ΔΙΚΤΥΑ ΕΠΙΚΟΙΝΩΝΙΩΝ/ΕΠΙΚΟΙΝΩΝΙΑΣ ΥΠΟΛΟΓΙΣΤΩΝ

ΒΙΒΛΙΑ:

(TEXTBOOKS ON: Computer Networks)

- James Kurose, Keith Rose,
  «Computer Networking: A Top-Down Approach Featuring the Internet».

- Andrew S. Tanenbaum,
  «Computer Networks».

Πολλές εκδόσεις και τα δύο!

ΠΟΥ ΑΛΛΟΥ ΔΙΔΑΣΚΕΤΑΙ ΤΟ 1Ο ΒΙΒΛΙΟ

(ενδεικτικά στην ΕΛΛΑΔΑ):

ΩΣ ΠΡΩΤΗ ΕΠΙΛΟΓΗ ΒΙΒΛΙΟΥ

- **ΕΘΝΙΚΟ & ΚΑΠΟΔΙΣΤΡΙΑΚΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΑΘΗΝΩΝ ΠΛΗΡΟΦΟΡΙΚΗΣ ΚΑΙ ΤΗΛΕΠΙΚΟΙΝΩΝΙΩΝ**
- **Ε.Μ.Π. – ΗΛΕΚΤΡΟΛΟΓΟΙ**
  Μάθημα [3298]: ΔΙΚΤΥΑ ΥΠΟΛΟΓΙΣΤΩΝ
- **ΑΙΣΤΟΤΕΛΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΟΝΙΚΗΣ**
  Μάθημα [TH0501]: Δίκτυα Τηλεπικοινωνιών

ΠΡΟΣΩΠΙΚΑ ΑΠΟ ΤΟ 2000!

ΠΟΥ ΑΛΛΟΥ ΔΙΔΑΣΚΕΤΑΙ ΤΟ 1Ο ΒΙΒΛΙΟ

(ενδεικτικά στο ΕΞΩΤΕΡΙΚΟ):

Columbia University (USA): http://www.cs.columbia.edu/~danr/4119/4119-info.pdf
Stanford University (USA): http://www.scs.stanford.edu/08sp-cs144/notes/l1.pdf
Tufts University (USA): http://www.cs.tufts.edu/comp/112/
University of California at Santa Barbara (USA):
http://www.cs.ucsb.edu/~almeroth/classes/S06.176A
University of California at Berkley (USA):
http://www.google.gr/url?sa=t&rct=j&q=where%20the%20book%20of%20kurose%20-%20ross%20%22computer%20networking%22%20is%20taught&source=web&cd=7&ved=0CF8QFjAG&url=http%3A%2F%2Fwww-inst.eecs.berkeley.edu%2F~ee122%2Ffa10%2Fnotes%2F01-Overview.ppt&ei=nNT1T_mOCKn74QT5-_zsBg&usg=AFQjCNH4Q_ApOrmHK0pyAZFLw9uiO7-Djg
New York University (USA**):** http://www.nyu.edu/classes/jcf/CSCI-GA.2262-001/index.html
The University of Texas at Austin (USA): http://www.cs.utexas.edu/~vin/Classes/CS386M-Fall04/
Ira A. Fulton Schools of Engineering at Arizona State University (USA):
http://enpub.fulton.asu.edu/iacdev/courses/eee459/home.html
The University of Utah (USA): http://www.eng.utah.edu/~cs5480/
Rose-Hulman Institute of Technology (USA):
http://www.rose-hulman.edu/class/csse/csse432/201230/syllabus.html
University of Saarlandes (Germany): http://depend.cs.uni-sb.de/index.php?413
University of Torino (Italy):
http://disi.unitn.it/locigno/index.php/teaching-duties/advanced-networking/advanced-networkingaa09-10

Part I: Introduction

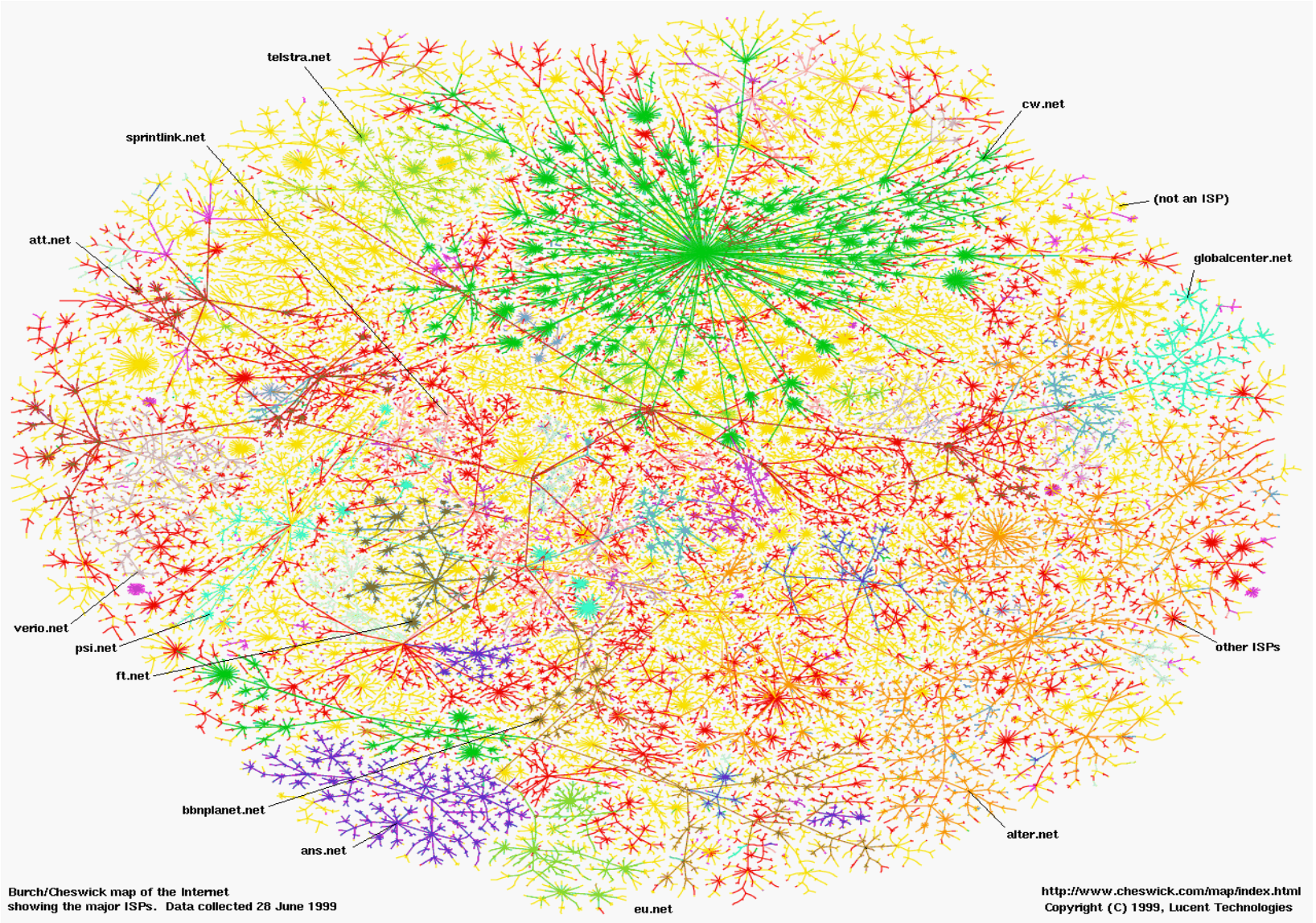
Chapter goal:

- get context, overview, "feel" of networking
- more depth, detail *later* in course
- approach:
  - descriptive
  - use Internet as example

Overview:

- what's the Internet
- what's a protocol?
- network edge
- network core
- access net, physical media
- performance: loss, delay
- protocol layers, service models
- backbones, NAPs, ISPs
- history
- ATM network

