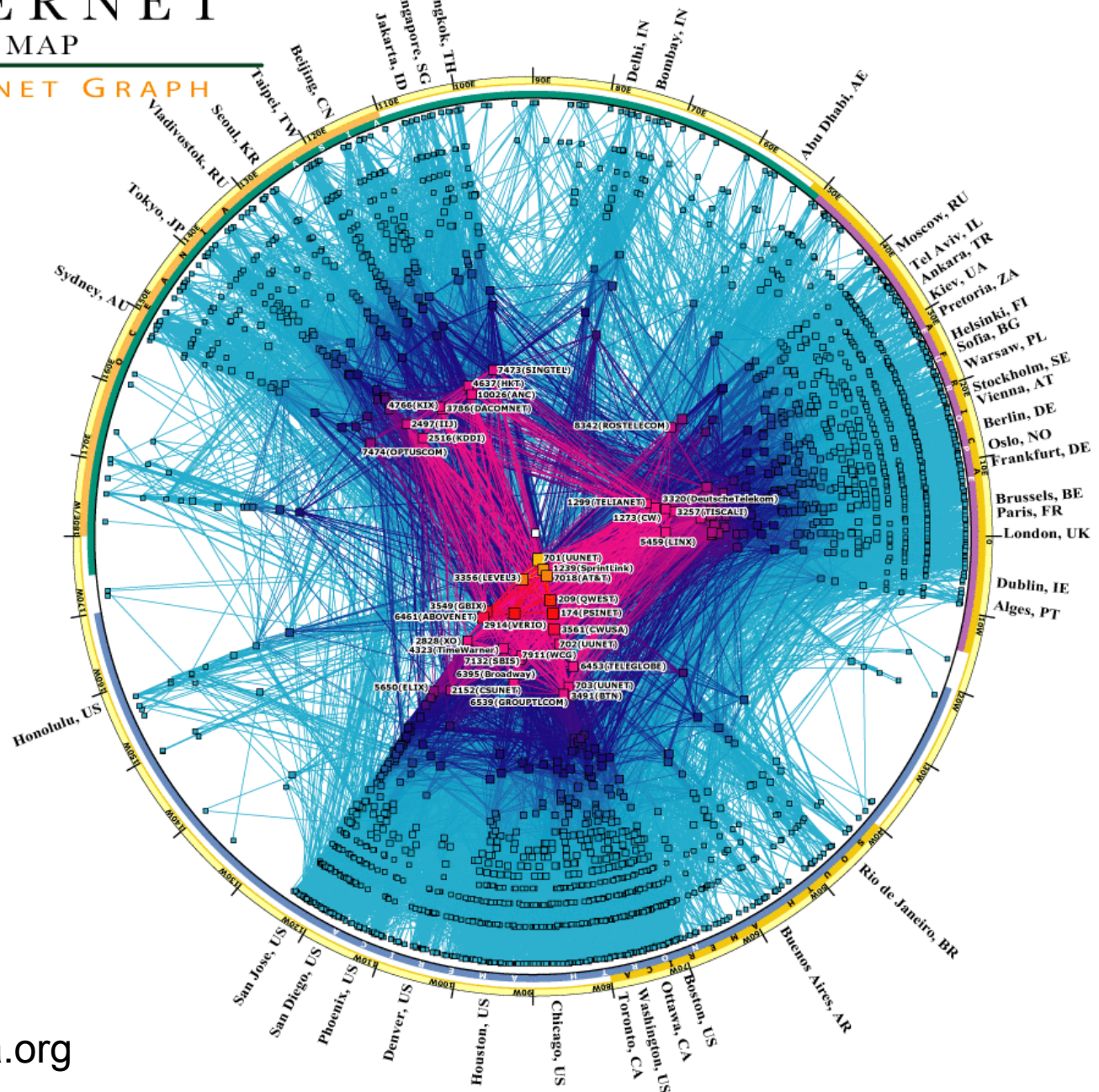
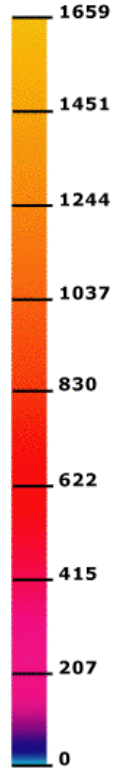


