Dipartimento di Informatica
Via Salaria 113 - 00198, Roma

Sapienza
Università di Roma

# Reti di Elaboratori

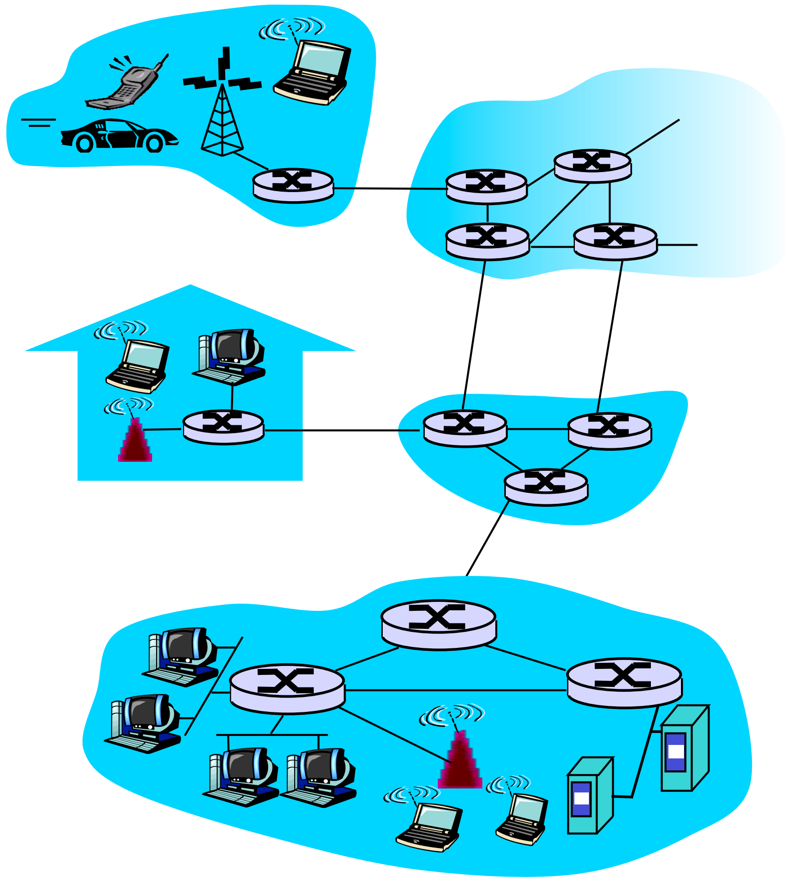
Corso di Laurea in Informatica
Università degli Studi di Roma “La Sapienza”
Canale A-L
Prof.ssa Chiara Petrioli

Parte di queste slide sono state prese dal materiale associato al libro *Computer Networking: A Top Down Approach* , 5th edition.

Thanks also to Antonio Capone, Politecnico di Milano, Giuseppe Bianchi and Francesco LoPresti, Un. di Roma Tor Vergata

# What' s the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - Web, VoIP, email, games, e-commerce, file sharing
- communication services provided to apps:
  - reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery



# What’s a protocol?

**human protocols:**

- “what’s the time?”
- “I have a question”
- introductions

… specific msgs sent

… specific actions taken when msgs received, or other events

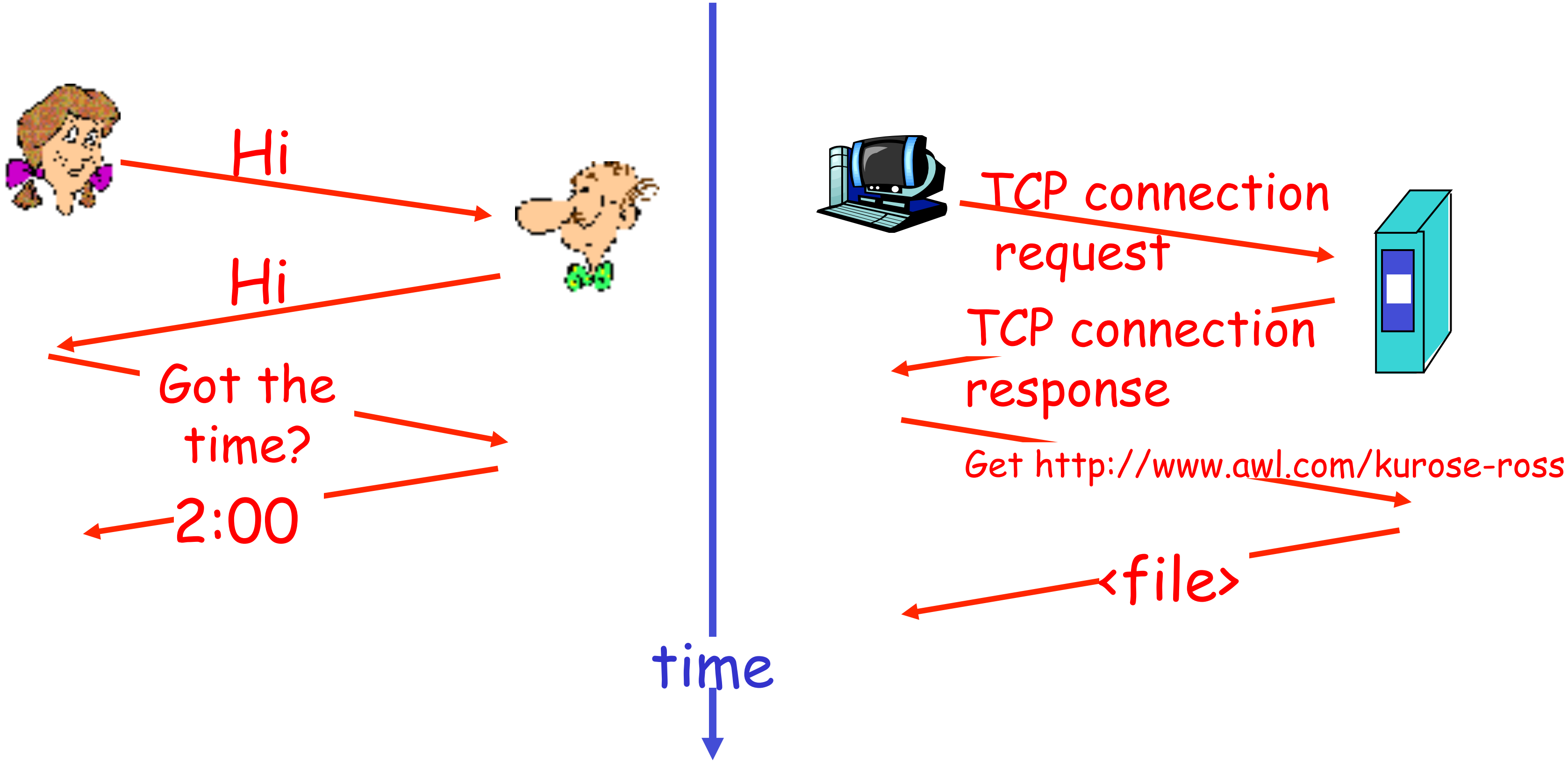
**network protocols:**

- machines rather than humans
- all communication activity in Internet governed by protocols

*protocols define format, order of messages sent and received among network entities, and actions taken on msg transmission, receipt*

# What’s a protocol?

a human protocol and a computer network protocol:




Q: Other human protocols?