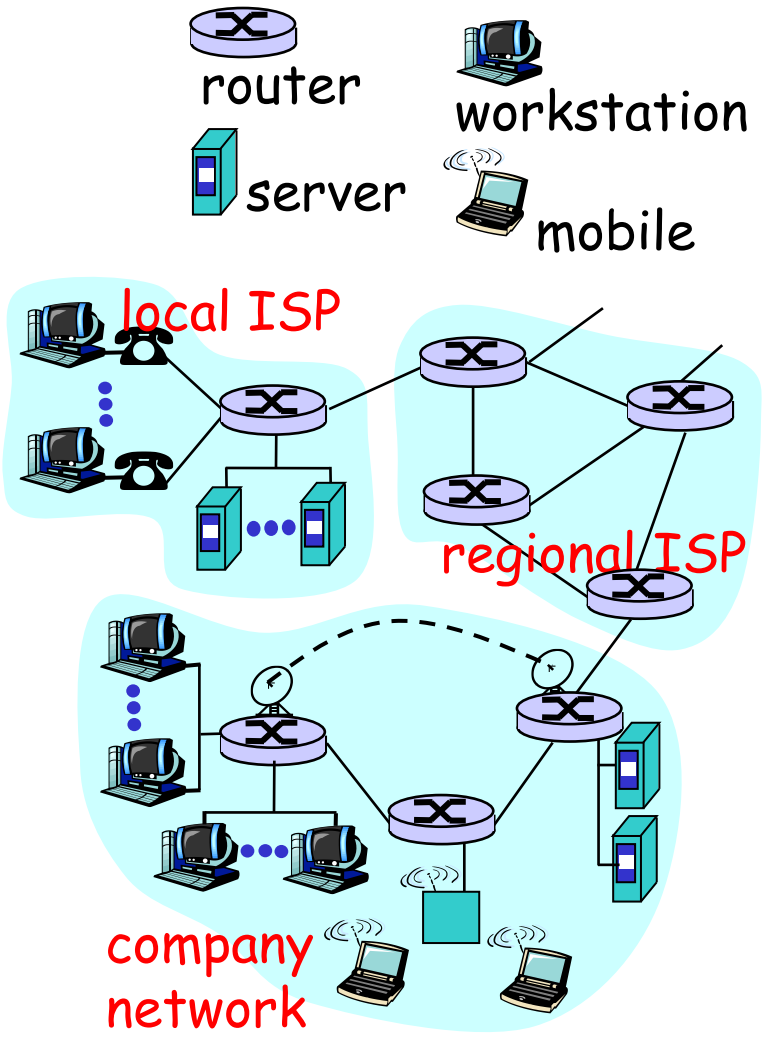
Παράδειγμα Δικτύου



What's the Internet: "nuts and bolts" view

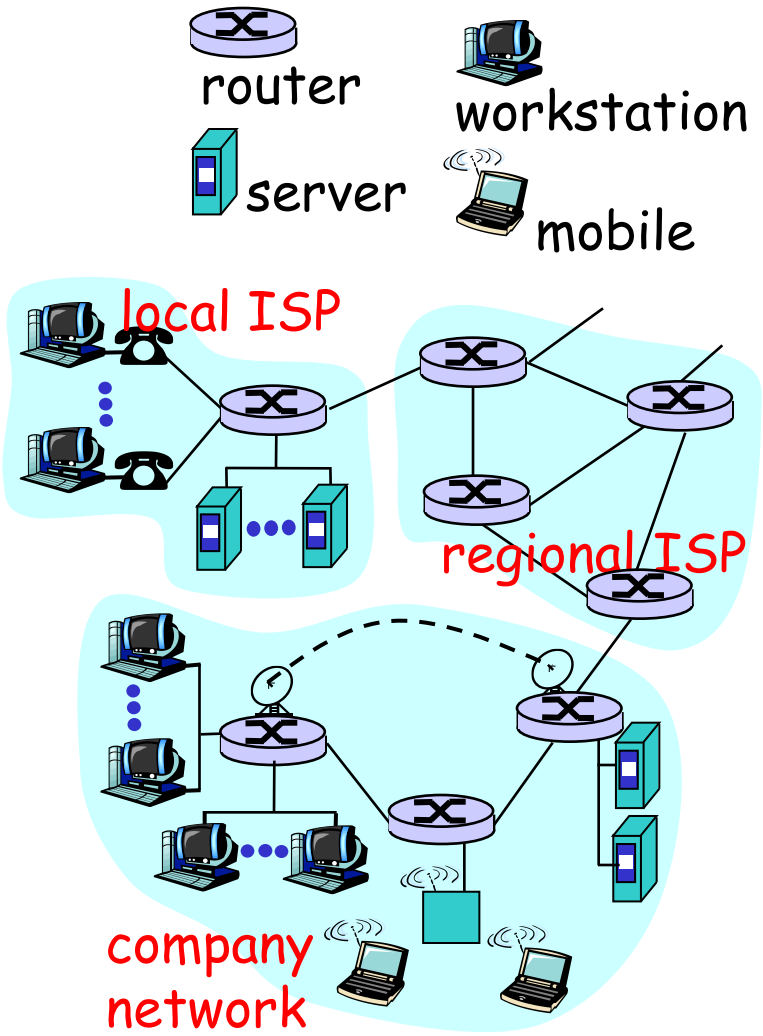
- millions of connected computing devices: *hosts, end-systems*
  - pc's workstations, servers
  - PDA's phones, toasters

  running *network apps*
- *communication links*
  - fiber, copper, radio, satellite
- *routers:* forward packets (chunks) of data thru network



What's the Internet: "nuts and bolts" view

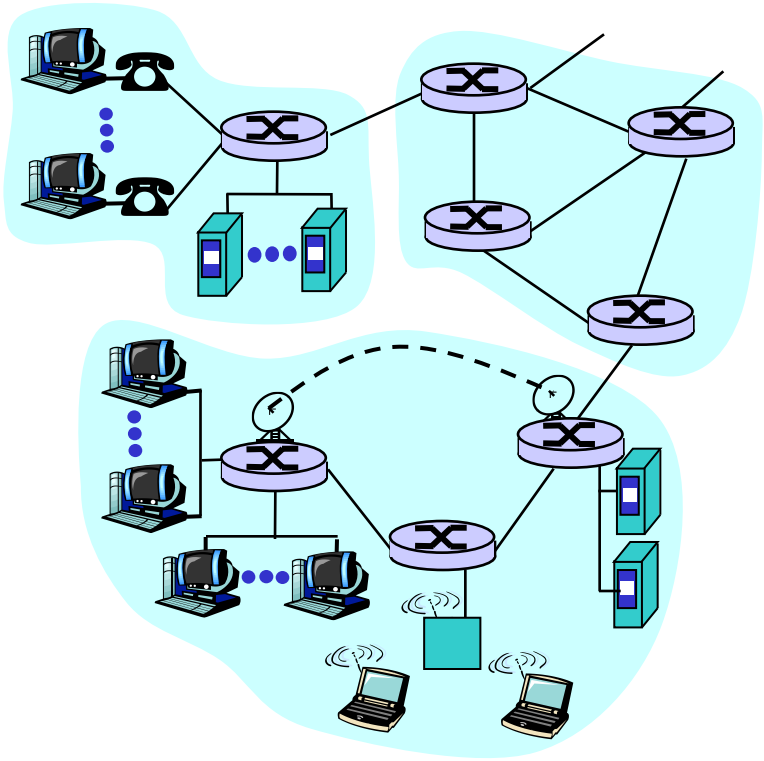
- *protocols*: control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, FTP, PPP
- *Internet*: "network of networks"
  - loosely hierarchical
  - public Internet versus private intranet
- Internet standards
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



What's the Internet: a service view

- communication *infrastructure* enables distributed applications:
  - WWW, email, games, e-commerce, database., voting,
  - more?
- communication services provided:
  - connectionless
  - connection-oriented
- cyberspace [Gibson]:

  "a consensual hallucination experienced daily by billions of operators, in every nation, ..."



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

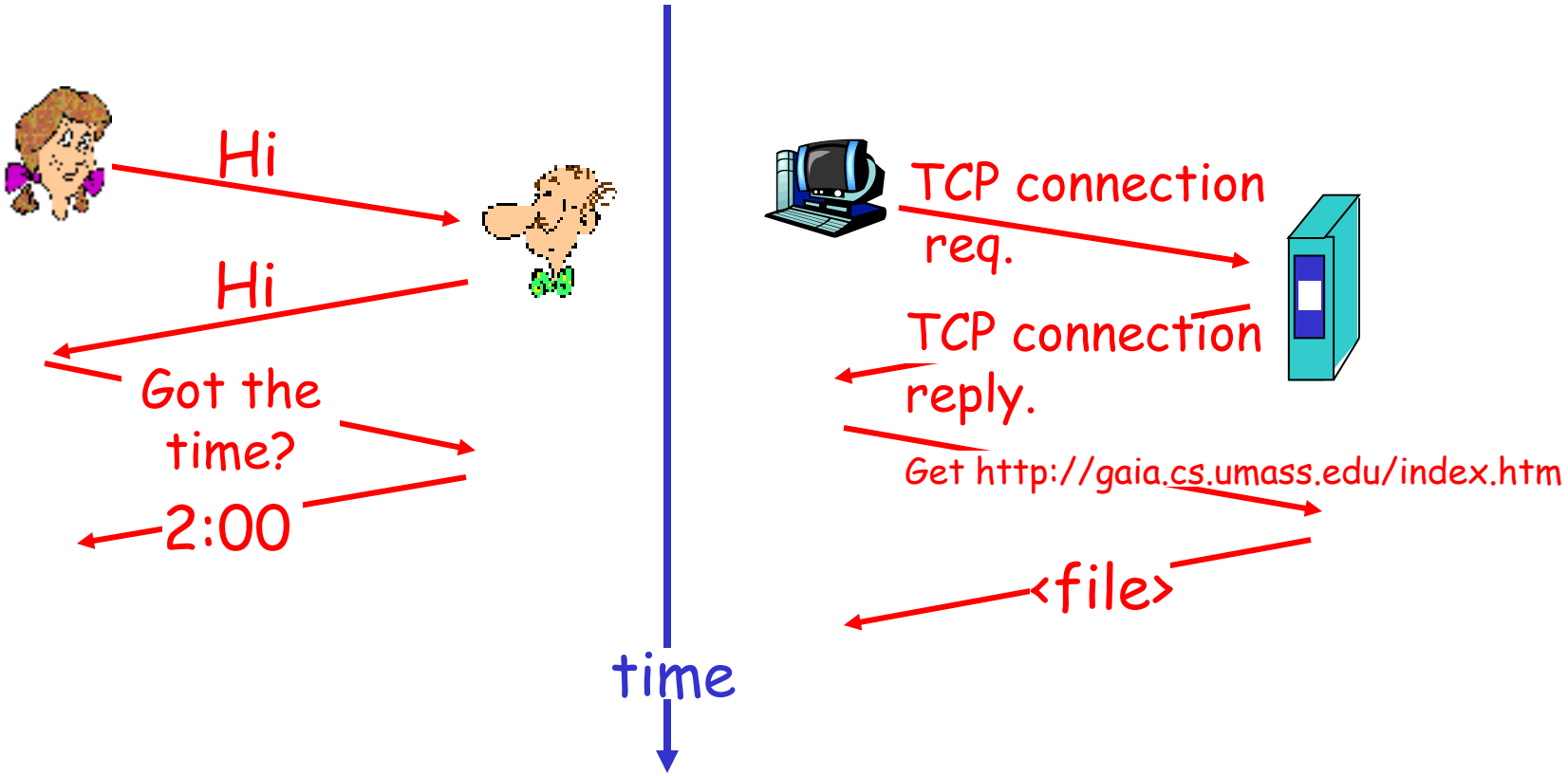
network protocols:

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

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

What's a protocol?

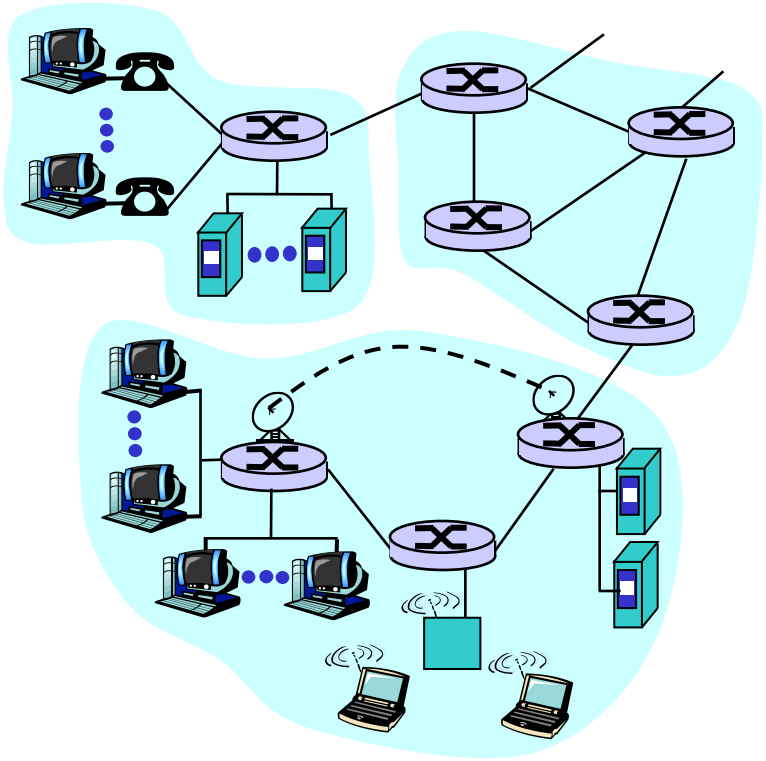
a human protocol and a computer network protocol:



Q: Other human protocol?