IPv4 INTERNET TOPOLOGY MAP

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AS-level INTERNET GRAPH

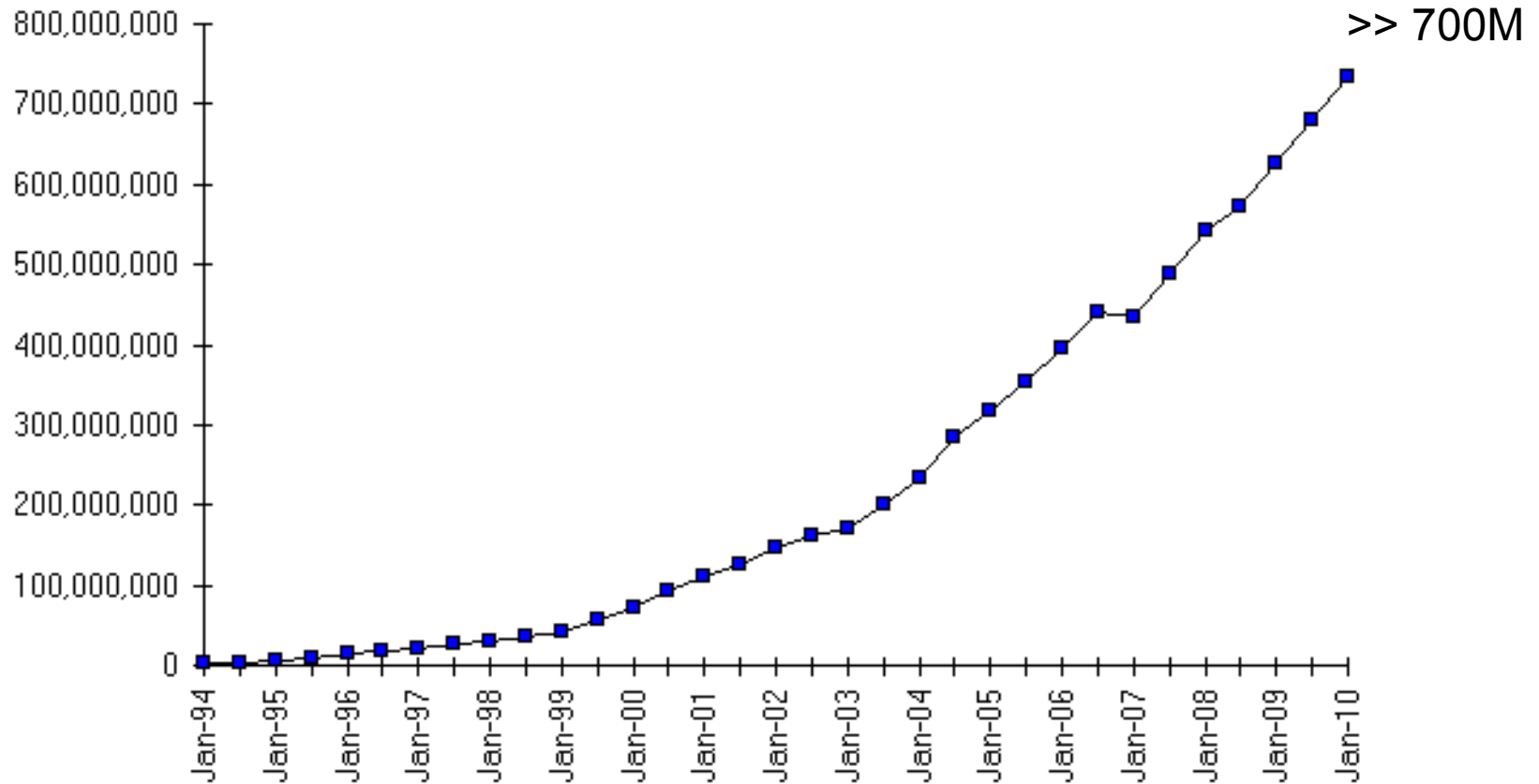
Peering:
OutDegree



<http://www.caida.org>

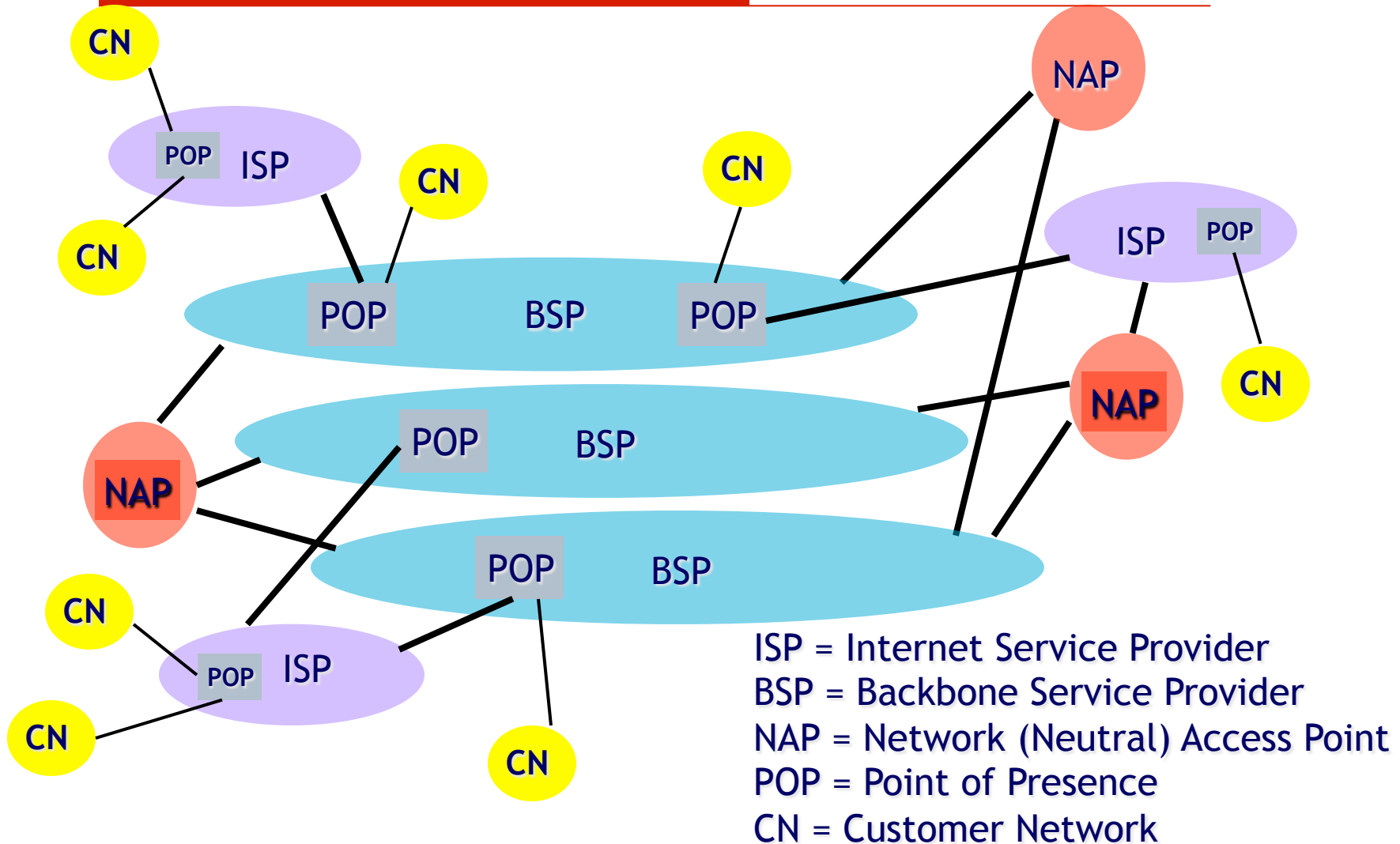
Internet Growth

Internet Domain Survey Host Count

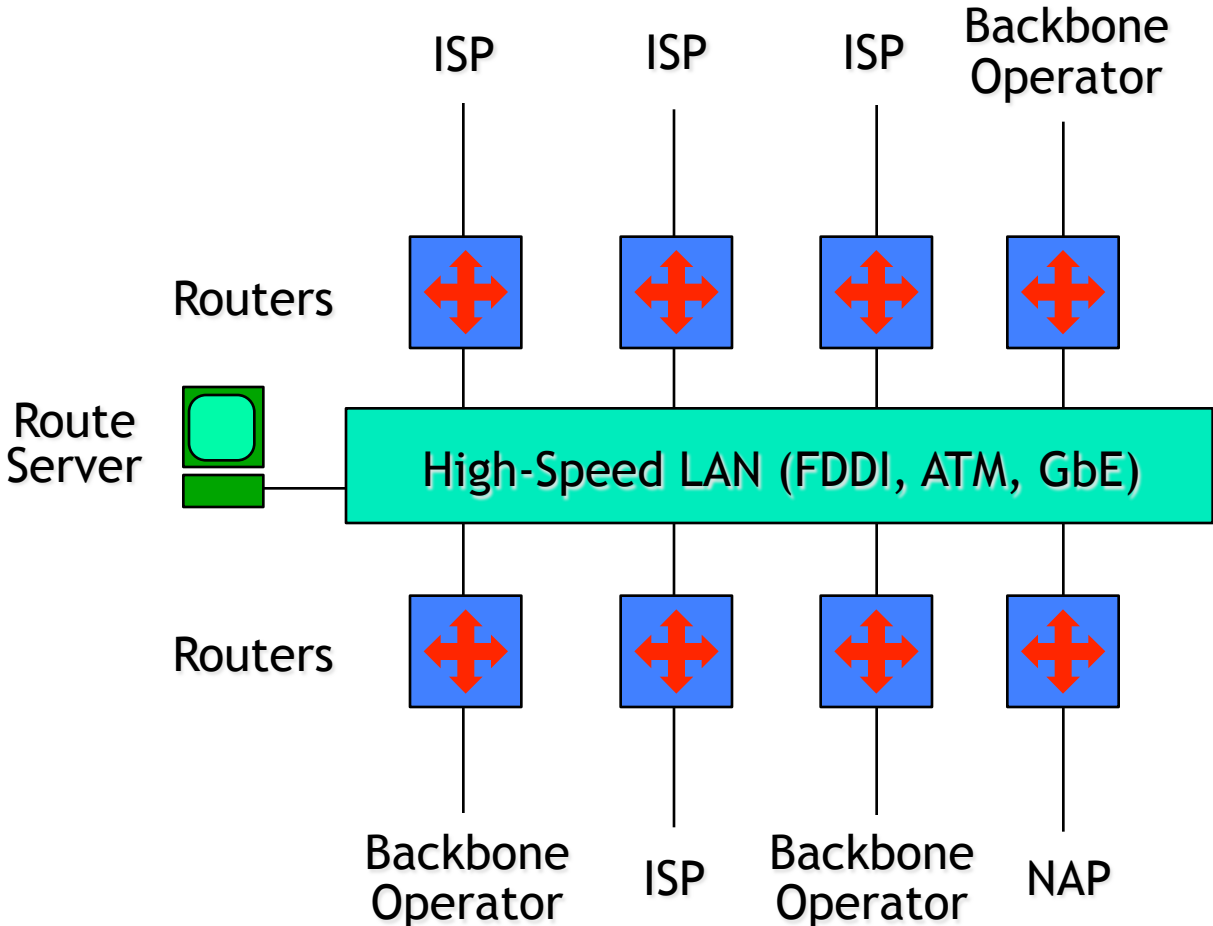


Source: Internet Systems Consortium (www.isc.org)

