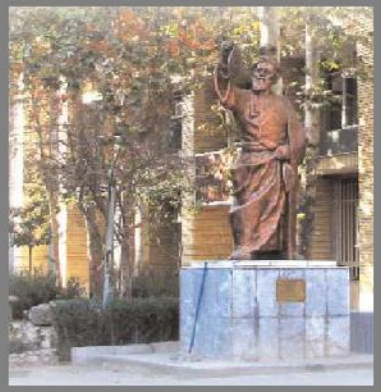
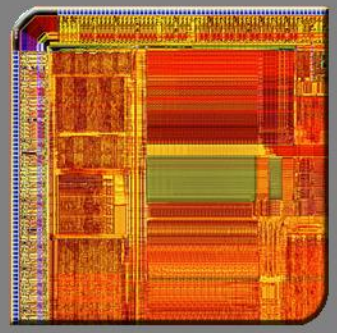
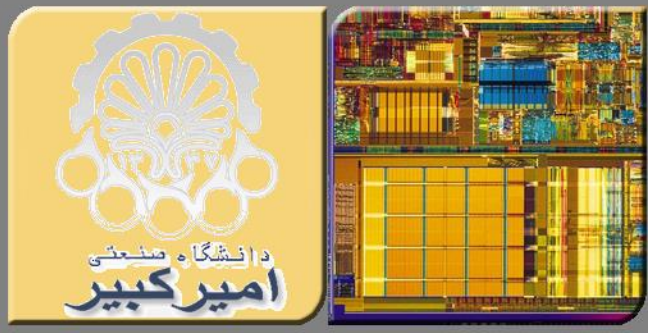
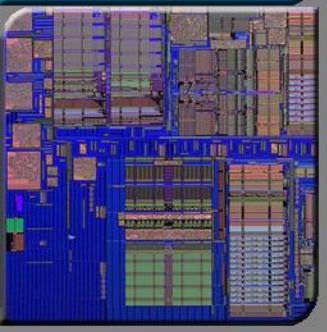