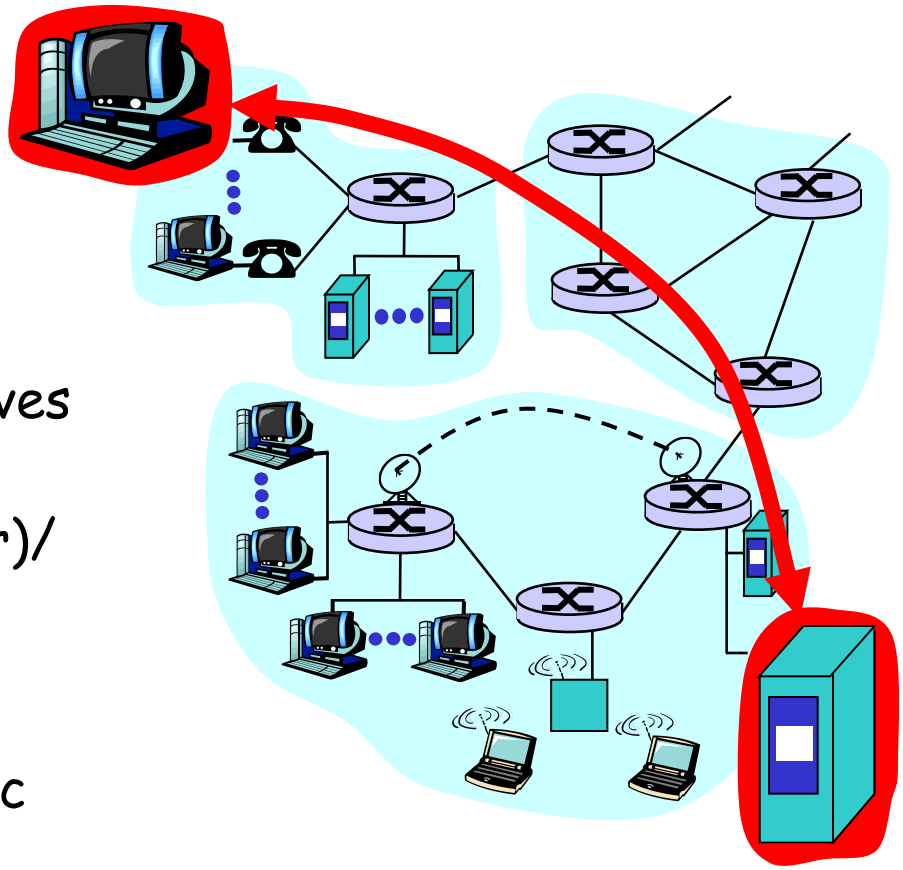
A closer look at network structure:

- network edge: applications and hosts
- network core:
  - routers
  - network of networks
- access networks, physical media: communication links



The network edge:

- end systems (hosts):
  - run application programs
  - e.g., WWW, email
  - at "edge of network"
- client/server model
  - client host requests, receives service from server
  - e.g., WWW client (browser)/ server; email client/server
- peer-peer model:
  - host interaction symmetric
  - e.g.: teleconferencing



Network edge: connection-oriented service

Goal: data transfer between end sys.

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

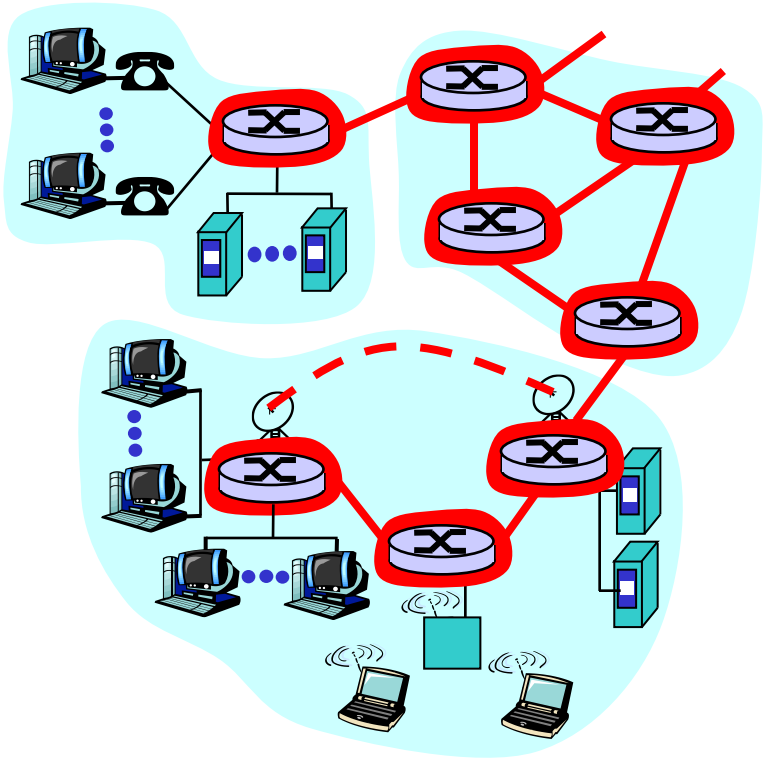
- HTTP (WWW), FTP (file transfer), Telnet (remote login), SMTP (email)

App's using UDP:

- streaming media, teleconferencing, Internet telephony

The Network Core

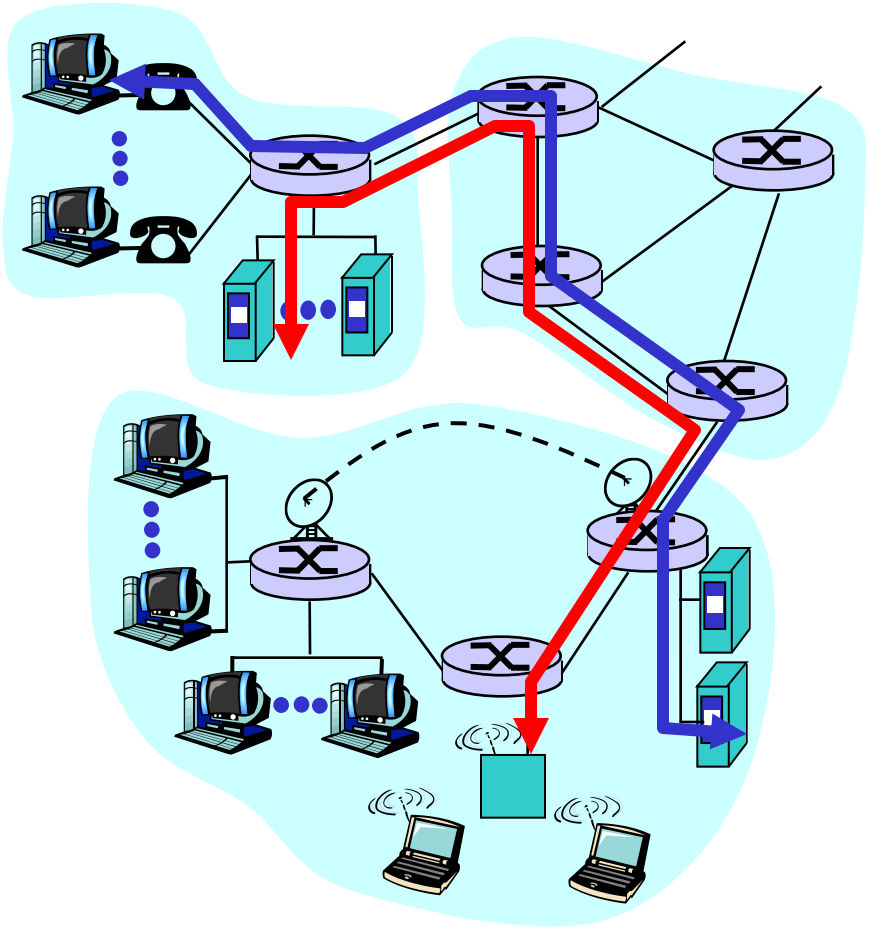
- mesh of interconnected routers
- *the* fundamental question: how is data transferred through net?
  - circuit switching: dedicated circuit per call: telephone net
  - packet-switching: data sent thru net in discrete "chunks"



Network Core: Circuit Switching

End-end resources reserved for "call"

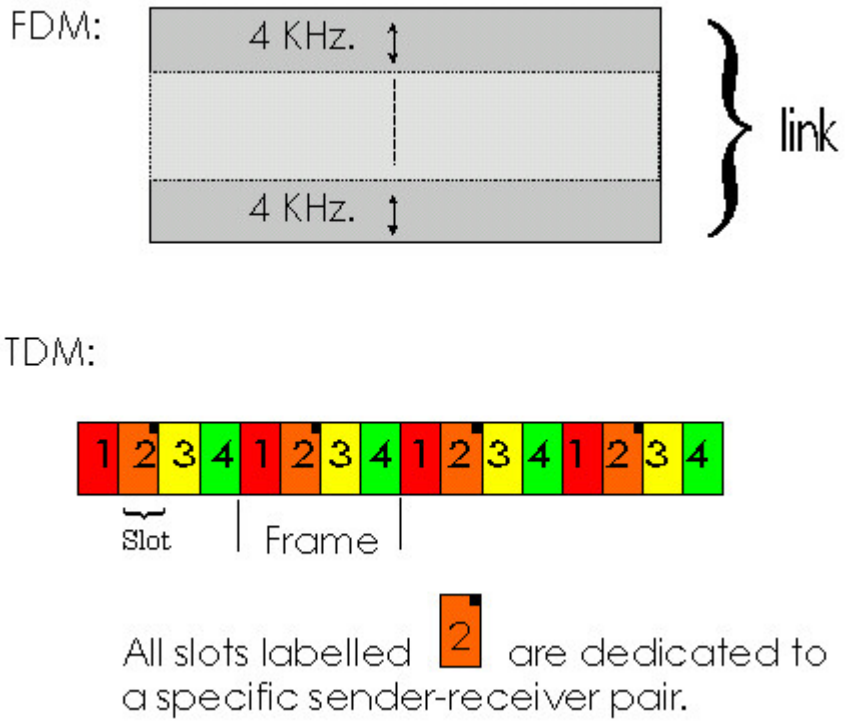
- link bandwidth, switch capacity
- dedicated resources: no sharing
- circuit-like (guaranteed) performance
- call setup required