Internet Architecture



NAP Architecture



Examples:
www.mix-it.net



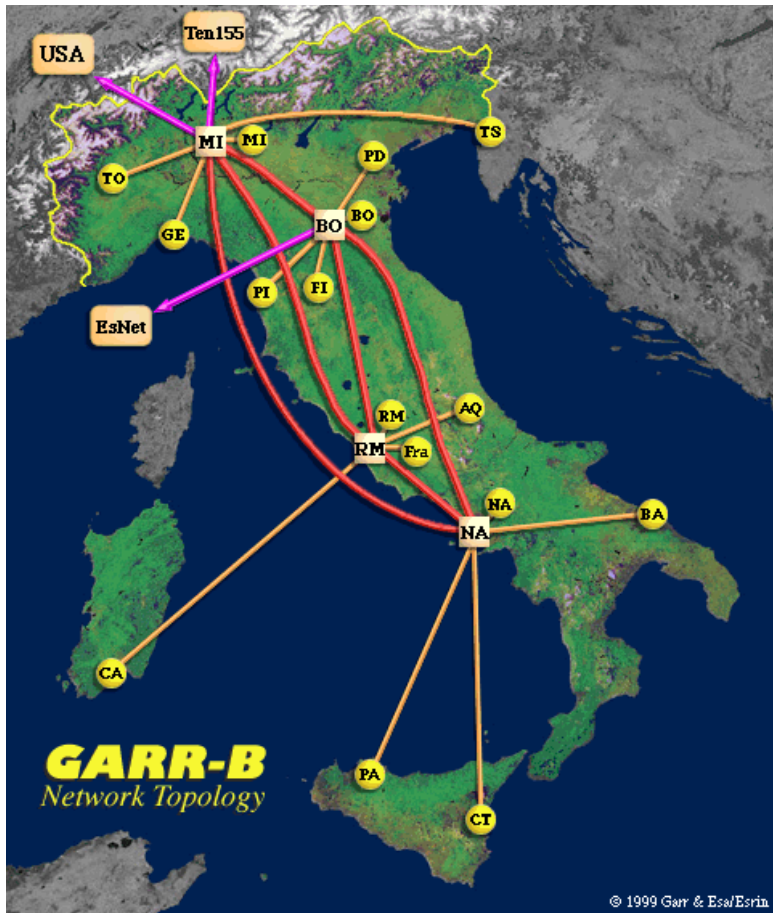
Milan Internet eXchange
www.namex.it



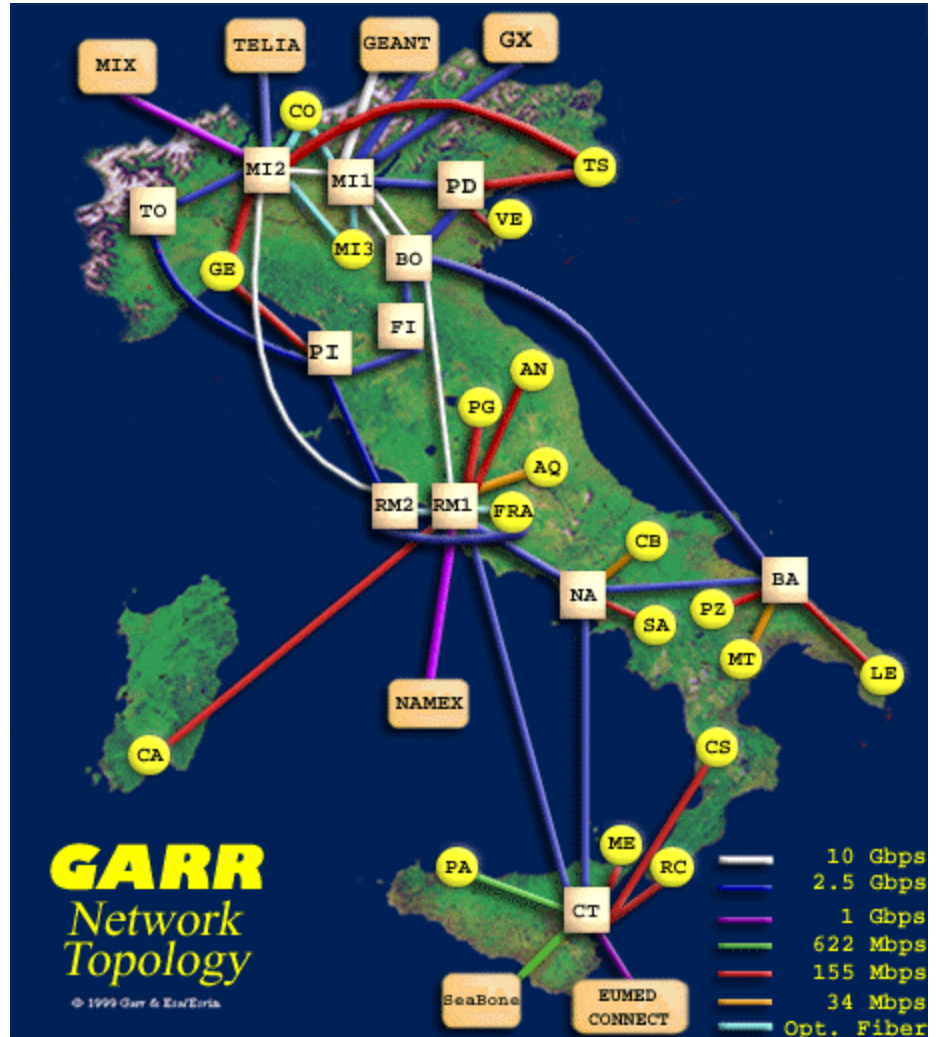
www.topix.it



National ISP: An Italian Example

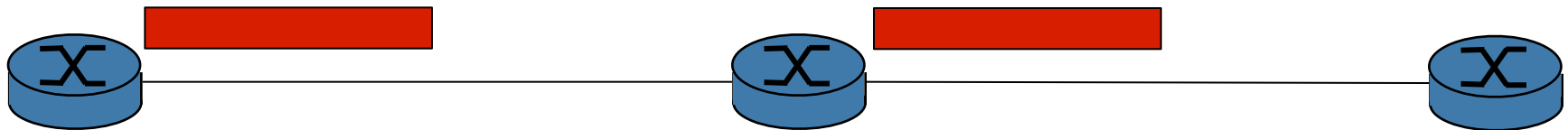


1999



2005

Store and forward



T_0 =transmission start

T_1 =transmission end

T_2 =first bit arrival

T_3 =last bit arrival

Transmission Time:

$T = T_1 - T_0 = L/R$ L =packet length [bit]

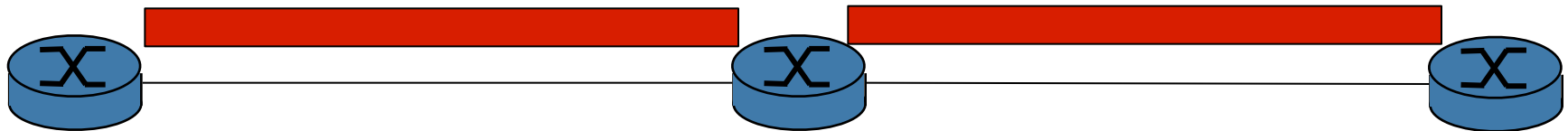
R =transmission rate [bit/s]

Propagation Time:

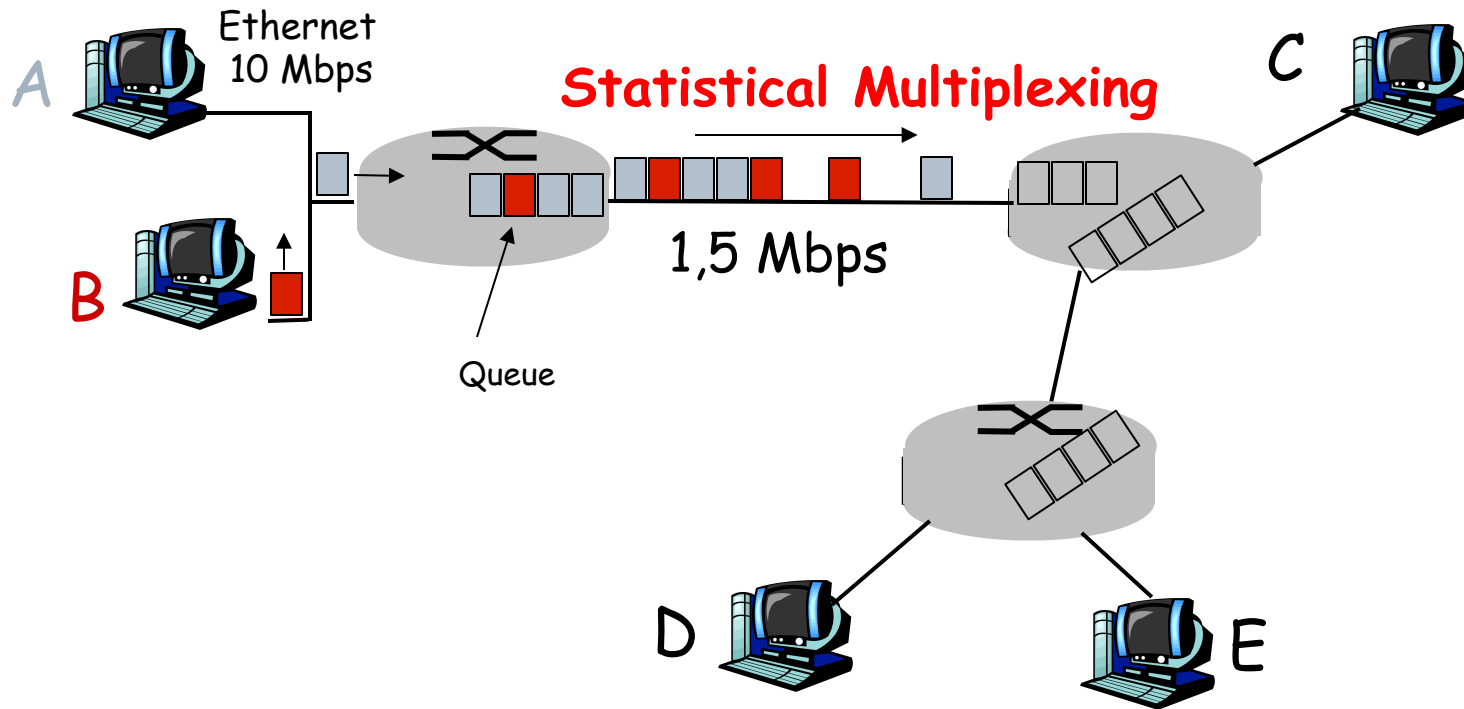
$\tau = T_2 - T_0 = l/C$ l =link length [m]

C =wave speed [m/s]

Store and forward



Statistical Multiplexing

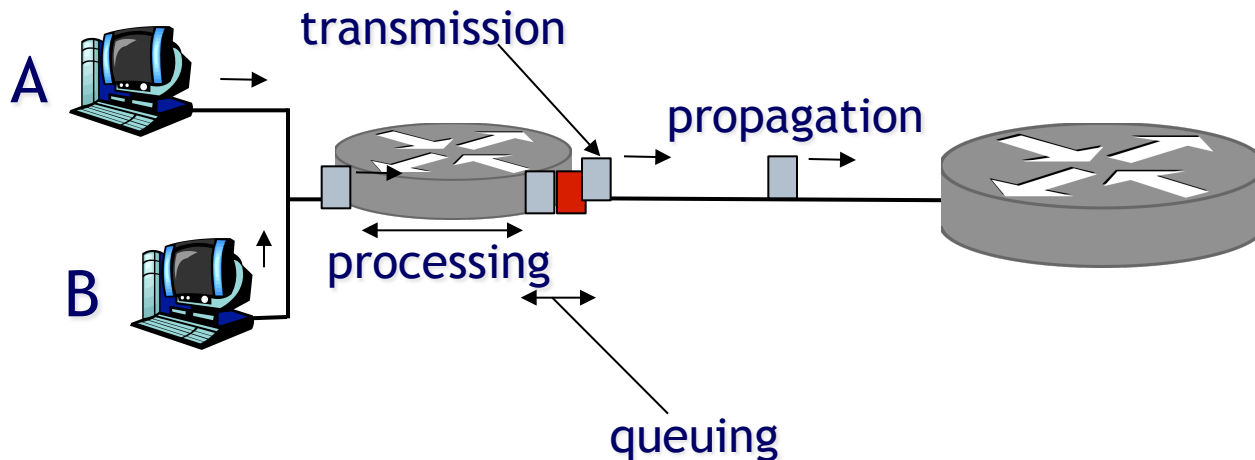


Packet transmission does not follow a fixed sequencing but resources are statistically shared ➡ **statistical multiplexing**.

Packet (or Nodal) Delay

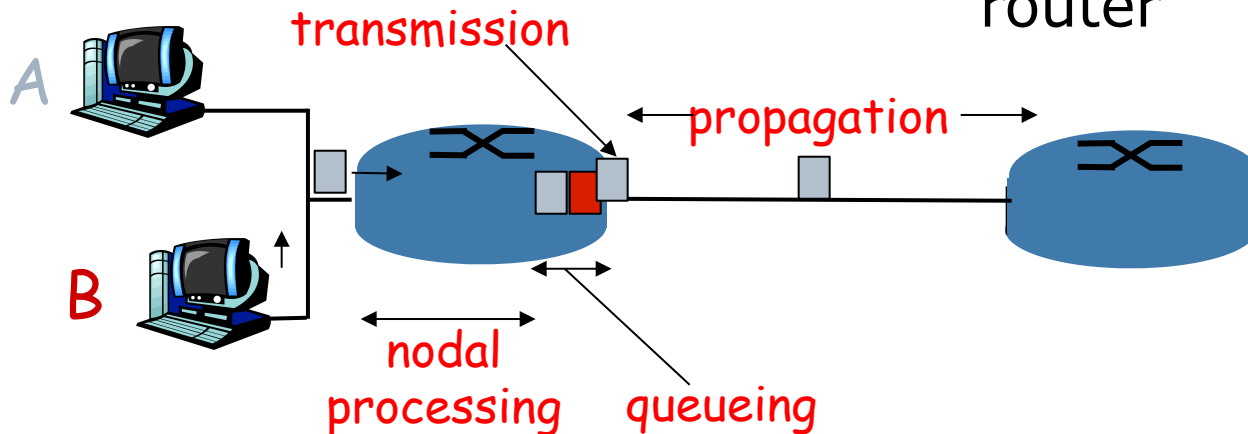
Each packet experiences a variable delay due to:

- Processing
- Queuing
- Transmission
- Propagation



Four sources of packet delay

- 1. nodal processing:
 - check bit errors
 - determine output link
- 2. queueing
 - time waiting at output link for transmission
 - depends on congestion level of router



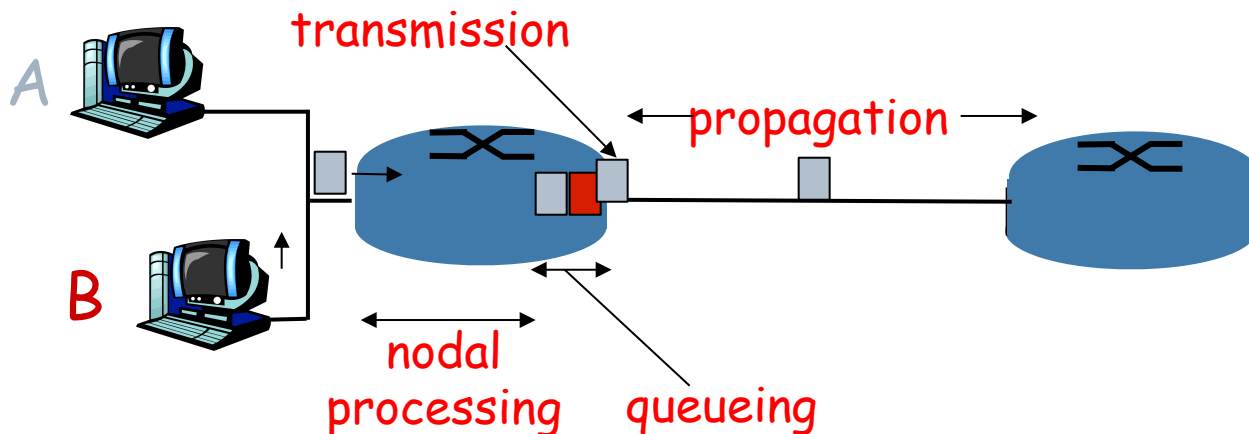
Delay in packet-switched networks

3. Transmission delay:

- R = link bandwidth (bps)
- L = packet length (bits)
- time to send bits into link = L/R