# What's the Internet: a service view

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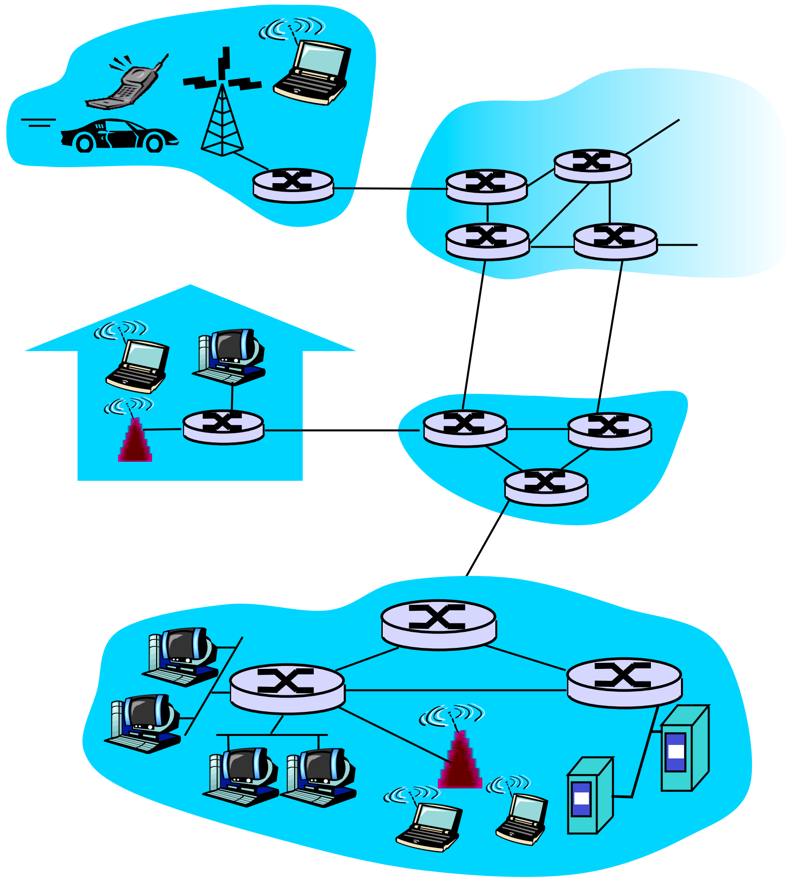


# Network edge: connection-oriented service

*Goal:* data transfer between end systems

- *handshaking:* setup (prepare for) data transfer ahead of time
  - Hello, hello back human protocol
  - *set up "state"* in two communicating hosts

  (not in the network!!)
- TCP - Transmission Control Protocol
  - Internet's connection-oriented service

TCP service [RFC 793]

- *reliable, in-order* byte-stream data transfer
  - loss: acknowledgements and retransmissions
- *flow control:*
  - sender won't overwhelm receiver
- *congestion control:*
  - senders "slow down sending rate" when network congested

# Network edge: connectionless service

*Goal:* data transfer between end systems
- same as before!

- UDP - User Datagram Protocol [RFC 768]: Internet's connectionless service
  - unreliable data transfer
  - no flow control
  - no congestion control

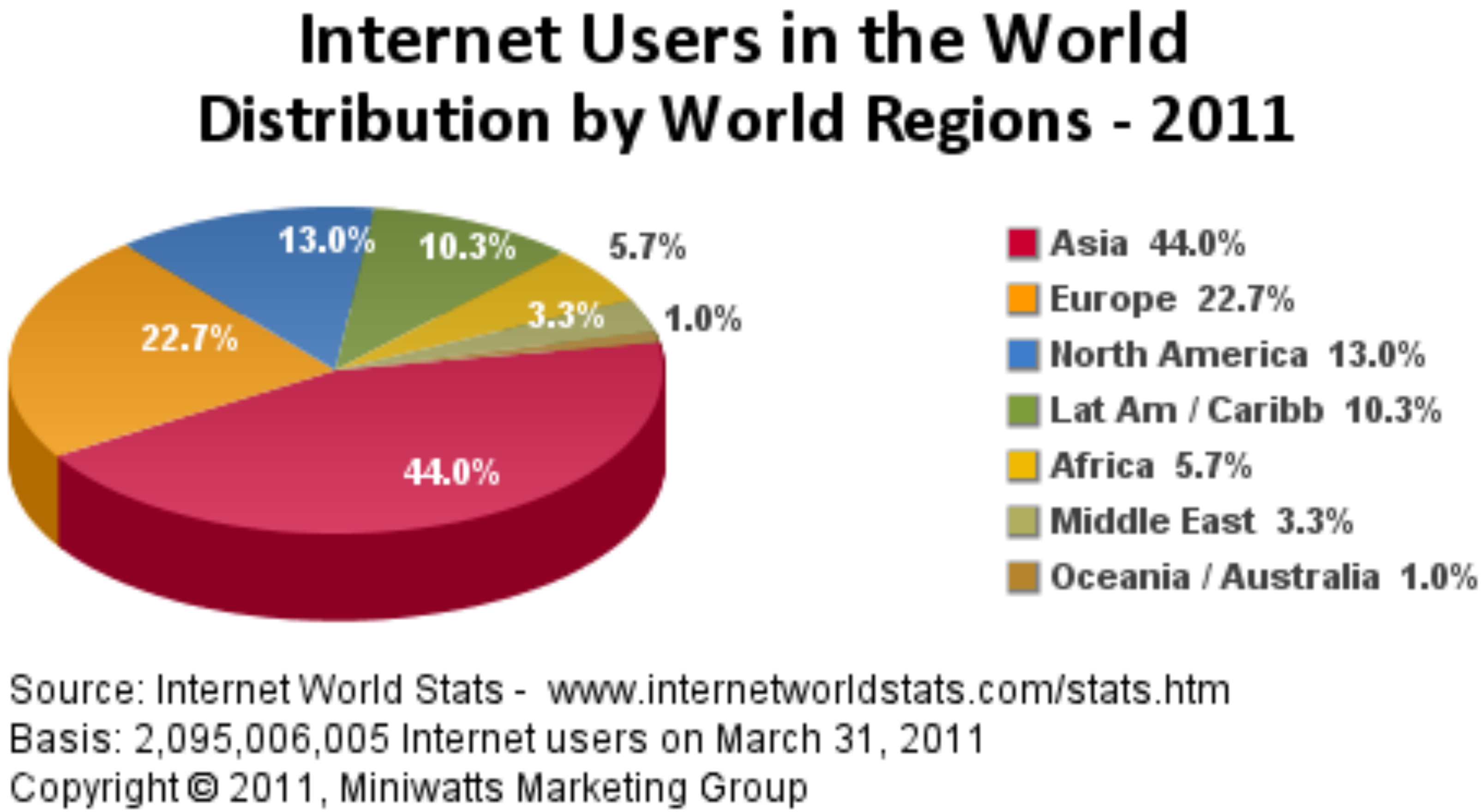
## App's using TCP:

- HTTP (Web), FTP (file transfer), Telnet (remote login), SMTP (email)

## App's using UDP:

- streaming media, teleconferencing, DNS, Internet telephony

# To conclude general introduction: Why is Internet So Important-- Some Statistics

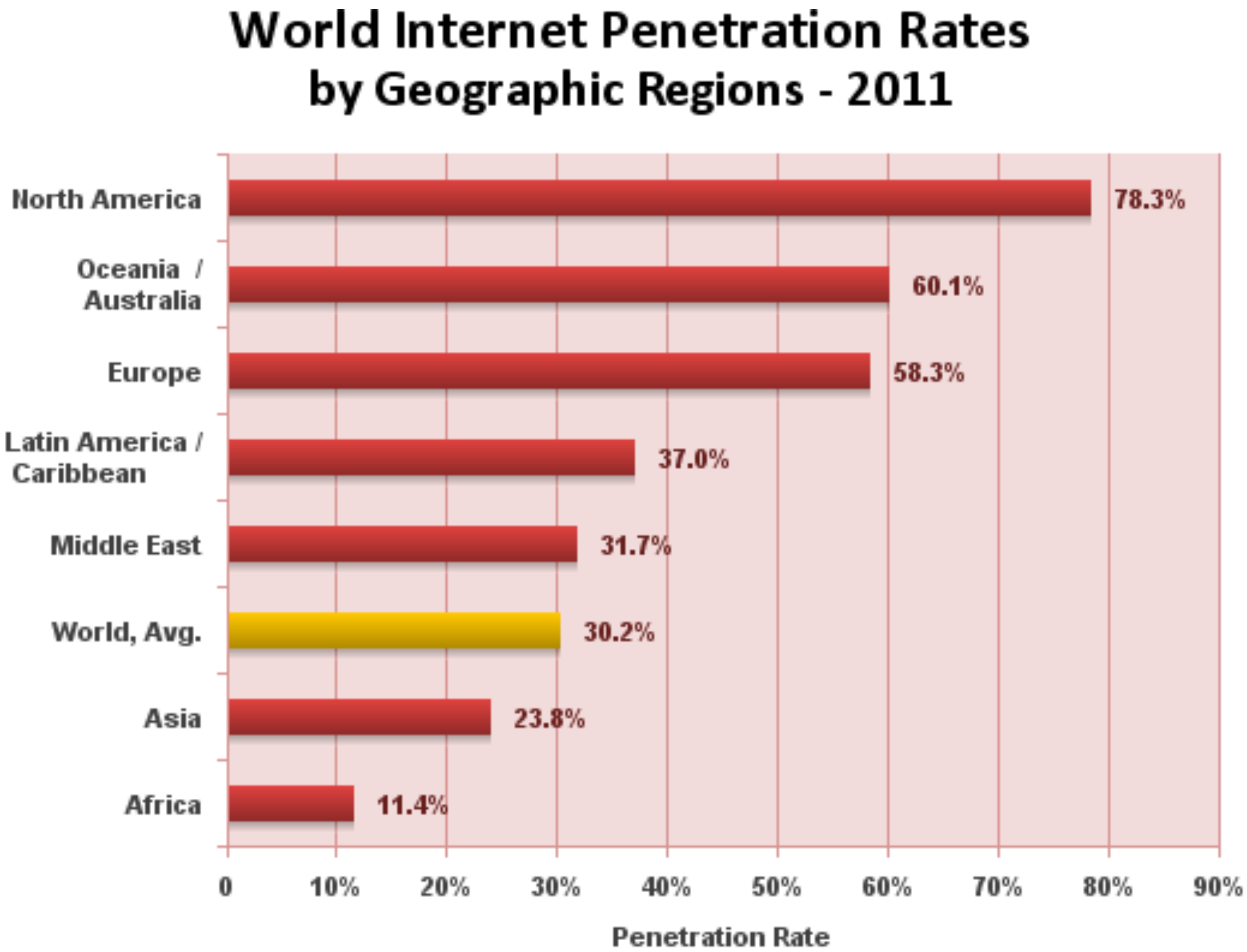


# Some Statistics

| WORLD INTERNET USAGE AND POPULATION STATISTICS<br>March 31, 2011 | | | | | | |
|---|---|---|---|---|---|---|
| World Regions | Population (2011 Est.) | Internet Users Dec. 31, 2000 | Internet Users Latest Data | Penetration (% Population) | Growth 2000-2011 | Users % of Table |
| Africa | 1,037,524,058 | 4,514,400 | **118,609,620** | 11.4 % | 2,527.4 % | 5.7 % |
| Asia | 3,879,740,877 | 114,304,000 | **922,329,554** | 23.8 % | 706.9 % | 44.0 % |
| Europe | 816,426,346 | 105,096,093 | **476,213,935** | 58.3 % | 353.1 % | 22.7 % |
| Middle East | 216,258,843 | 3,284,800 | **68,553,666** | 31.7 % | 1,987.0 % | 3.3 % |
| North America | 347,394,870 | 108,096,800 | **272,066,000** | 78.3 % | 151.7 % | 13.0 % |
| Latin America / Carib. | 597,283,165 | 18,068,919 | **215,939,400** | 36.2 % | 1,037.4 % | 10.3 % |
| Oceania / Australia | 35,426,995 | 7,620,480 | **21,293,830** | 60.1 % | 179.4 % | 1.0 % |
| **WORLD TOTAL** | **6,930,055,154** | **360,985,492** | **2,095,006,005** | **30.2 %** | **480.4 %** | **100.0 %** |

NOTES: (1) Internet Usage and World Population Statistics are for March 31, 2011. (2) CLICK on each world region name for detailed regional usage information. (3) Demographic (Population) numbers are based on data from the US Census Bureau . (4) Internet usage information comes from data published by Nielsen Online, by the International Telecommunications Union, by GfK, local Regulators and other reliable sources. (5) For definitions, disclaimer, and navigation help, please refer to the Site Surfing Guide. (6) Information in this site may be cited, giving the due credit to www.internetworldstats.com. 