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

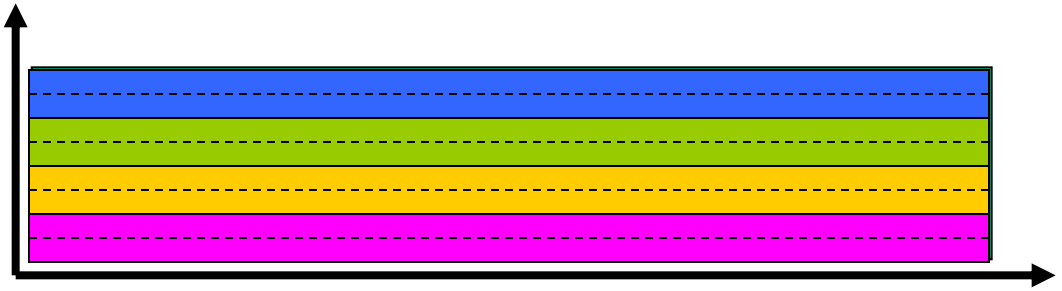


Circuit switching: FDM versus TDM

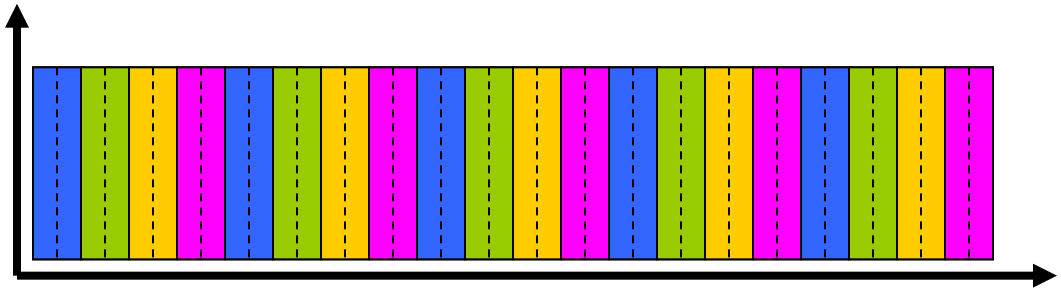
Example:

4 users

FDM



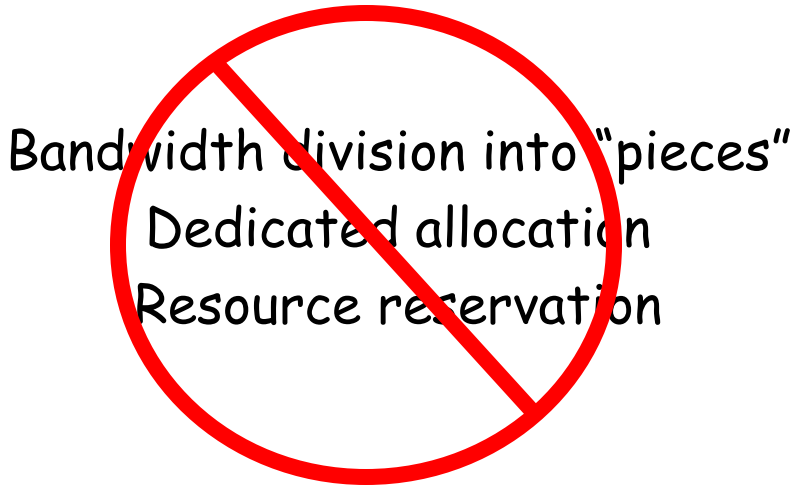
TDM



Network Core: Packet Switching

each end-end data stream divided into *packets*

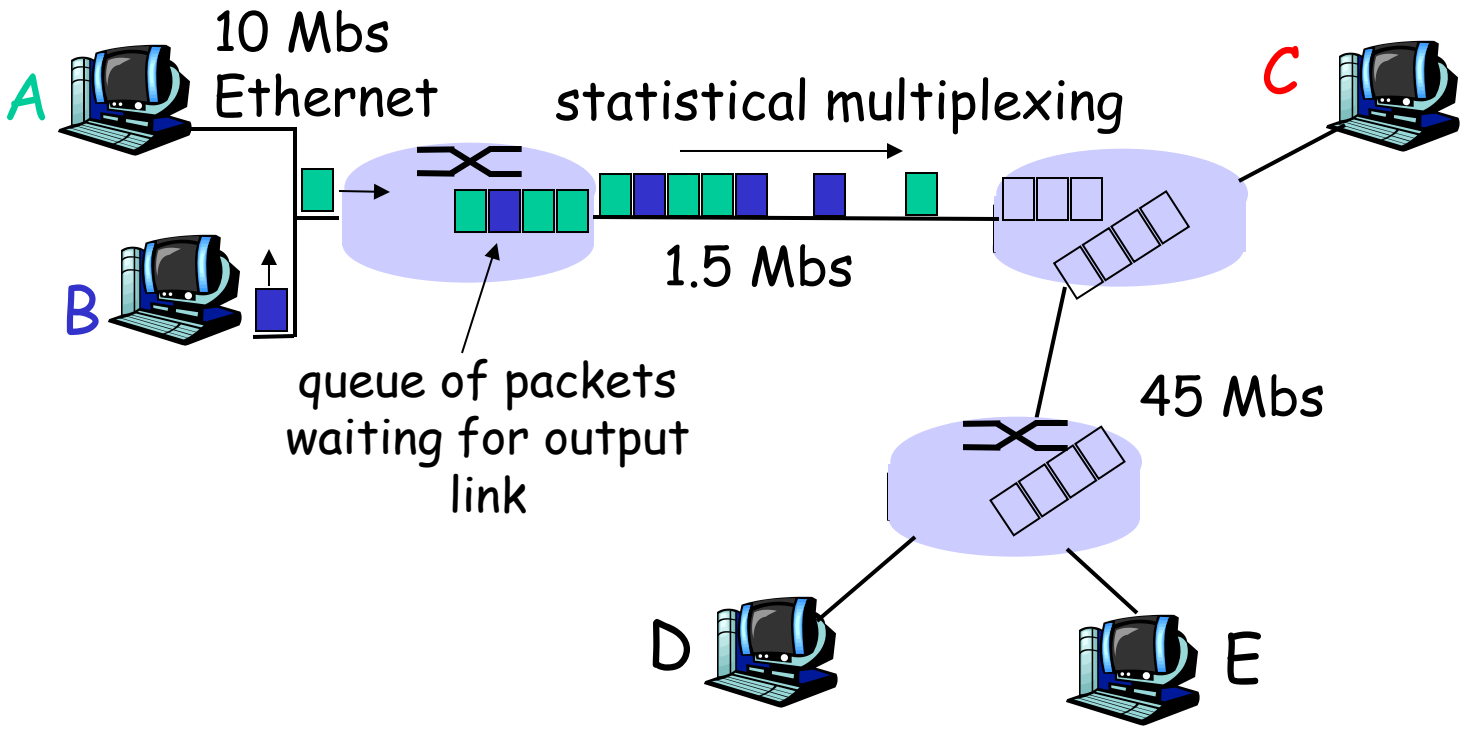
- user A, B packets *share* network resources
- each packet uses full link bandwidth
- resources used *as needed*,



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
  - transmit over link
  - wait turn at next link

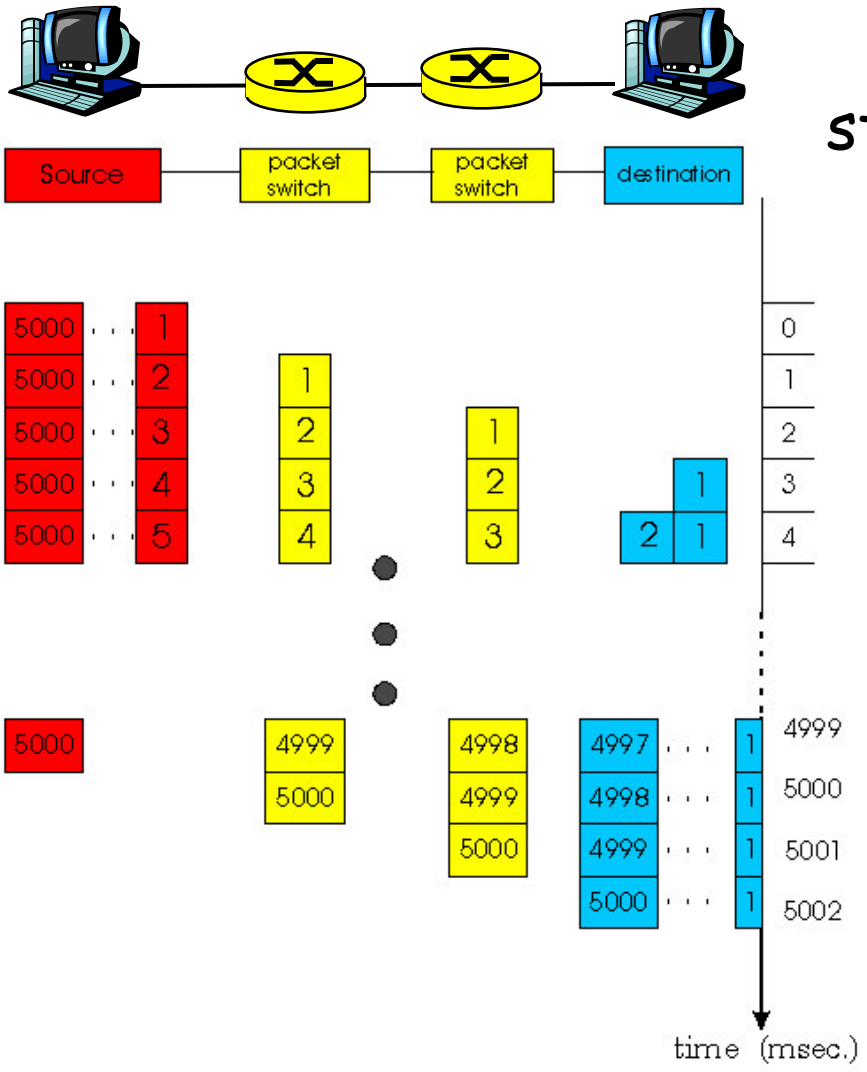
Network Core: Packet Switching



Packet-switching versus circuit switching: human restaurant analogy

- other human analogies?