4. Propagation delay:

- I = length of physical link
- C = propagation speed in medium ($\sim 2 \times 10^8$ m/sec)
- propagation delay = I/C

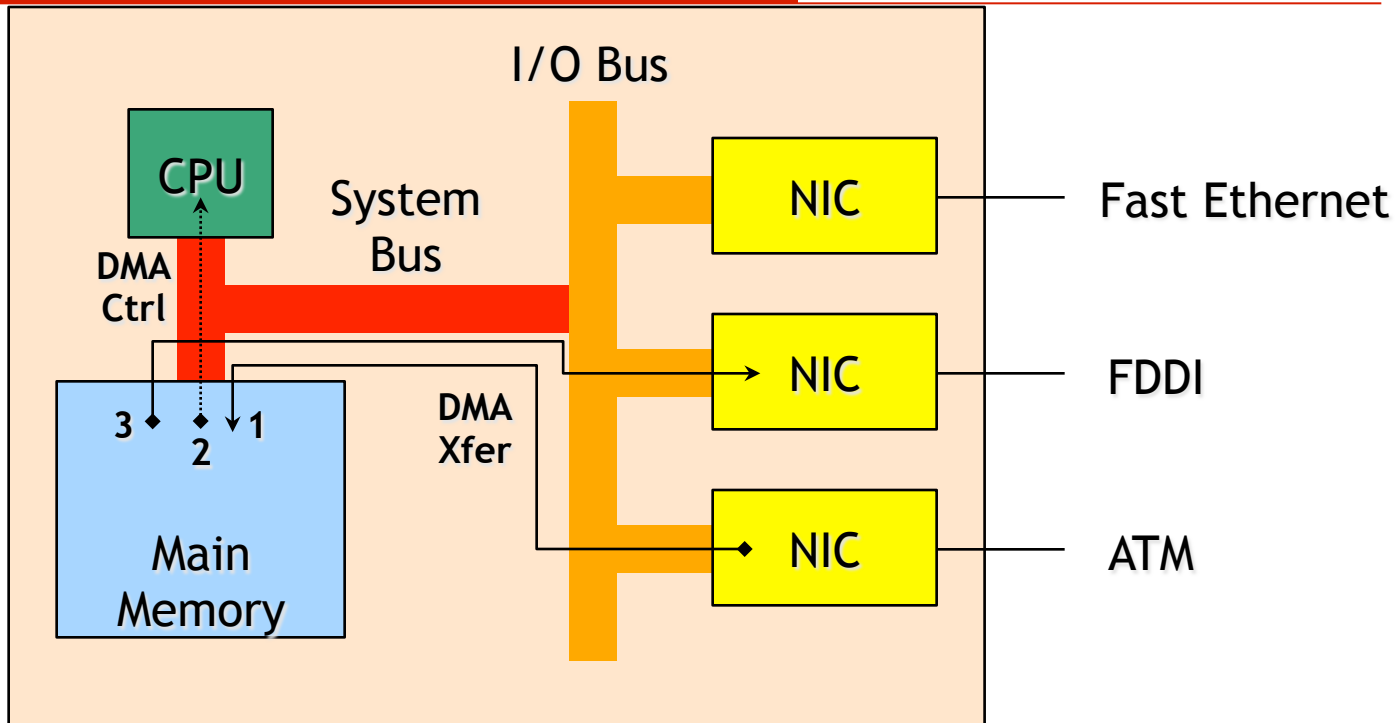


Nodal delay

$$d_{\text{nodal}} = d_{\text{proc}} + d_{\text{queue}} + d_{\text{trans}} + d_{\text{prop}}$$

- d_{proc} = processing delay
 - typically a few microseconds or less
- d_{queue} = queuing delay
 - depends on congestion
- d_{trans} = transmission delay
 - = L/R , significant for low-speed links
- d_{prop} = propagation delay
 - a few microseconds to hundreds of msecs