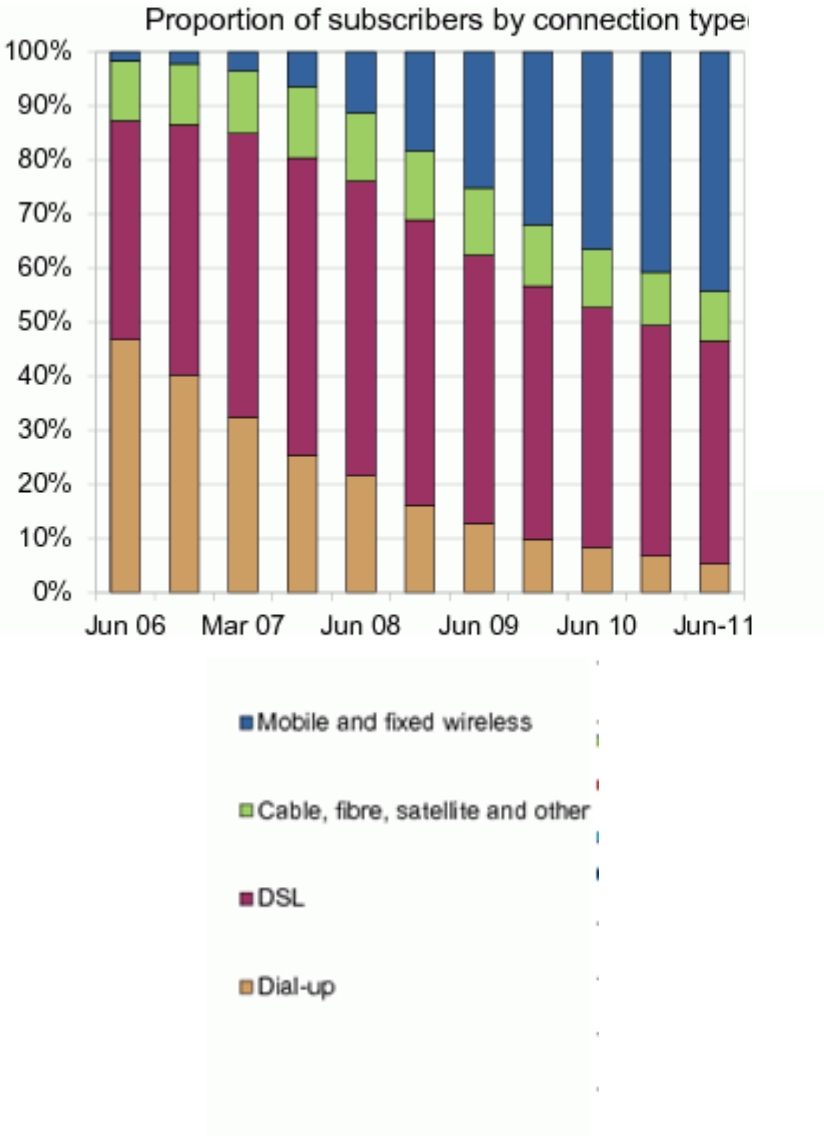
# Some Statistics

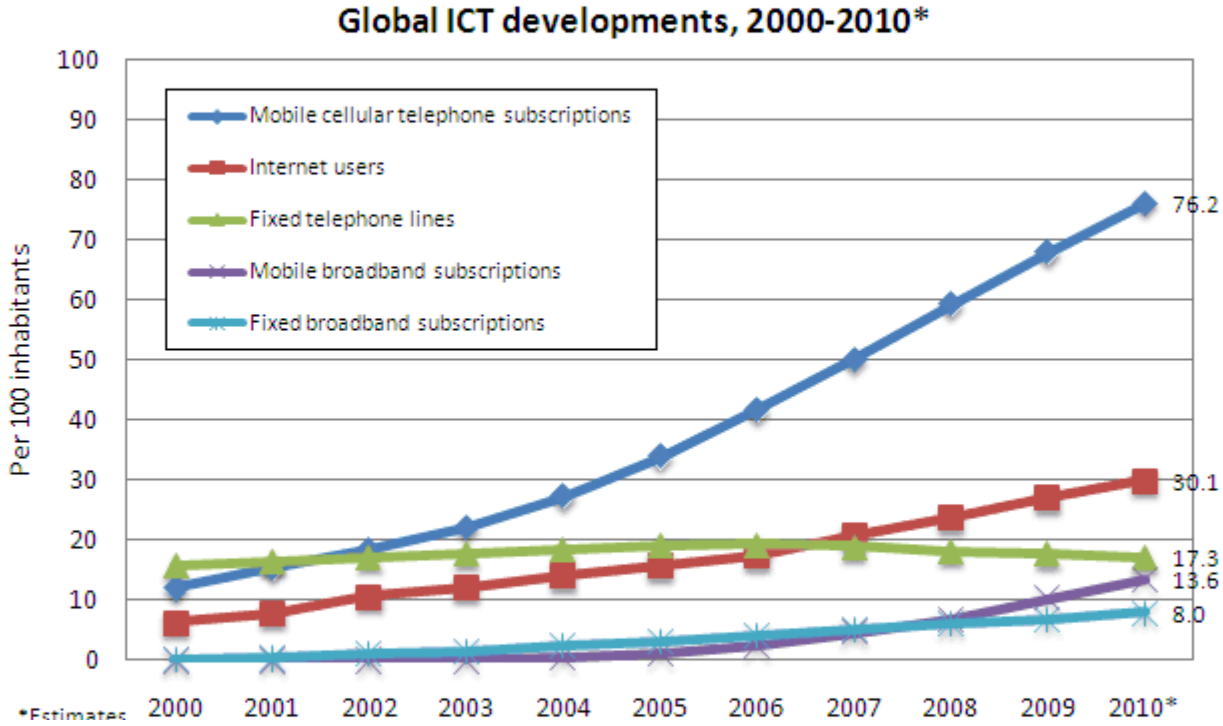


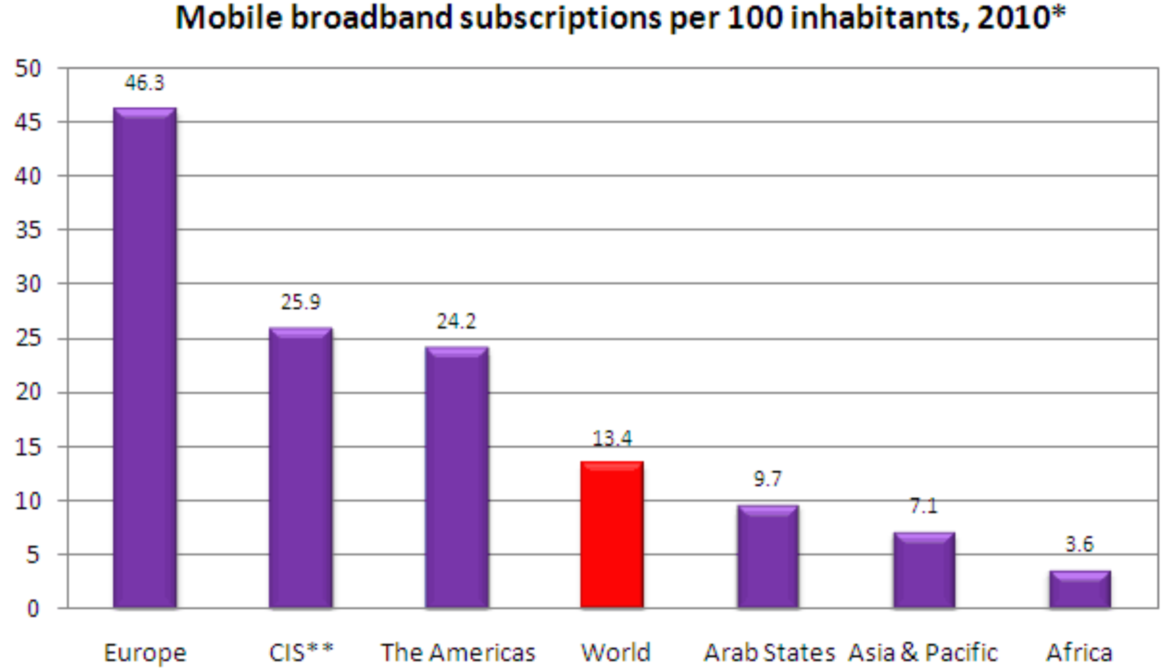

Source: Internet World Stats - www.internetworldststs.com/stats.htm

# Some Statistics

Australian Data



# Chapter 1: roadmap

1.1 What *is* the Internet?

1.2 Network edge

- end systems, access networks, links

1.3 Network core

- circuit switching, packet switching, network structure

1.4 Delay, loss and throughput in packet-switched networks

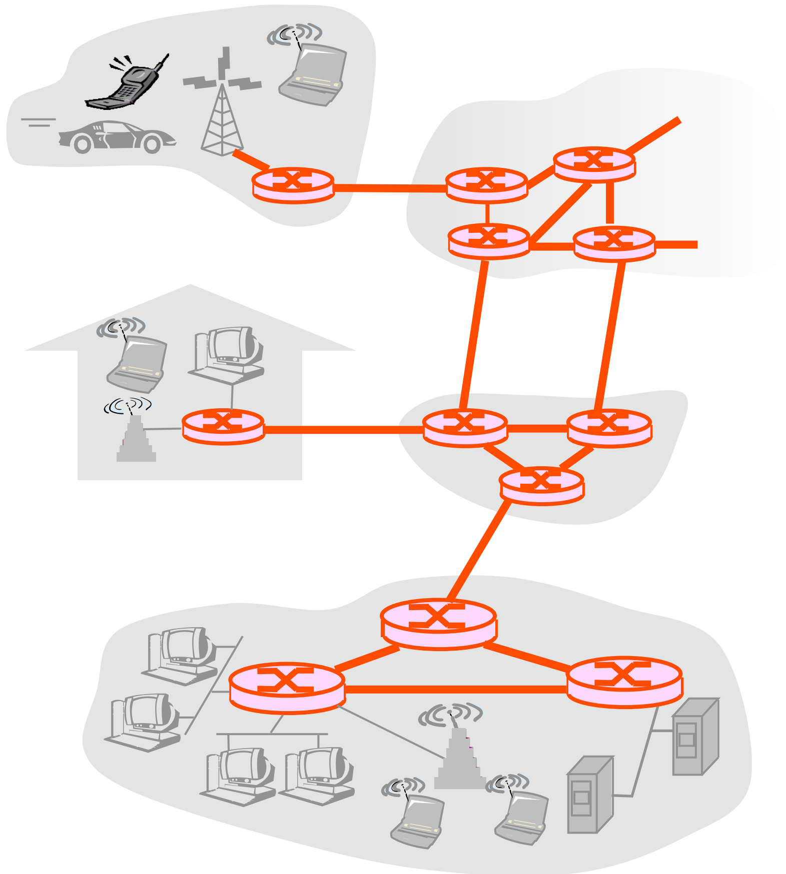