شبکه های کامپیوتری

فصل اول: مقدمه



مدرس: دکتر محمد حسن شیرعلی شهرضا
دانشگاه صنعتی امیرکبیر

بخش های فصل اول

۱-۱ اینترنت چیست؟

۱-۲ لبه های شبکه

- سیستم‌های انتهایی، شبکه های دسترسی، لینک‌ها

۱-۳ هسته شبکه

- سوئیچ بسته، سوئیچ مدار، ساختار شبکه

۱-۴ تاخیر، تلفات و بازده در شبکه‌ها

۱-۵ پروتکل لایه ها، مدل های سرویس

۱-۶ حمله به شبکه‌ها، امنیت شبکه

اینترنت چیست؟ دیدگاه پیچ و مهره‌های اینترنت

- میلیون‌ها وسیله محاسباتی متصل به هم

میزبان = سیستم انتهایی که کاربرد شبکه را اجرا می‌کند

PC
کامپیوتر شخصی

Server
سرویس دهنده

wireless Laptop
لپ تاپ بی‌سیم

Smartphone
تلفن هوشمند

wireless Links
لینک‌های بی‌سیم

Wired links
لینک‌های باسیم

❖ *لینک مخابراتی*

❖ فیبر نوری، سیم مسی، ارتباطات بی‌سیم، ماهواره

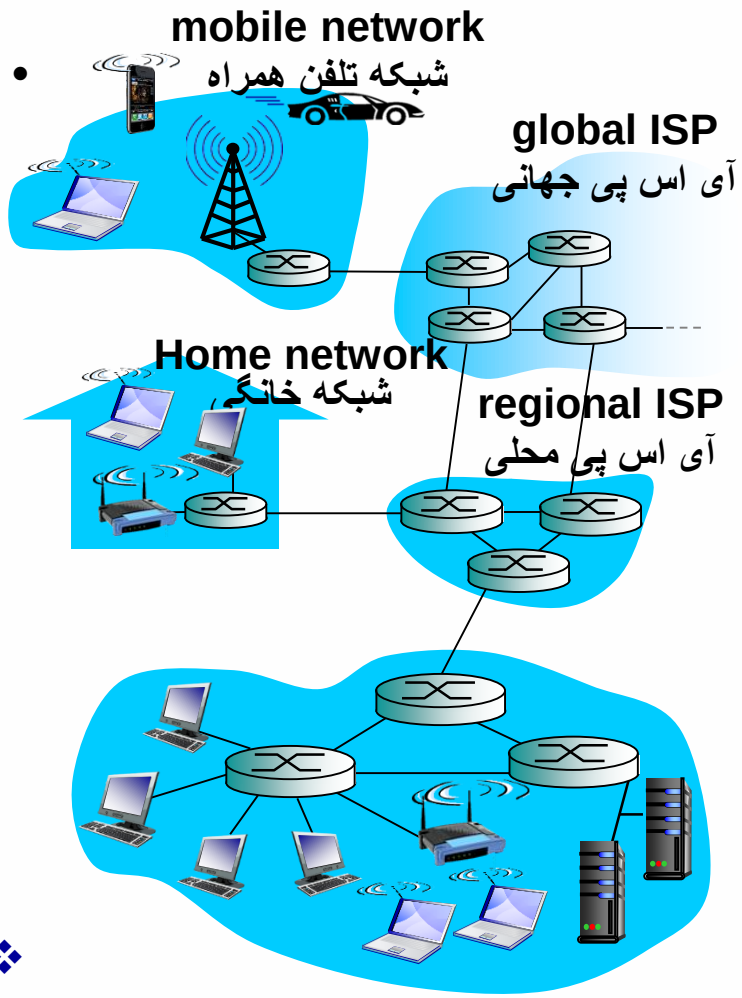
- نرخ ارسال، *پهنای باند*

Router
مسیریاب

❖ *سوئیچ بسته‌ها*

❖ هدایت بسته‌ها (قطعات داده)

- *مسیریاب‌ها و سوئیچ‌ها*



کاربردهای جالب اینترنت

IP picture frame
قاب عکس اینترنتی

Web-enabled toaster + weather forecaster
تستر تحت وب
پیش بینی هوا روی نان تست

Tweet-a-watt: monitor energy use
ارسال مصرف برق روی توییتر

Internet Refrigerator
یخچال اینترنتی

Slingbox: watch, control cable TV remotely
گیرنده دیجیتال تلویزیون
با امکان کنترل تلویزیون از راه دور

Internet phones
تلفن اینترنتی

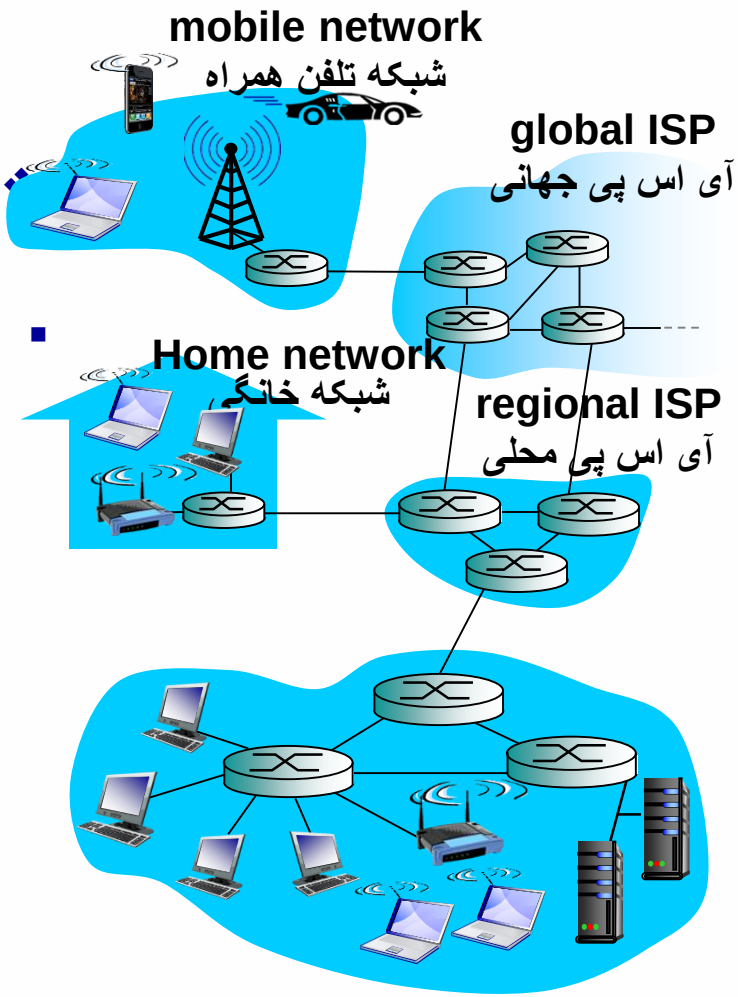
اینترنت چیست؟ دیدگاه پیچ و مهره‌های اینترنت