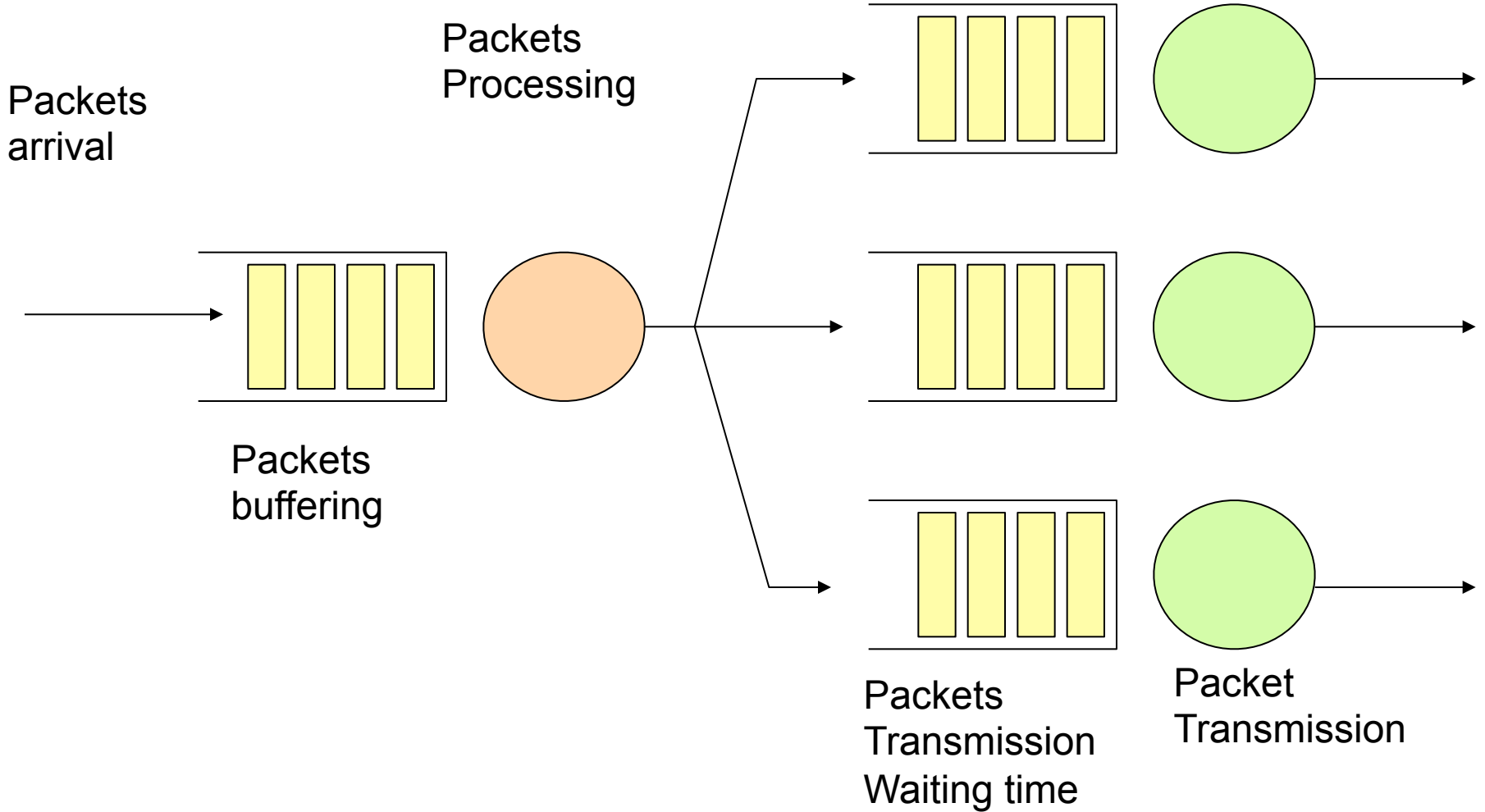
Node Architecture



1. Packet input
2. Header processing
 - Routing table lookup
 - DMA transaction
3. Packet output

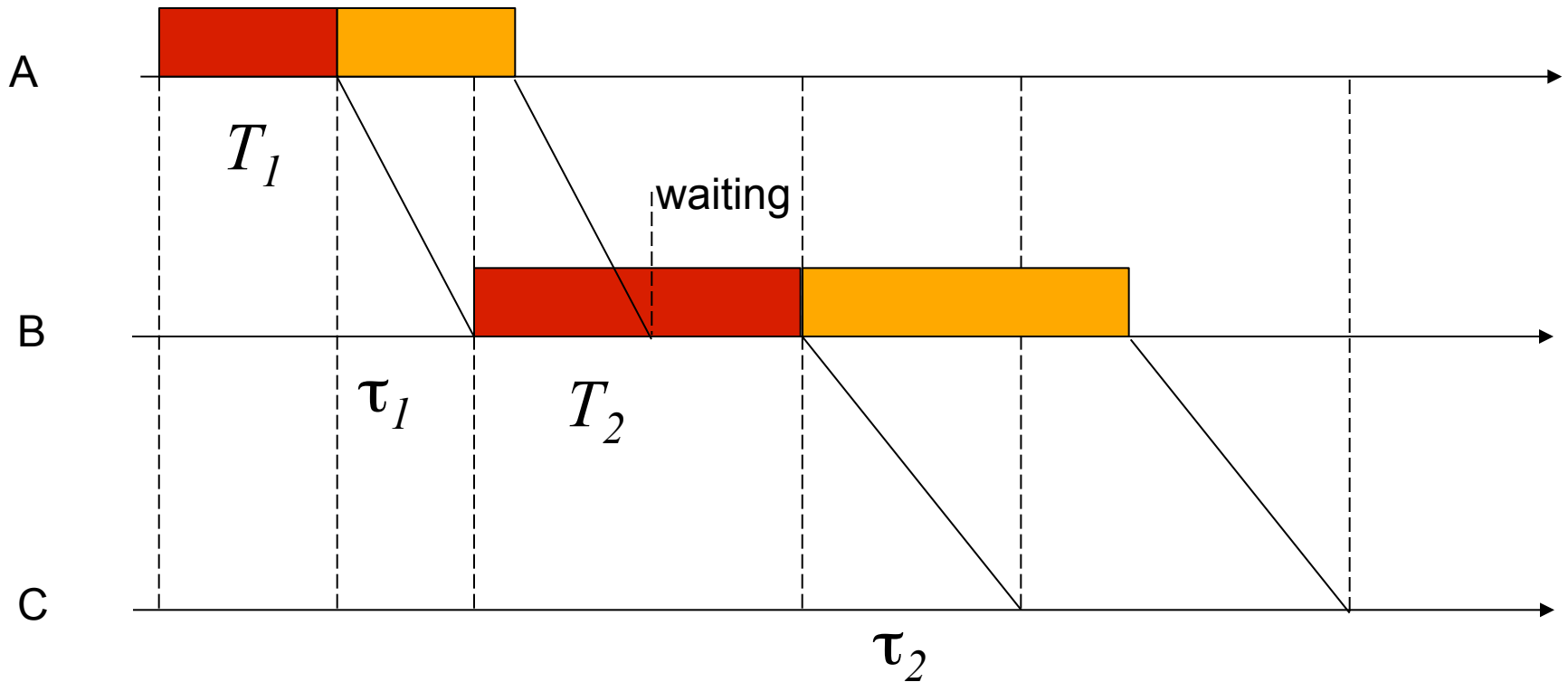
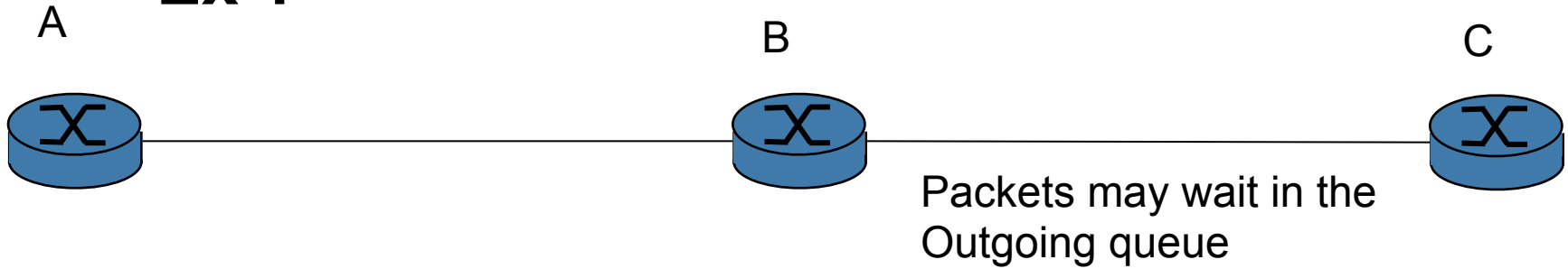
NIC = Network Interface Controller
DMA = Direct Memory Access