1.5 Protocol layers, service models

1.6 Networks under attack: security

1.7 History

# The Network Core

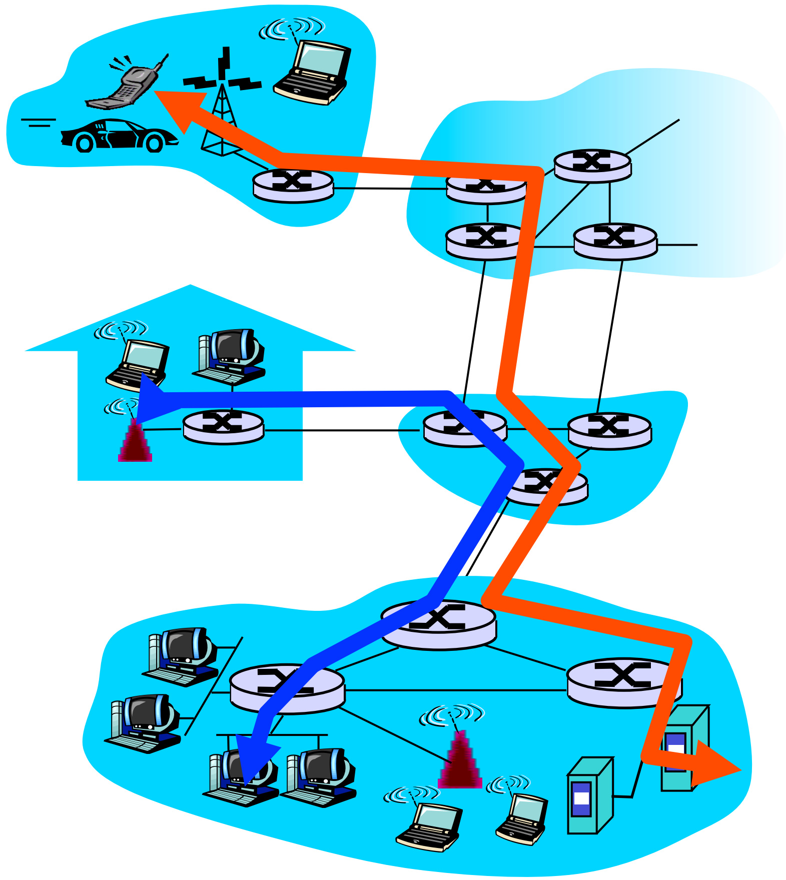
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete "chunks"



# Network Core: Circuit Switching

End-end resources reserved for "call"

- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



# Network Core: Circuit Switching

network resources (e.g., bandwidth) divided into "pieces"

- pieces allocated to calls
- resource piece *idle* if not used by owning call *(no sharing)*