Network Core: Packet Switching

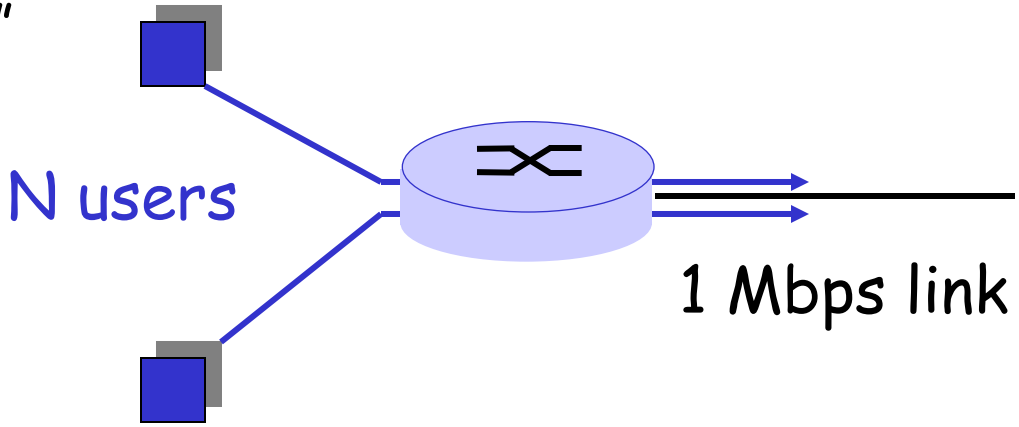


Packet-switching:
store and forward behavior

Packet switching versus circuit switching

Packet switching allows more users to use network!

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



Packet switching versus circuit switching

Is packet switching a "slam dunk winner?"

- Great for bursty data
  - resource sharing
  - no call setup
- Excessive congestion: packet delay and loss
  - protocols needed for reliable data transfer, congestion control
- Q: How to provide circuit-like behavior?
  - bandwidth guarantees needed for audio/video apps

  still an unsolved problem (chapter 6)

Packet-switched networks: routing

- *Goal:* move packets among routers from source to destination
  - we'll study several path selection algorithms (chapter 4)
- datagram network:
  - *destination address* 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
  - routers maintain per-call state

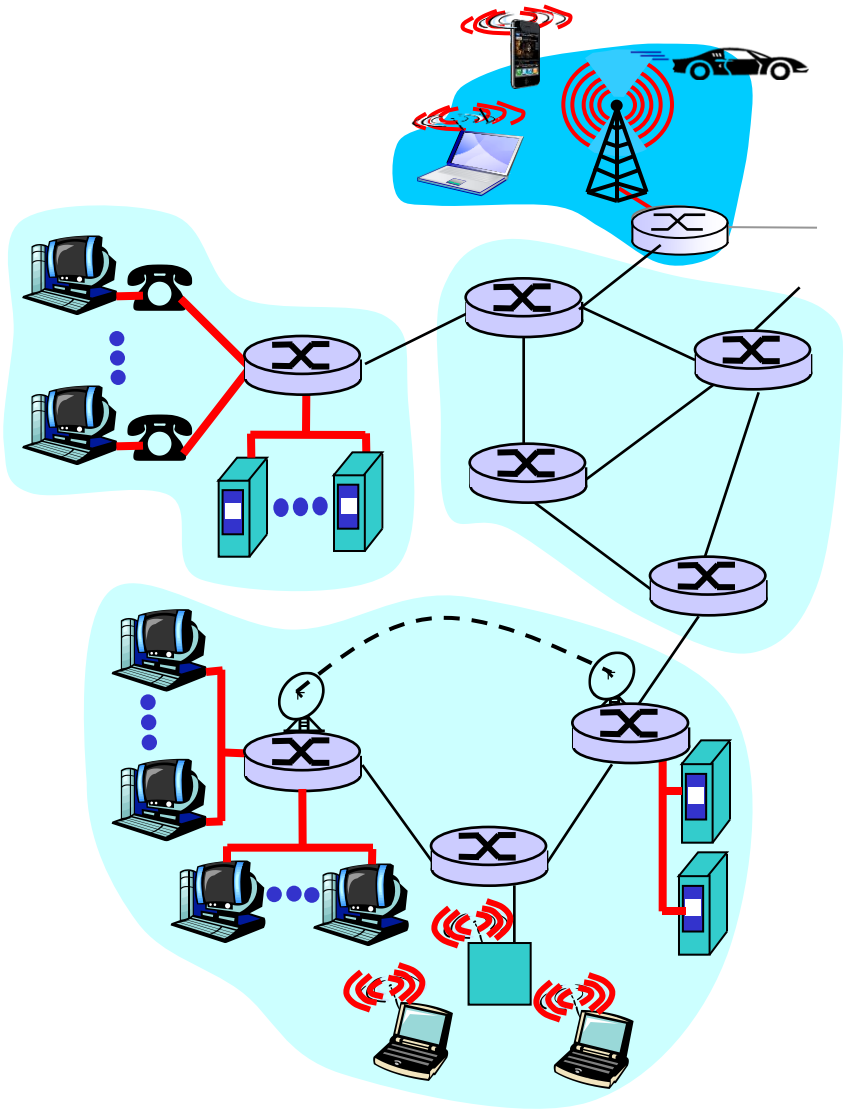
Access networks and physical media

Q: How to connection end systems to edge router?

- residential access nets
- institutional access networks (school, company)
- mobile access networks

Keep in mind:

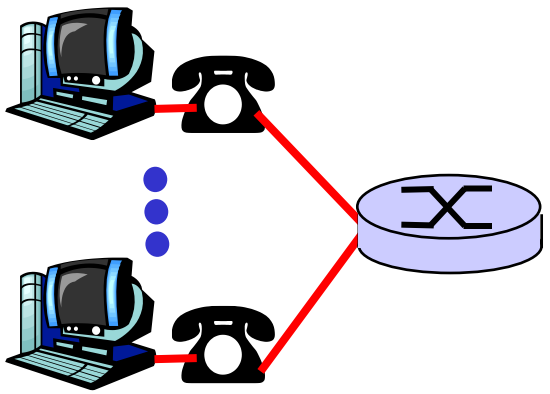
- bandwidth (bits per second) of access network?
- shared or dedicated?



Residential access: point to point access

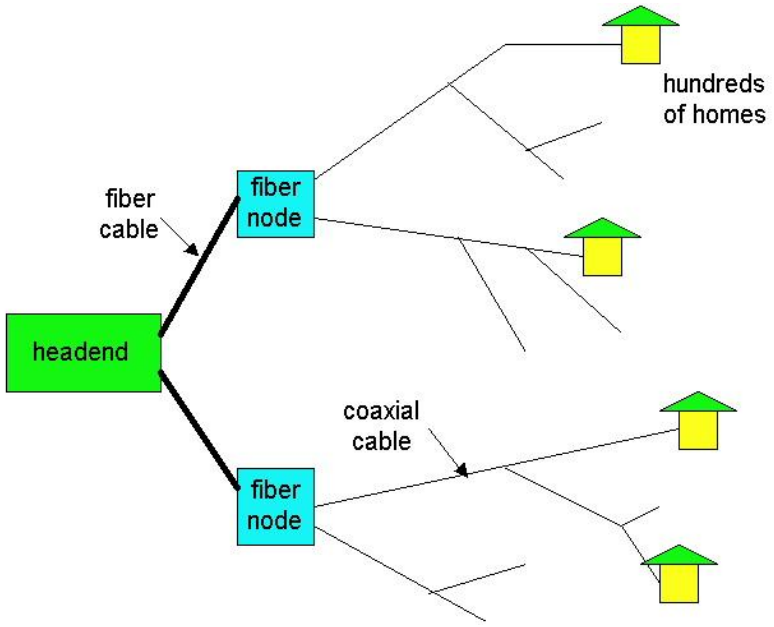
- Dialup via modem
  - up to 56Kbps direct access to router (conceptually)
- ISDN: intergrated services digital network: 128Kbps all-digital connect to router
- ADSL: asymmetric digital subscriber line
  - up to 2 Mbps home-to-router
  - up to 24 Mbps router-to-home
- VDSL/VDSL2: Very-high-speed DSL
  - up to 3/100 Mbps home-to-router
  - up to 55/300 Mbps router-to-home

Υψηλές ταχύτητες σε κοντινές αποστάσεις.



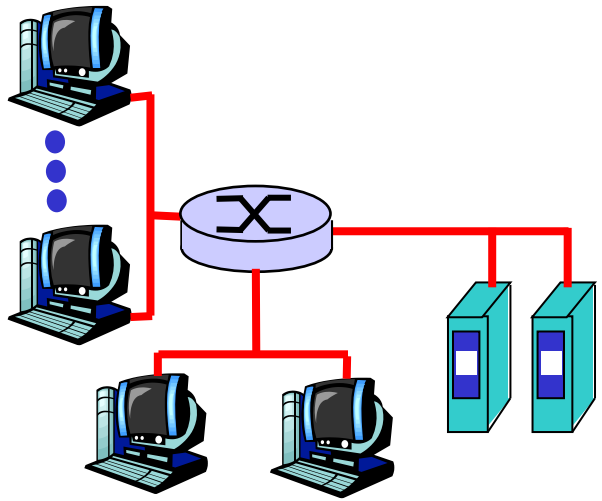
Residential access: cable modems

- HFC: hybrid fiber coax
  - asymmetric: up to 100 Mbps upstream, up to 1 Gbps downstream
- network of cable and fil attaches homes to ISP router
  - shared access to router among home
  - issues: congestion, dimensioning
- deployment: available via cable companies, e.g., MediaOne