Node Model



Queuing Delay

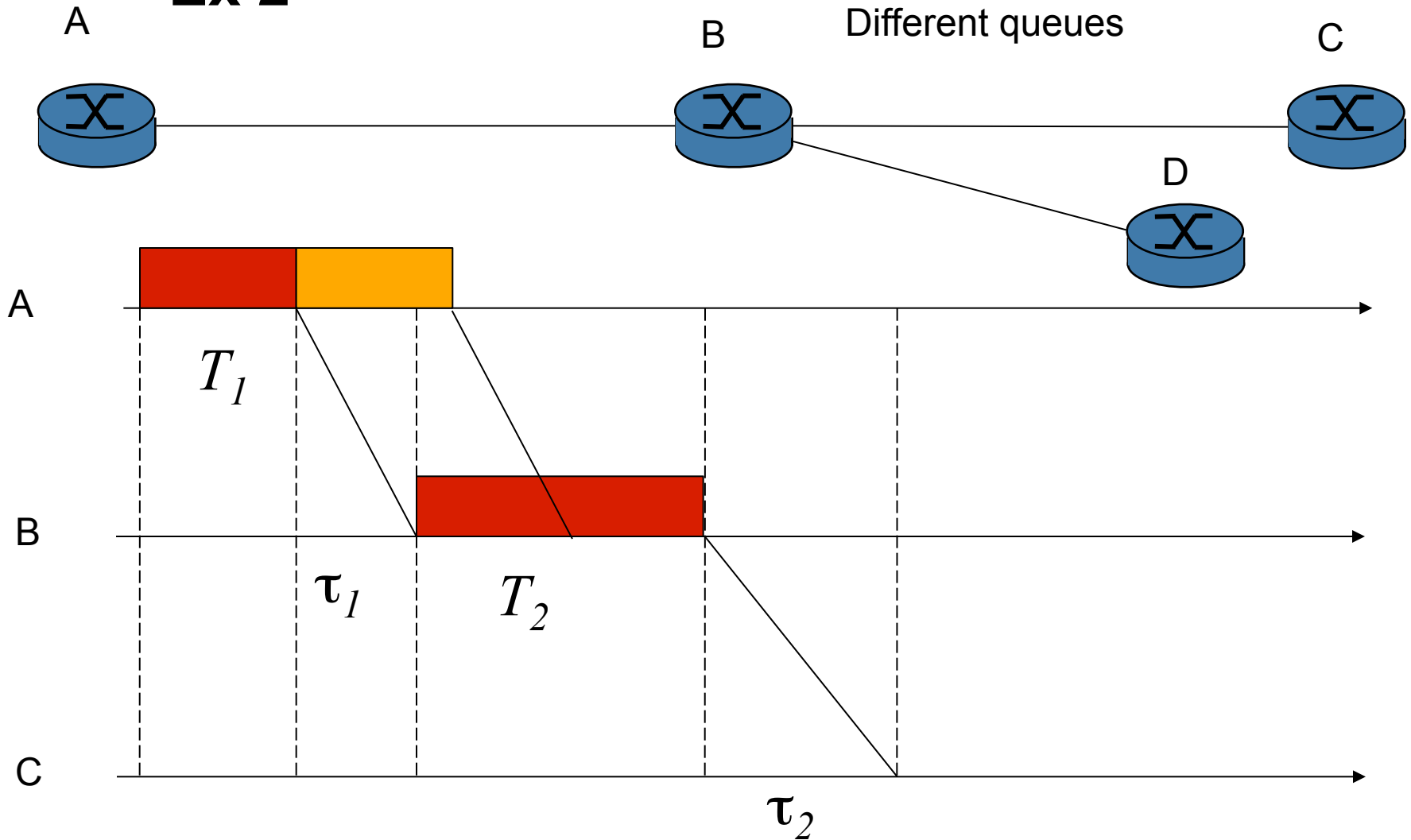
Ex 1



Queuing Delay

Ex 2

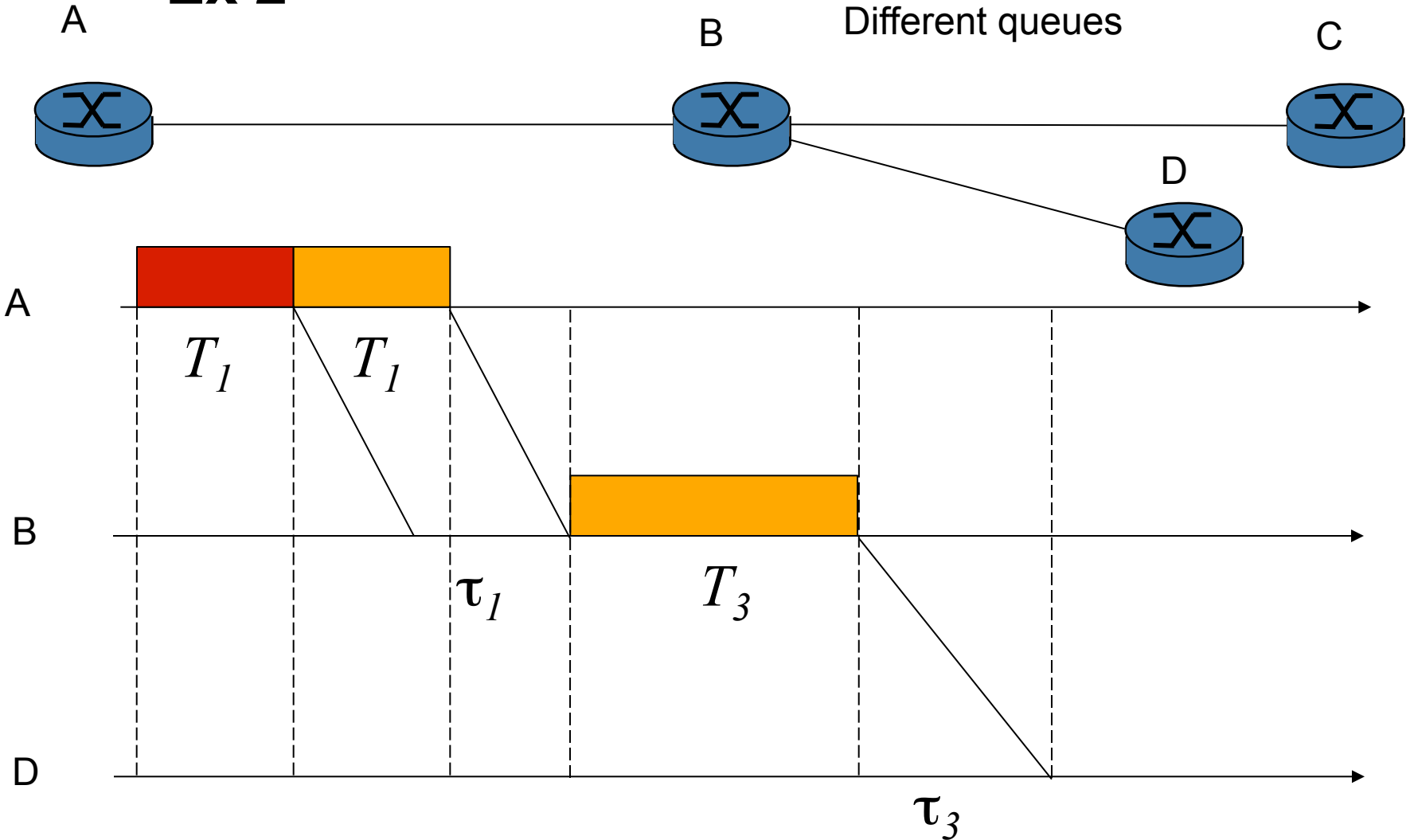
Different interfaces
Different queues



Queuing Delay

Ex 2

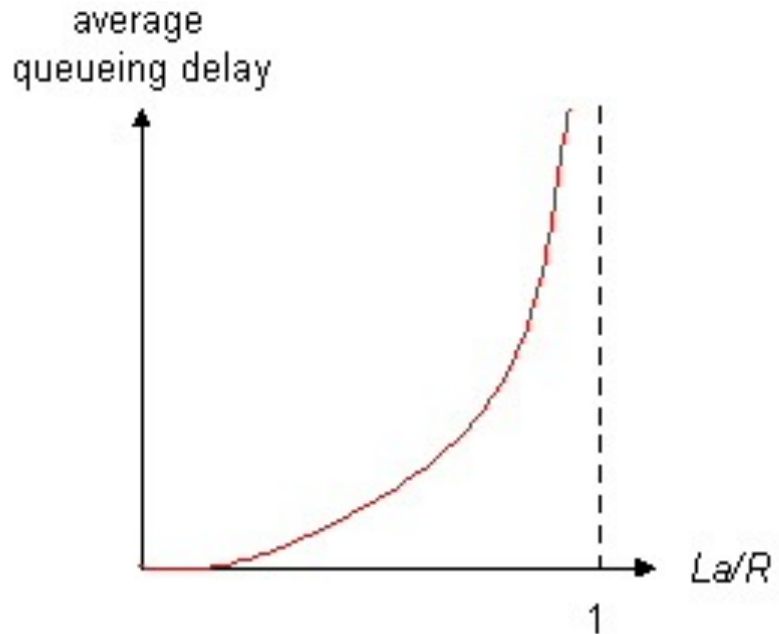
Different interfaces
Different queues



Queueing delay

- R =link bandwidth (bps)
- L =packet length (bits)
- a =average packet arrival rate

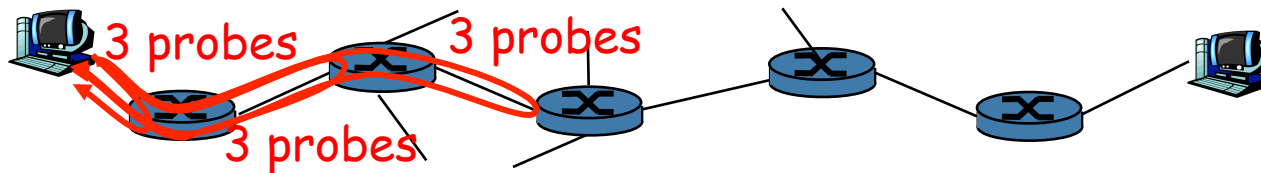
traffic intensity = $\frac{La}{R}$



- $La/R \sim 0$: average queueing delay small
- $La/R \rightarrow 1$: delays become infinite

“Real” Internet delays and routes

- **Traceroute program:** provides delay measurement from source to router along end-end Internet path towards destination. For all i :
 - sends three packets that will reach router i on path towards destination
 - router i will return packets to sender
 - sender times interval between transmission and reply.



“Real” Internet delays and routes

traceroute: gaia.cs.umass.edu to www.eurecom.fr

Three delay measurements from
gaia.cs.umass.edu to cs-gw.cs.umass.edu

1	cs-gw (128.119.240.254)	1 ms	1 ms	2 ms
2	border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)	1 ms	1 ms	2 ms
3	cht-vbns.gw.umass.edu (128.119.3.130)	6 ms	5 ms	5 ms
4	jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)	16 ms	11 ms	13 ms
5	jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)	21 ms	18 ms	18 ms
6	abilene-vbns.abilene.ucaid.edu (198.32.11.9)	22 ms	18 ms	22 ms
7	nycm-wash.abilene.ucaid.edu (198.32.8.46)	22 ms	22 ms	22 ms
8	62.40.103.253 (62.40.103.253)	104 ms	109 ms	106 ms
9	de2-1.de1.de.geant.net (62.40.96.129)	109 ms	102 ms	104 ms
10	de.fr1.fr.geant.net (62.40.96.50)	113 ms	121 ms	114 ms
11	renater-gw.fr1.fr.geant.net (62.40.103.54)	112 ms	114 ms	112 ms
12	nio-n2.cssi.renater.fr (193.51.206.13)	111 ms	114 ms	116 ms
13	nice.cssi.renater.fr (195.220.98.102)	123 ms	125 ms	124 ms
14	r3t2-nice.cssi.renater.fr (195.220.98.110)	126 ms	126 ms	124 ms
15	eurecom-valbonne.r3t2.ft.net (193.48.50.54)	135 ms	128 ms	133 ms
16	194.214.211.25 (194.214.211.25)	126 ms	128 ms	126 ms
17	***			
18	***			
19	fantasia.eurecom.fr (193.55.113.142)	132 ms	128 ms	136 ms

trans-oceanic
link

* means no response (probe lost, router not replying)