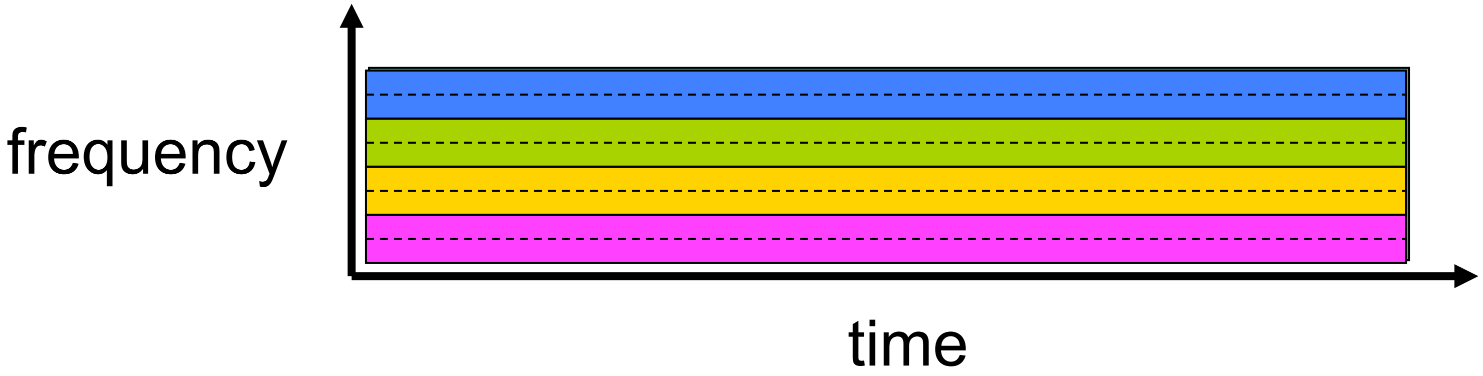
- dividing link bandwidth into "pieces"
  - frequency division
  - time division

# Circuit Switching: FDM and TDM

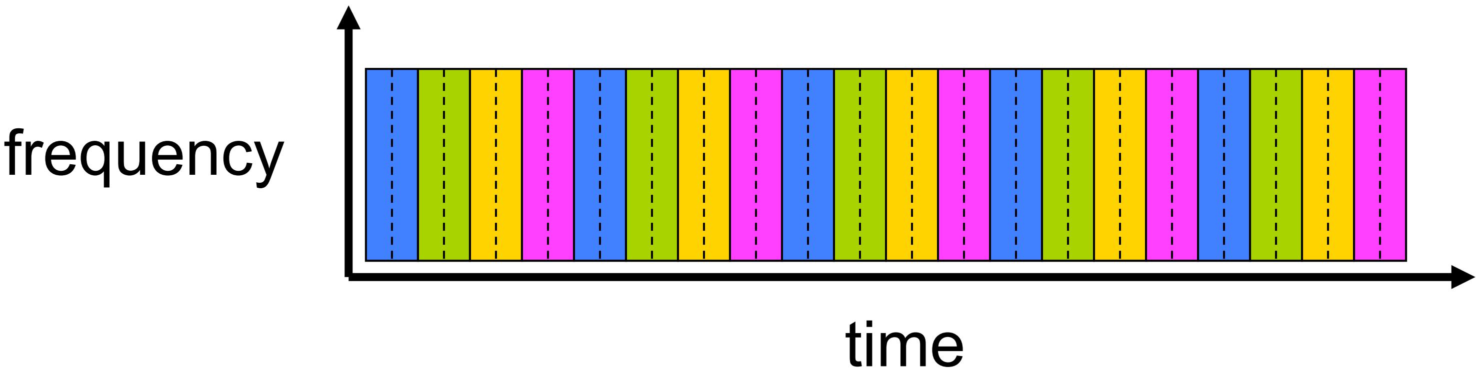
Example:

4 users

FDM




TDM



# Numerical example

- How long does it take to send a file of 640,000 bits from host A to host B over a circuit-switched network?
  - All links are 1.536 Mbps
  - Each link uses TDM with 24 slots/sec
  - 500 msec to establish end-to-end circuit

Let's work it out!