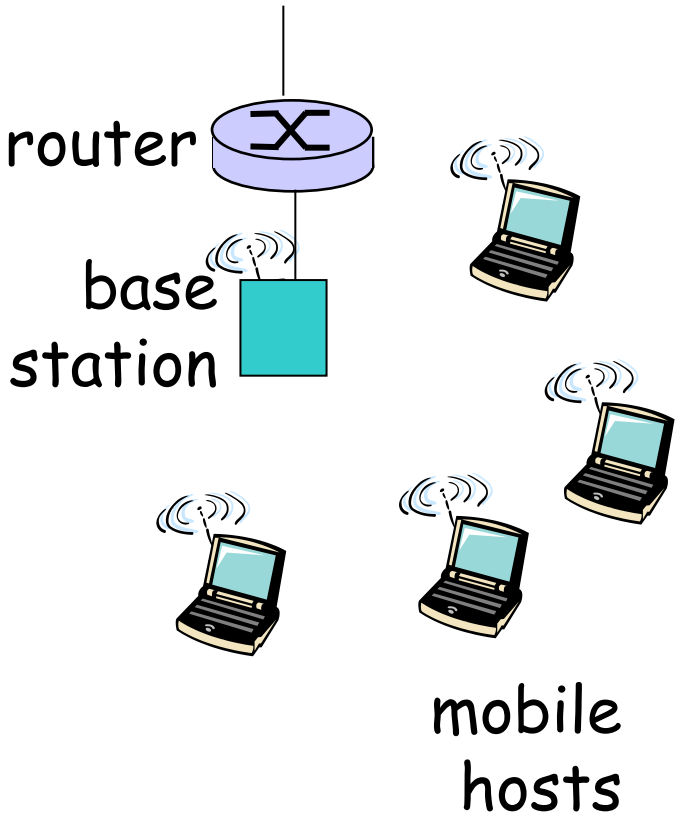
Institutional access: local area networks

- company/univ local area network (LAN) connects end system to edge router
- Ethernet:
  - shared or dedicated cable connects end system and router
  - 10 Mbs, 100Mbps, Gigabit Ethernet
- deployment: institutions, home LANs soon
- LANs: chapter 5



Wireless access networks

- shared *wireless* access network connects end system to router
- wireless LANs:
  - radio spectrum replaces wire
  - e.g., Lucent Wavelan 10 Mbps
- wider-area wireless access
  - CDPD: wireless access to ISP router via cellular network



Physical Media

- physical link: transmitted data bit propagates across link
- guided media:
  - signals propagate in solid media: copper, fiber
- unguided media:
  - signals propagate freelye.g., radio

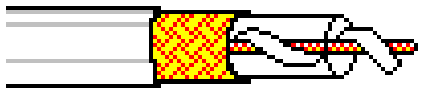
Twisted Pair (TP)

- two insulated copper wires
  - Category 3: traditional phone wires, 10 Mbps ethernet
  - Category 5 TP: 100Mbps ethernet

Physical Media: coax, fiber

Coaxial cable:

- wire (signal carrier) within a wire (shield)
  - baseband: single channel on cable
  - broadband: multiple channel on cable
- bidirectional
- common use in 10Mbs Ethernet



Fiber optic cable:

- glass fiber carrying light pulses
- high-speed operation:
  - 100Mbps Ethernet
  - high-speed point-to-point transmission (e.g., 5 Gps)
- low error rate

Physical media: radio

- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

Radio link types:

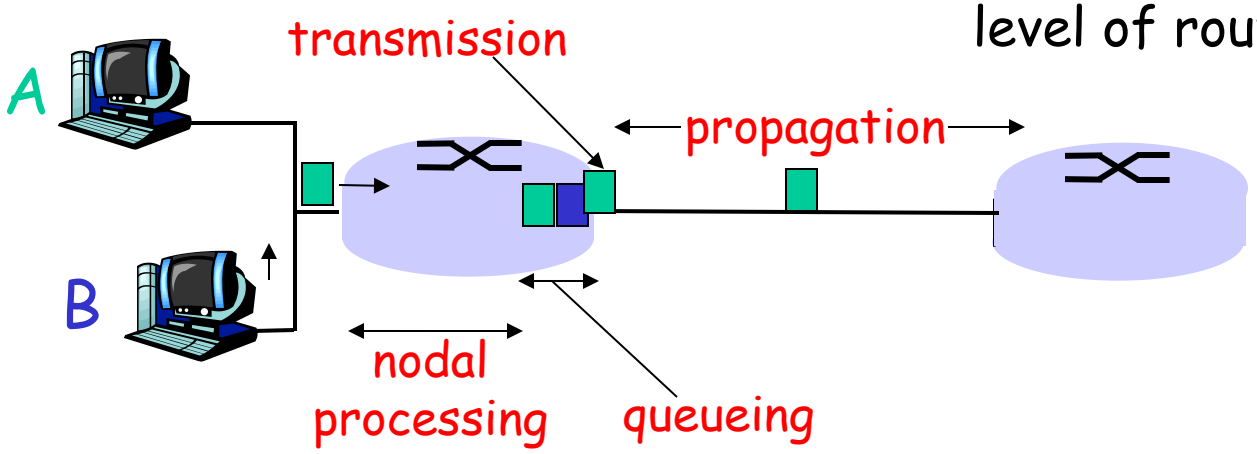
- microwave
  - e.g. up to 45 Mbps channels
- LAN (e.g., waveLAN)
  - 2Mbps, 11Mbps
- wide-area (e.g., cellular)
  - e.g. CDPD, 10's Kbps
- satellite
  - up to 50Mbps channel (or multiple smaller channels)
  - 270 Msec end-end delay
  - geosynchronous versus LEOS

Delay in packet-switched networks

packets experience delay on end-to-end path

- four sources of delay at each hop

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



Delay in packet-switched networks

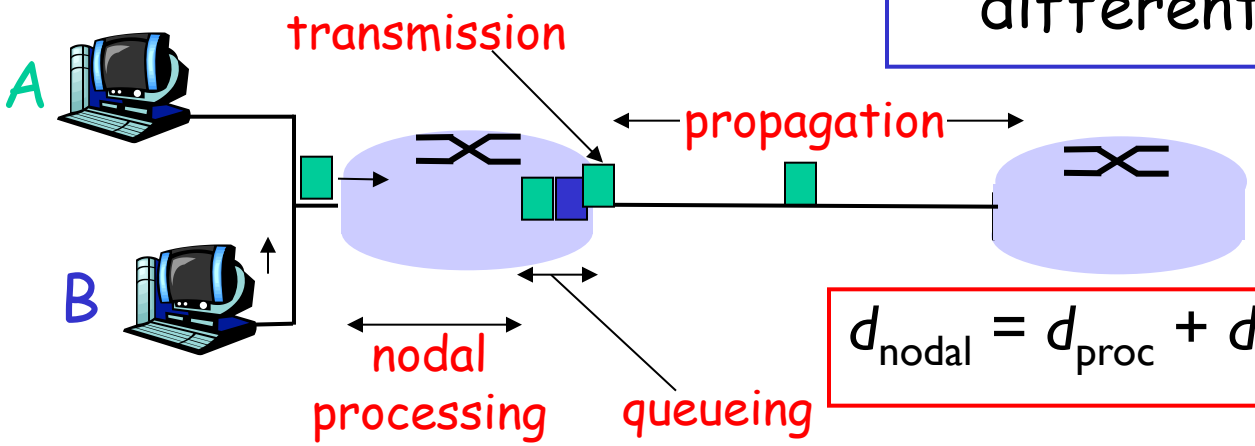
Transmission delay:

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

Propagation delay:

- d = length of physical link
- s = propagation speed in medium (~2×10^8 m/sec)
- propagation delay = d/s

Note: s and R are *very* different quantitites!

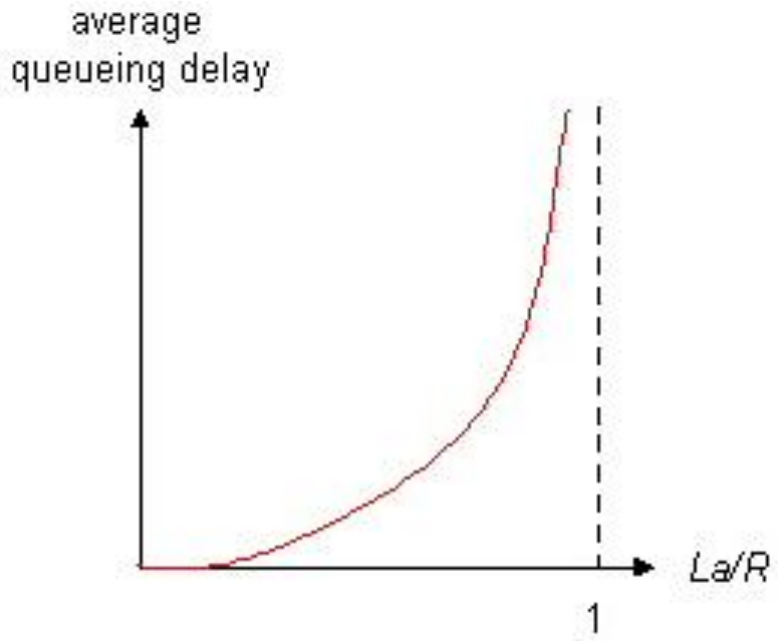


$$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$$

Queueing delay (revisited)

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

traffic intensity = La/R



- La/R ~ 0: average queueing delay small
- La/R -> 1: delays become large
- La/R > 1: more "work" arriving than can be serviced, average delay infinite!

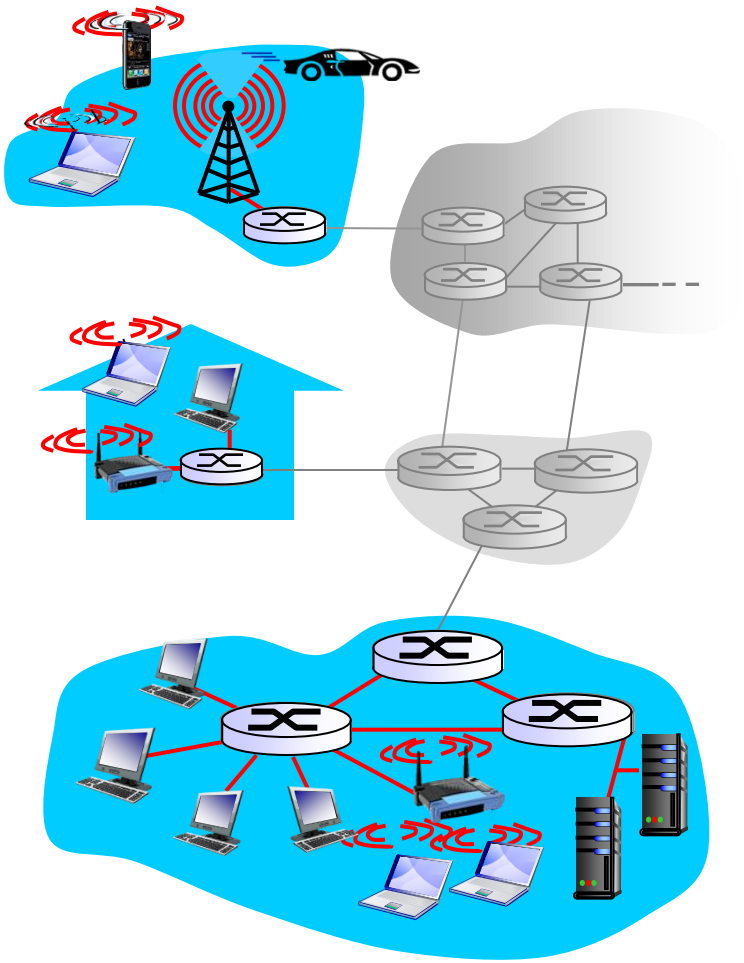
La/R ~ 0

La/R -> 1

Δίκτυα πρόσβασης και φυσικά μέσα

Ε: Πως μπορεί να συνδεθεί ένα τερματικό σύστημα με τον περιφερειακό δρομολογητή του;