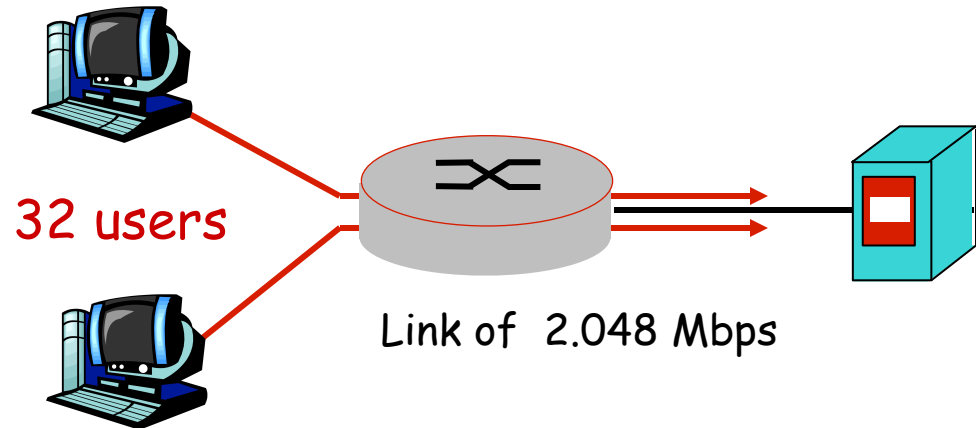
Packet loss

- ❑ queue preceding link in buffer has finite capacity
- ❑ when packet arrives to full queue, packet is dropped
- ❑ lost packet may be retransmitted by previous node, by source end system, or not retransmitted at all

Packet vs Circuit Switching

Packet switching provides lower transfer delays!

- 1 link of 2.048 Mbps
- Each user:
 - Calls for 50KB web pages every 62.5s on average
- Circuit switching:
 - 1 64 kbps channel for each user
 - Average page Transfer delay: 6.25s

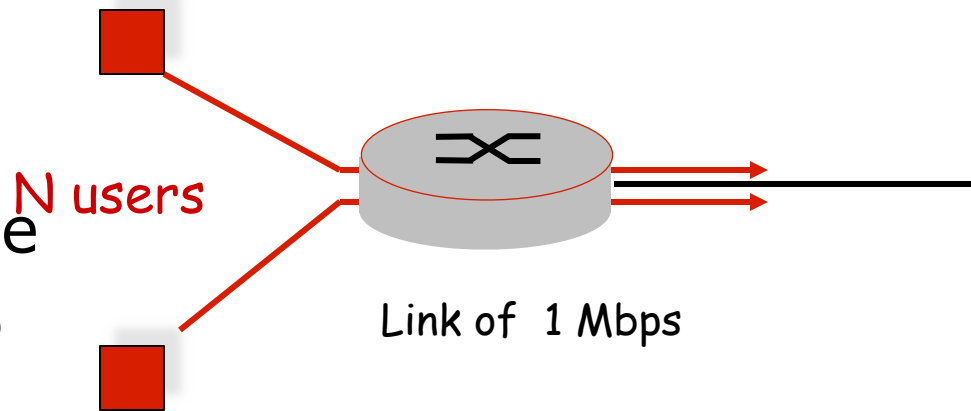


- Packet switching:
 - Average page transfer delay: 0.22s

Packet vs Circuit Switching

Packet switching supports greater number of users!

- 1 link of 1 Mbps
- Each user:
 - 100 kpbs when active
 - Activity cycle = 10%
- Circuit switching:
 - 10 supported users



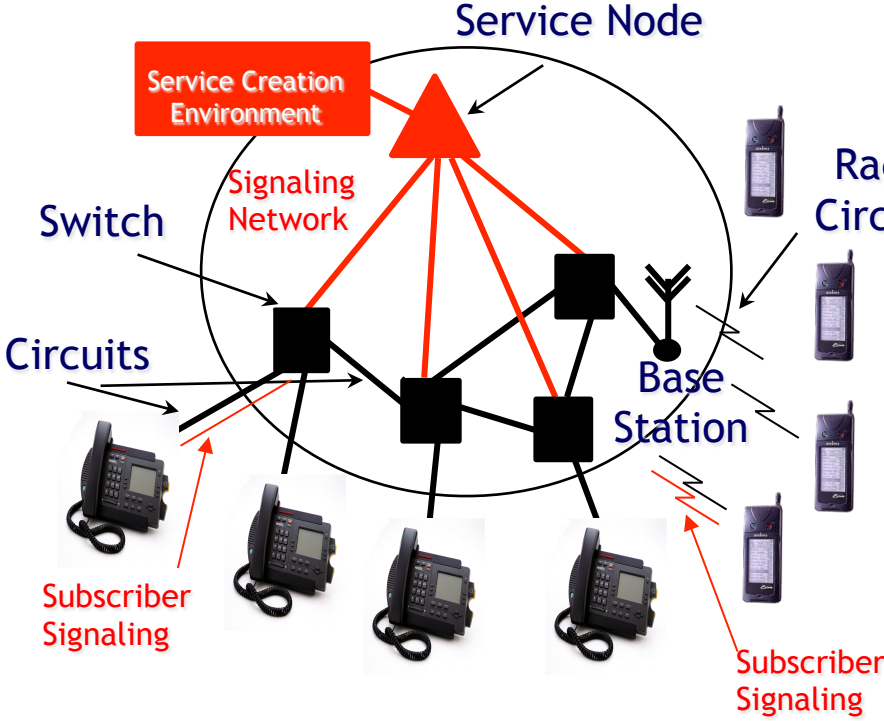
- Packet switching:
 - with 35 users, the probability of having more than 10 active users simultaneously is less than 0,0004

Packet Switching: PROs and CONs

- Very simple to implement (fewer signalling)
- Very well suited for bursty traffic
 - Resource sharing
- Delay and Losses
 - Protocols for reliable data transfer are needed (congestion control, loss recovery)

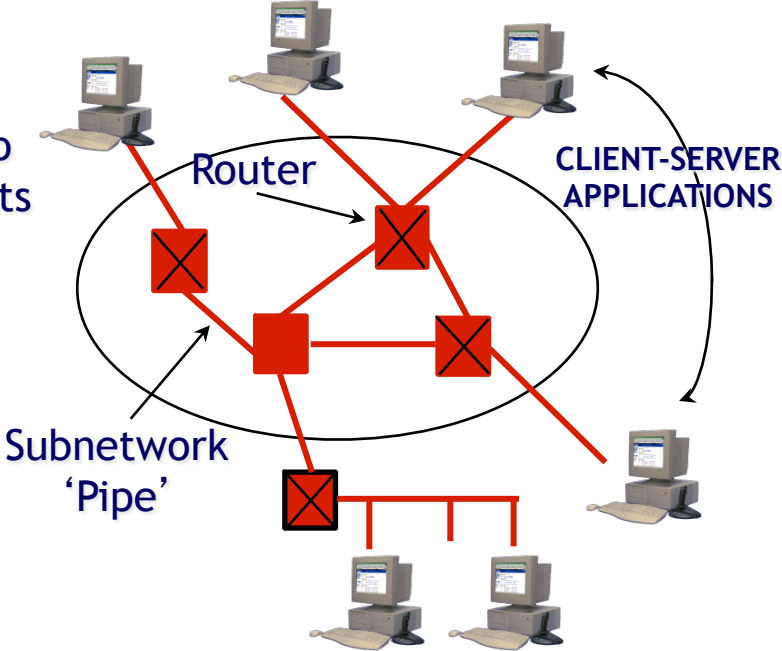
PSTN vs Internet

Clever Networks



Dumb Terminals

Dumb Network



Clever Terminals