# ..Numerical example

- Each circuit has a transmission rate of (1,536Mbps)/24=64Kbps
- 640000/64000=10s
- Plus the circuit establishment→10,5s

# Network Core: Packet Switching

each end-end data stream divided into *packets*

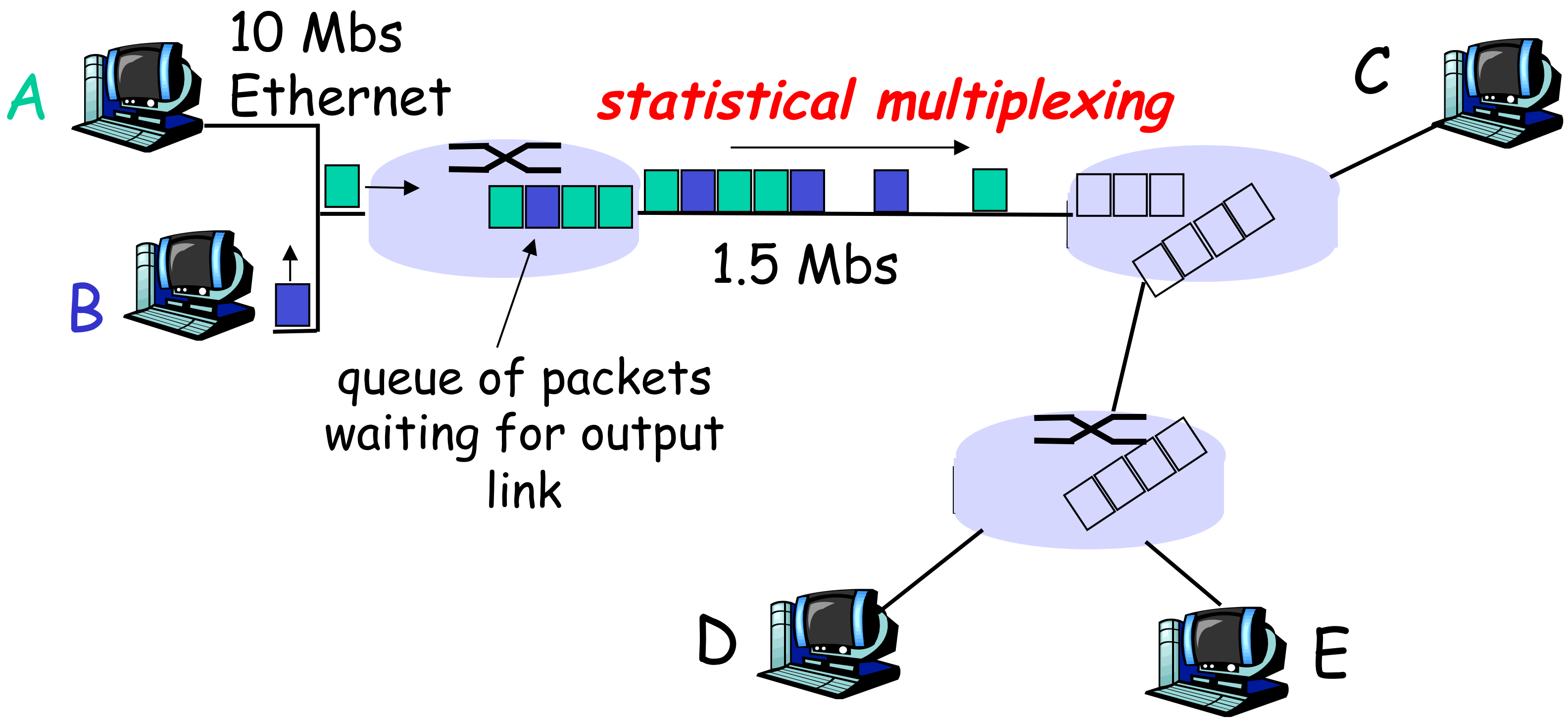
- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*

Bandwidth division into "pieces"
Dedicated allocation
Resource reservation

resource contention:

- aggregate resource demand can exceed amount available
- congestion: packets queue, wait for link use
- store and forward: packets move one hop at a time
  - Node receives complete packet before forwarding

# Packet Switching: Statistical Multiplexing




Sequence of A & B packets does not have fixed pattern ➡ ***statistical multiplexing***.

In TDM each host gets same slot in revolving TDM frame.

# Network Core: Packet Switching

each end-end data stream divided into *packets*

- user A, B packets *share* network resources
- each packet uses full link bandwidth
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Bandwidth division into “pieces”
Dedicated allocation
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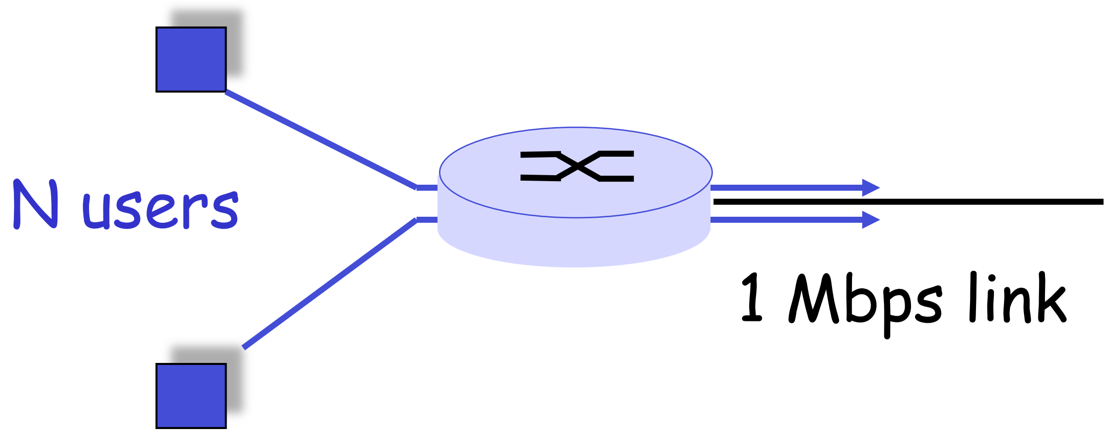
# Packet switching versus circuit switching

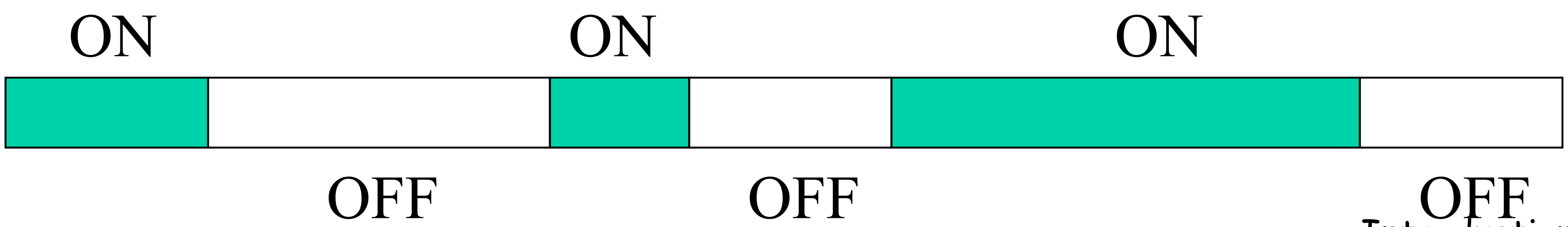
Packet switching allows more users to use network!