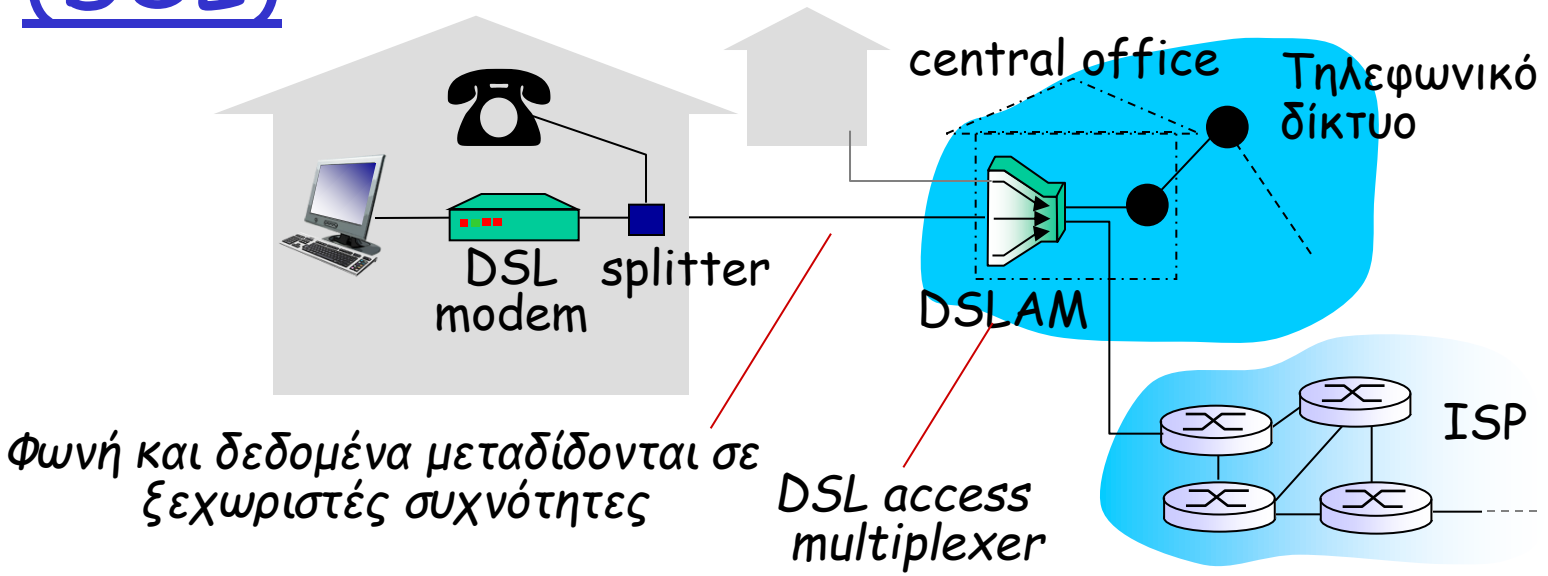
- Δίκτυα οικιακής πρόσβασης
- Δίκτυα εταιρικής πρόσβασης (σχολεία, εταιρείες)
- Δίκτυα ασύρματης πρόσβασης



Σημείωση:

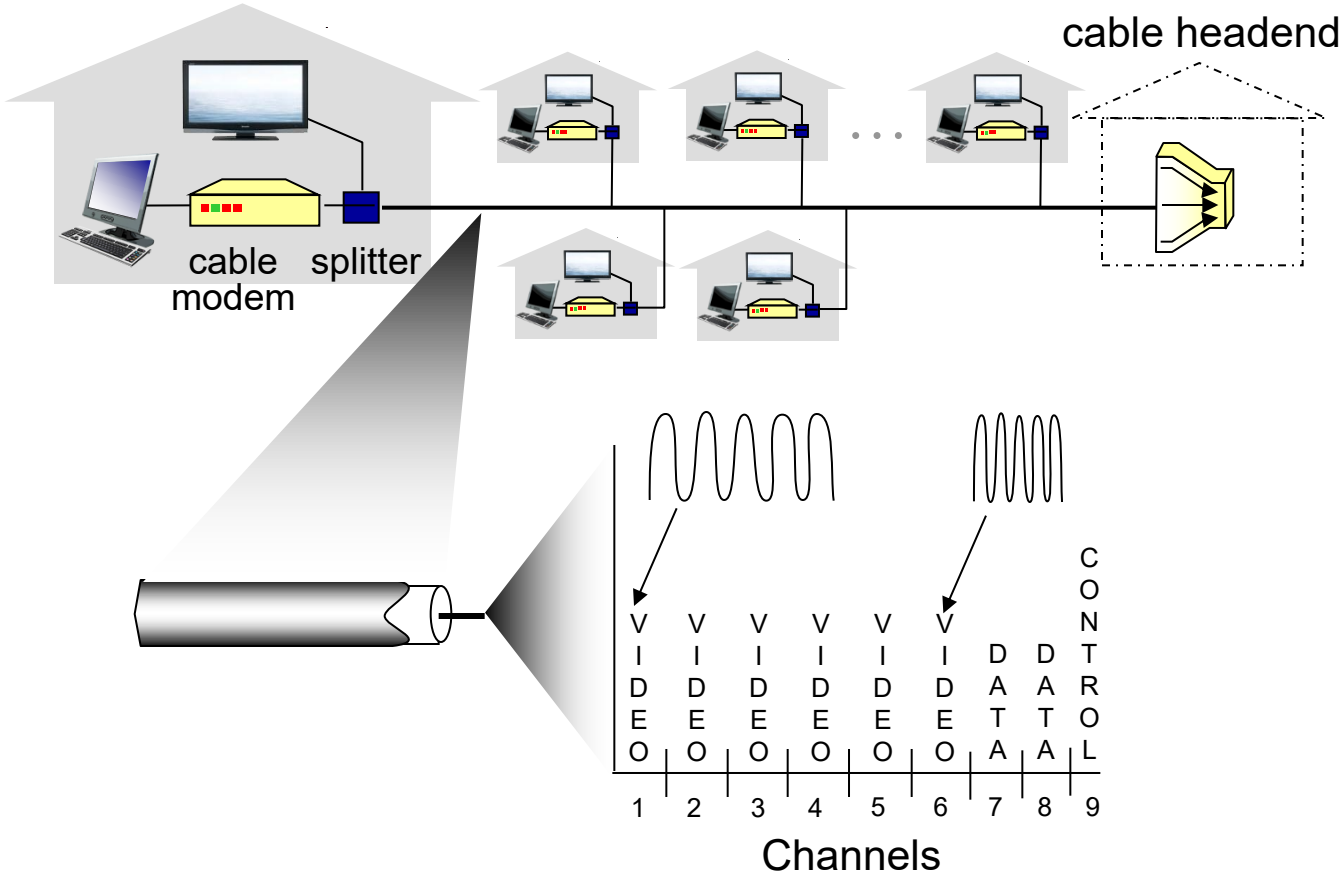
- Εύρος ζώνης (bits per second) δικτύου πρόσβασης;
- Διαμοιραζόμενο (shared) ή αποκλειστικής χρήσης (dedicated);

Πρόσβαση: Digital Subscriber Line (DSL)



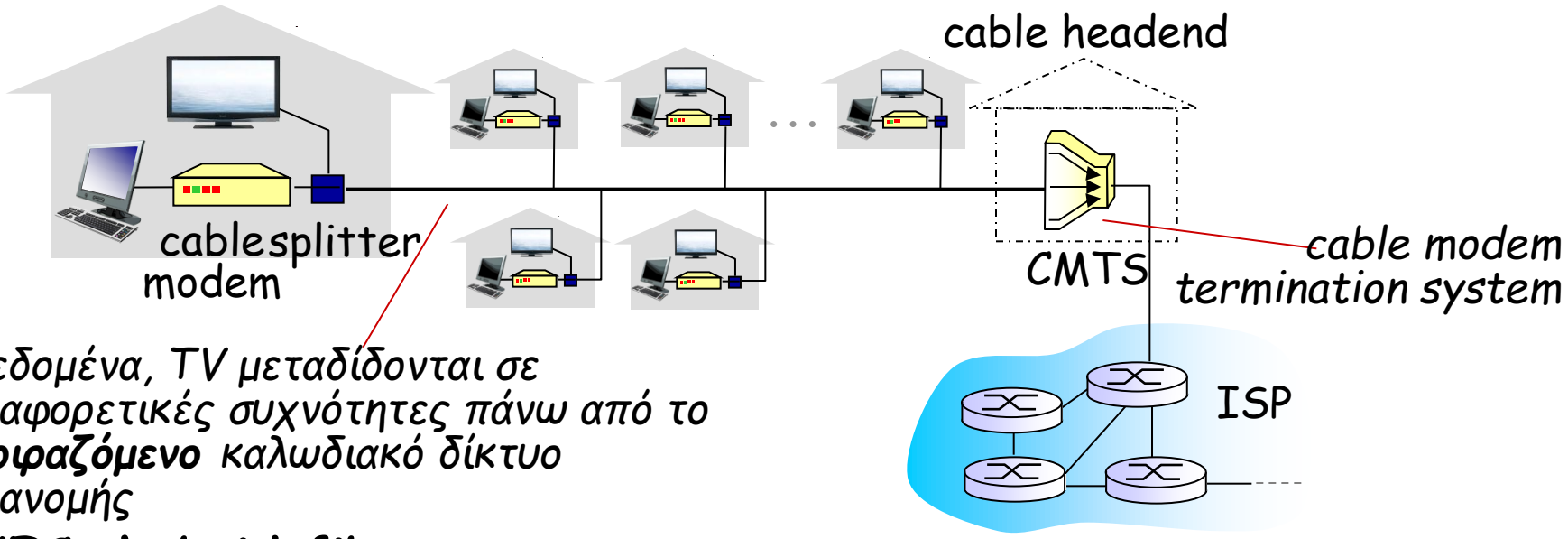
- Χρήση **υφιστάμενης** τηλεφωνικής γραμμής προς το DSLAM του κέντρου
  - Τα δεδομένα πάνω από την γραμμή DSL πάνε στο Διαδίκτυο
  - Η φωνή πάνω από την γραμμή DSL πάει στο τηλεφωνικό δίκτυο
- Upstream ρυθμός μετάδοσης < 2.5 Mbps (τυπικά < 1 Mbps)
- Downstream ρυθμός μετάδοσης < 24 Mbps (τυπικά < 10 Mbps)