- 1 Mbit link
- each user:
  - 100 kbps when "active"
  - active 10% of time
- circuit-switching:
  - 10 users
- packet switching:
  - with 35 users, probability > 10 active less than .0004



# Source types

- Constant Bit Rate (e.g. encoded voice without silence suppression→ voice packets have fixed size and are trasmitted periodically. Required bit rate: 64Kbps)
- Variable Bit Rate (e.g. Video encoding, voice with silence suppression, file downloading etc.)
  - The bit rate varies with time
  - Source behavior characterized by min/max transmission rate, and average bit rate. Source burstiness = max bit rate/ average bit rate.
  - Example: CBR ON/OFF



# Packet switching versus circuit switching

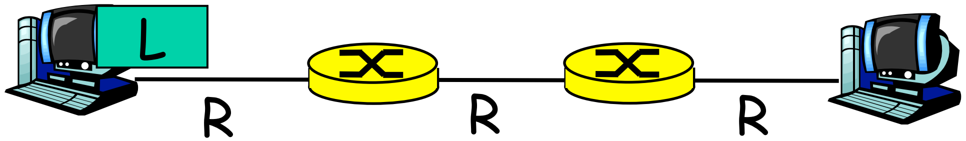
Is packet switching a "slam dunk winner?"

- Great for bursty data
  - resource sharing
  - simpler, no call setup
- Excessive congestion: packet delay and loss
  - protocols needed for reliable data transfer, congestion control

# Packet switching

- Perche’ dividere i messaggi trasmessi dall’applicazione in pacchetti di dimensione limitata.
  - Nelle prossime slides pro e contro….

# Packet-switching: store-and-forward



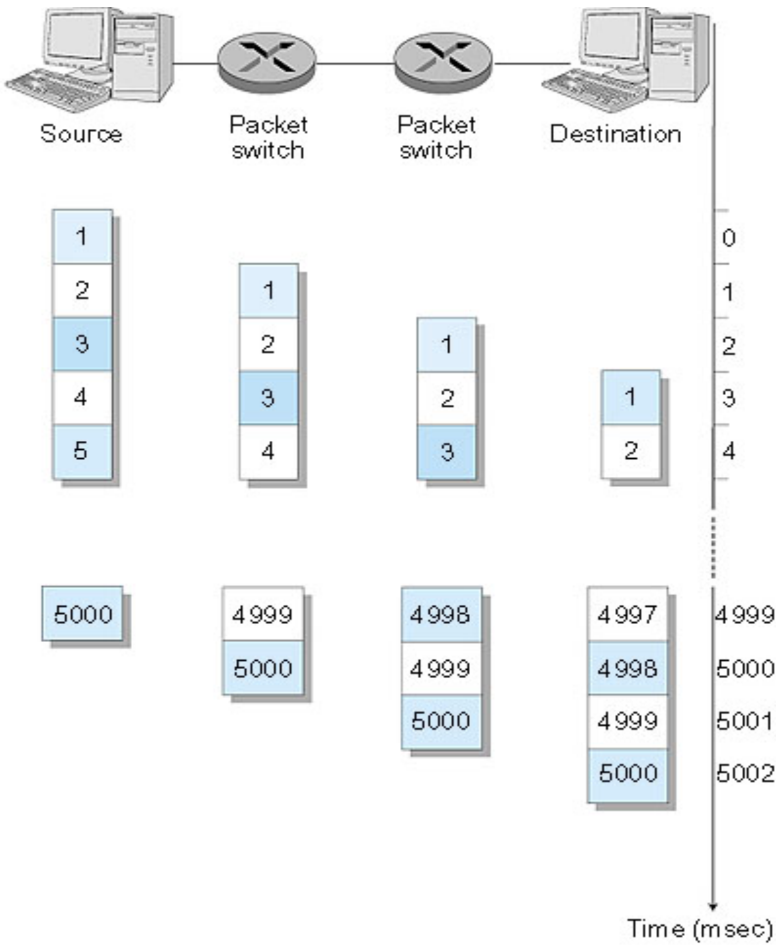

- Takes L/R seconds to transmit (push out) packet of L bits on to link or R bps
- Entire packet must arrive at router before it can be transmitted on next link: *store and forward*
- delay = 3L/R

Example:

- L = 7.5 Mbit
- R = 1.5 Mbps
- delay = 15 sec

(only transmission delay considered here)

# Packet Switching: Message Segmenting




Now break up the message into 5000 packets

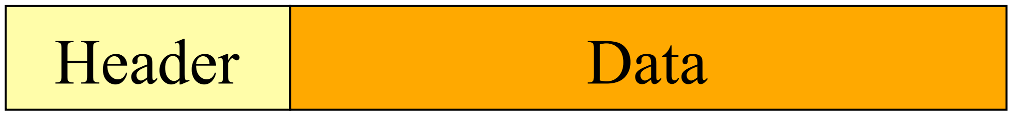
- Each packet 1,500 bits
- 1 msec to transmit packet on one link
- *pipelining:* each link works in parallel
- Delay reduced from 15 sec to 5.002 sec

Message switching iff dim pacchetti= dim. messaggio originale applicativo

See packet-switching vs. message switching (no segmentation) and the effect of queueing delay through the Java applets on the Kurose-Ross website.

# Effect of packet sizes

Packet format




- A longer packet (more data transmitted in a single packet) leads to a lower overhead
- Longer packets result in a higher chance to be corrupted (critical especially for wireless transmission)
- When a packet is corrupted all the data are lost and need to be retransmitted
- Longer packets might decrease the paralellism of transmission

# Packet-switched networks: forwarding

- *Goal:* move packets through routers from source to destination
  - we'll study several path selection (i.e. routing)algorithms (chapter 4)
- datagram network:
  - *destination address* in packet determines next hop
  - routes may change during session
  - analogy: driving, asking directions
- virtual circuit network:
  - each packet carries tag (virtual circuit ID), tag determines next hop
  - fixed path determined at *call setup time*, remains fixed thru call; VC share network resources
  - *routers maintain per-call state (the link on which a packet with a VC tag arriving to a given inbound link has to be forwarded and its VC tag on the next hop)*
  - Virtual circuit number changes from hop to hop. Each router has to map incoming interface, incoming VC # in outgoing interface, outgoing VC #
    - Why? (what would be the size of the VC number field and the complexity of the VC number assignment in case the same VC # had to be used over the whole path??)

**Internet L3 protocol: IP**

**MPLS**

# Network Taxonomy