Πρόσβαση: καλωδιακό δίκτυο



Πολύπλεξη διαίρεσης συχνότητας (frequency division multiplexing): Διαφορετικά κανάλια μεταδίδονται σε διαφορετικές ζώνες συχνοτήτων

Πρόσβαση: καλωδιακό δίκτυο

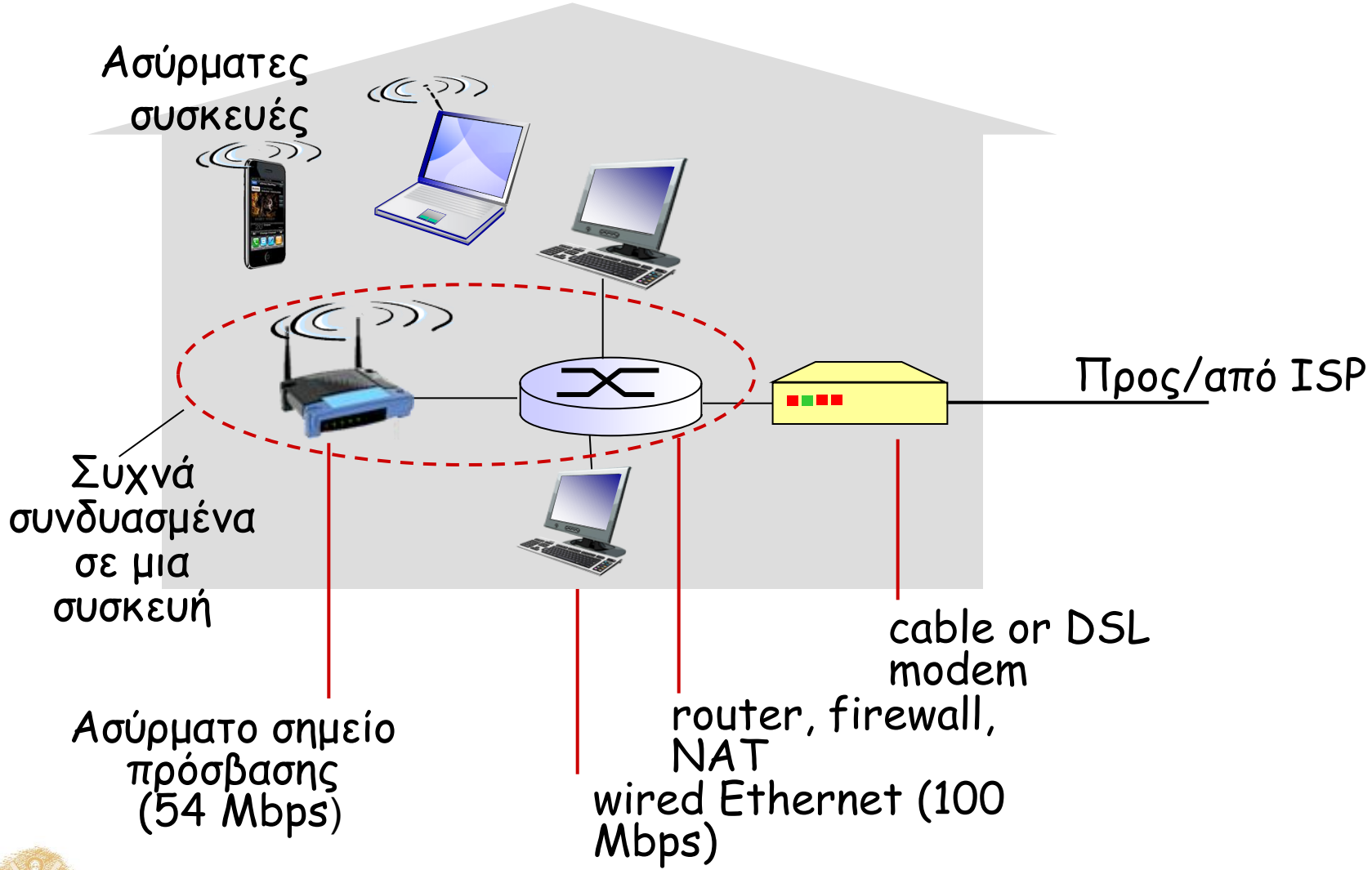


δεδομένα, TV μεταδίδονται σε διαφορετικές συχνότητες πάνω από το ***μοιραζόμενο*** *καλωδιακό δίκτυο διανομής*

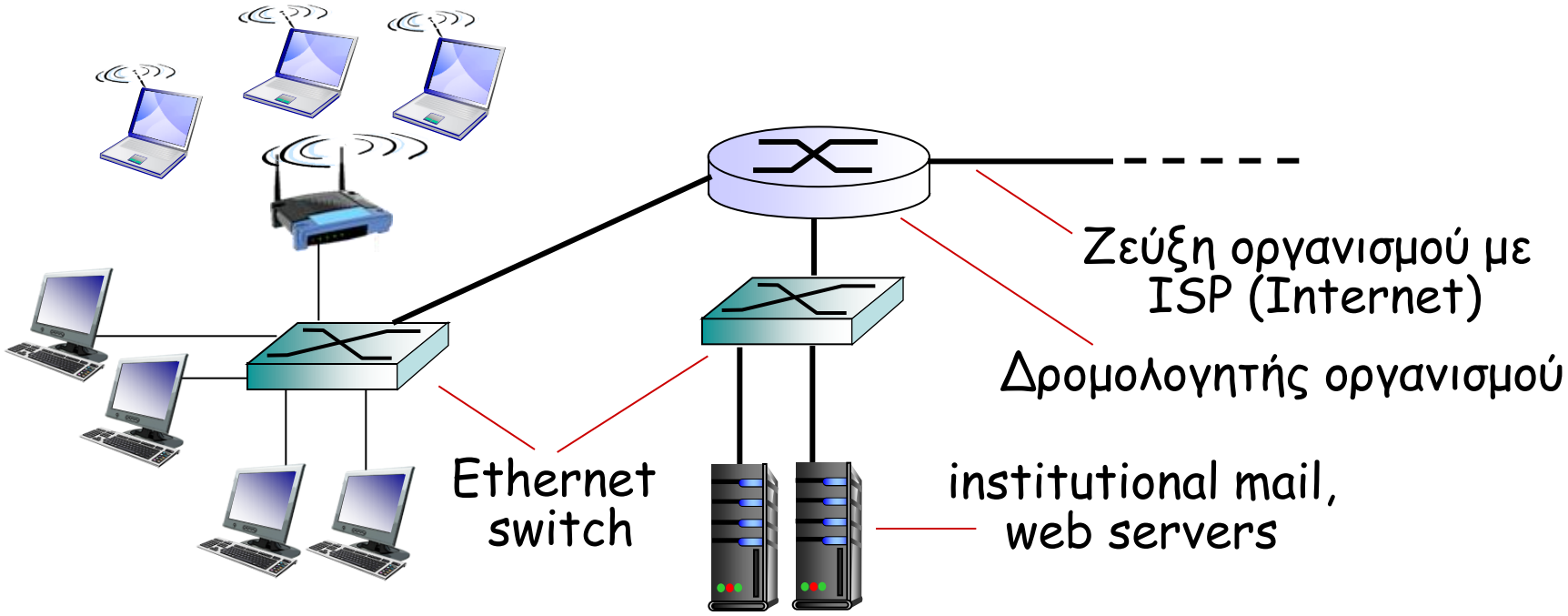
- **HFC: hybrid fiber coax**
  - ασύμμετρο: ρυθμός μετάδοσης μέχρι 30Mbps downstream, 2 Mbps upstream
- **Δίκτυο από καλώδιο και οπτική ίνα** συνδέει τα σπίτια με τον δρομολογητή ISP
  - Τα σπίτια ***μοιράζονται*** το δίκτυο πρόσβασης μέχρι το καλωδιακό κέντρο τερματισμού

  Αντίθετα το DSL προσφέρει αποκλειστική πρόσβαση

Πρόσβαση: οικιακό δίκτυο



Δίκτυα πρόσβασης επιχειρήσεων (Ethernet)



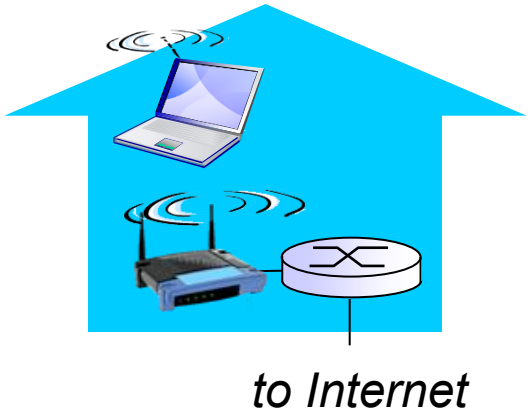
- Τυπική χρήση σε εταιρείες, πανεπιστήμια, κλπ
- Ρυθμοί μετάδοσης 10 Mbps, 100Mbps, 1Gbps, 10Gbps
- Σήμερα, τα τερματικά συστήματα συνδέονται σε μεταγωγείς Ethernet

Δίκτυα ασύρματης πρόσβασης

- Διαμοιραζόμενο δίκτυο ασύρματης πρόσβασης συνδέει τερματικά συστήματα με δρομολογητή
  - Μέσω σταθμού βάσης («σημείου πρόσβασης» - Access Point)

Ασύρματα LANs:

- Εντός κτιρίων (100 ft ή 30 m)
- 802.11b/g (WiFi): 11, 54 Mbps
- 802.11be: < 5 Gbps (θεωρ. 46 Gbps) Στα 2,4 ή 5 ή 6 GHz



Ασύρματη πρόσβαση ευρείας περιοχής WLAN:

- Παροχείς κυψελωτών συστημάτων, 10's km
- μεταξύ 1 και 10 Mbps
- 3G, 4G: LTE Σήμερα και 5G