❖ *اینترنت: شبکه شبکه ها*

- *آی آس پی های متصل به هم*
- پروتکل‌ها که ارسال و دریافت پیام‌ها را کنترل می‌کنند
- *مثال:* TCP, IP, HTTP, Skype, 802.11

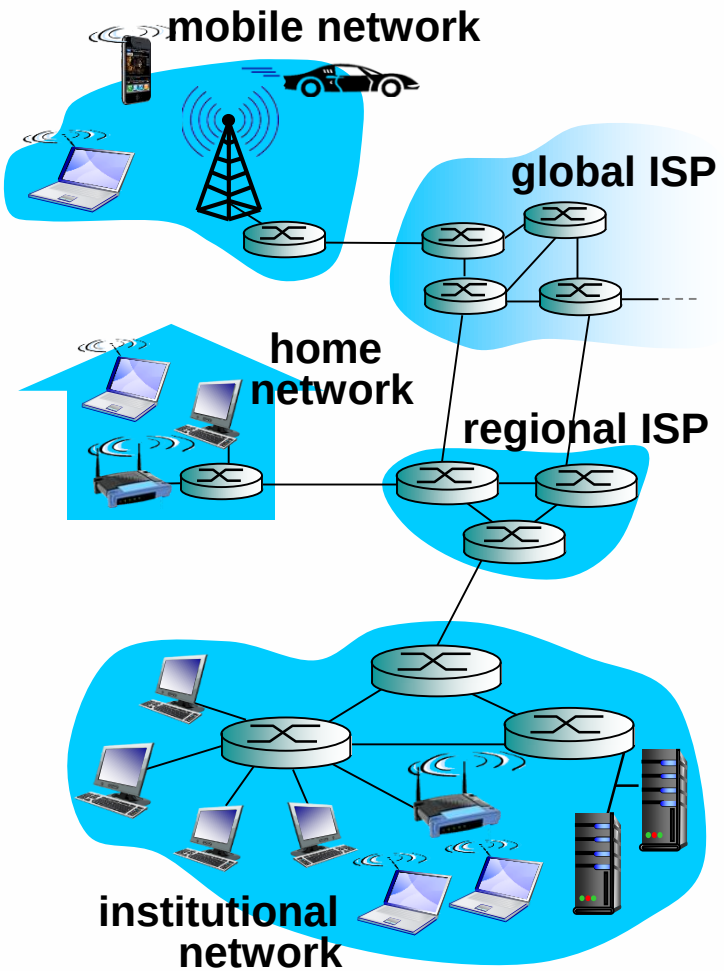
❖ استانداردهای اینترنت

- *RFC = تقاضا برای اظهار نظر*
- *IETF = گروه کاری مهندسی اینترنت*



اینترنت چیست؟ دیدگاه سرویس

- *Infrastructure that provides services to applications:*
  - Web, VoIP, email, games, e-commerce, social nets, …
- *provides programming interface to apps*
  - hooks that allow sending and receiving app programs to "connect" to Internet
  - provides service options, analogous to postal service



پروتکل چیست؟

پروتکل انسانی:

مثال پرسیدن ساعت

پرسیدن یک پرسش

معرفی خود

....مشخص نمودن پیام ارسالی

....مشخص نمودن عملی که باید پس از دریافت پیام یا هر رویداد دیگری انجام شود

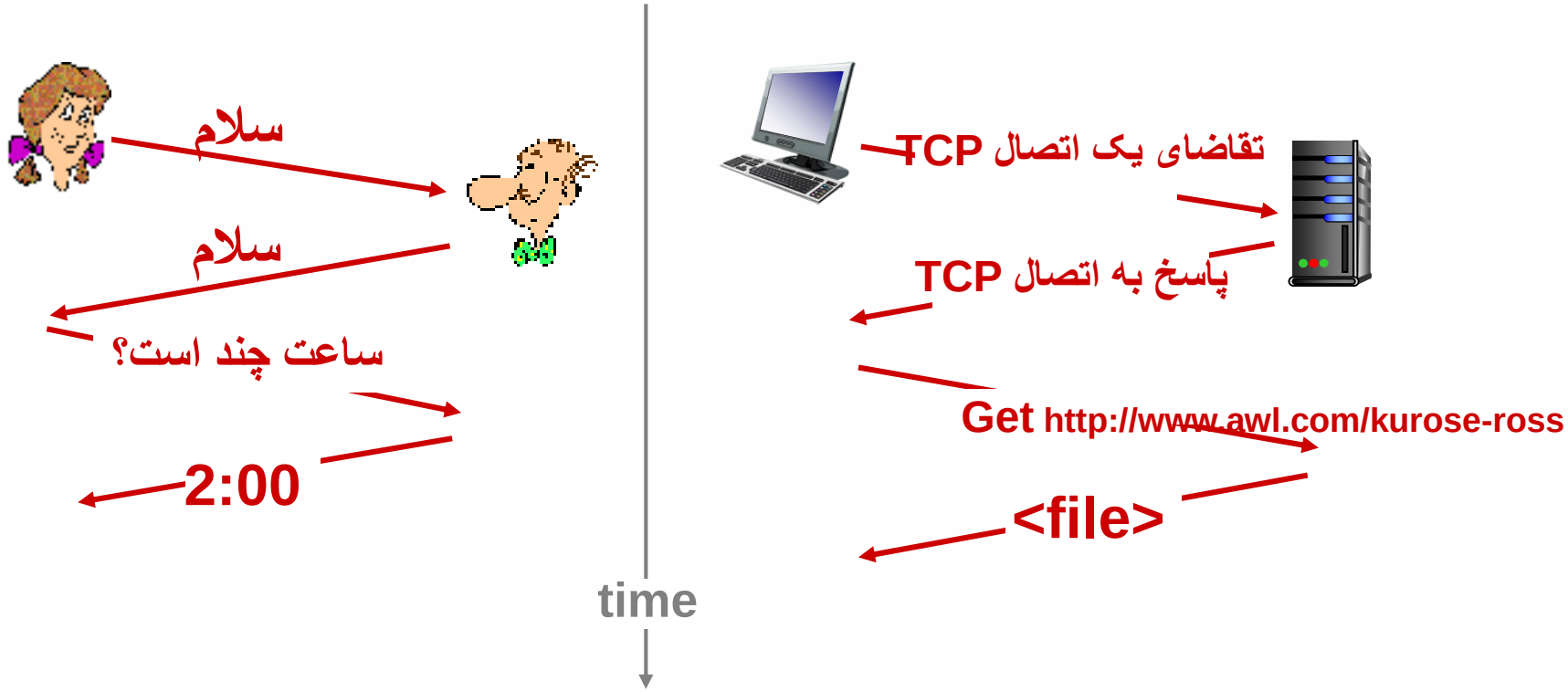
پروتکل شبکه:

- کامپیوترها بجای انسان‌ها
- تمام فعالیت‌های ارتباطی در اینترنت توسط پروتکل‌ها انجام می‌شوند

پروتکل مشخص کننده قالب و ترتیب برای پیام ارسالی و دریافتی در بین موجودیت‌های شبکه می‌باشد و مشخص می‌کند که چه عملی در هر رویداد انجام شود

پروتکل چیست؟

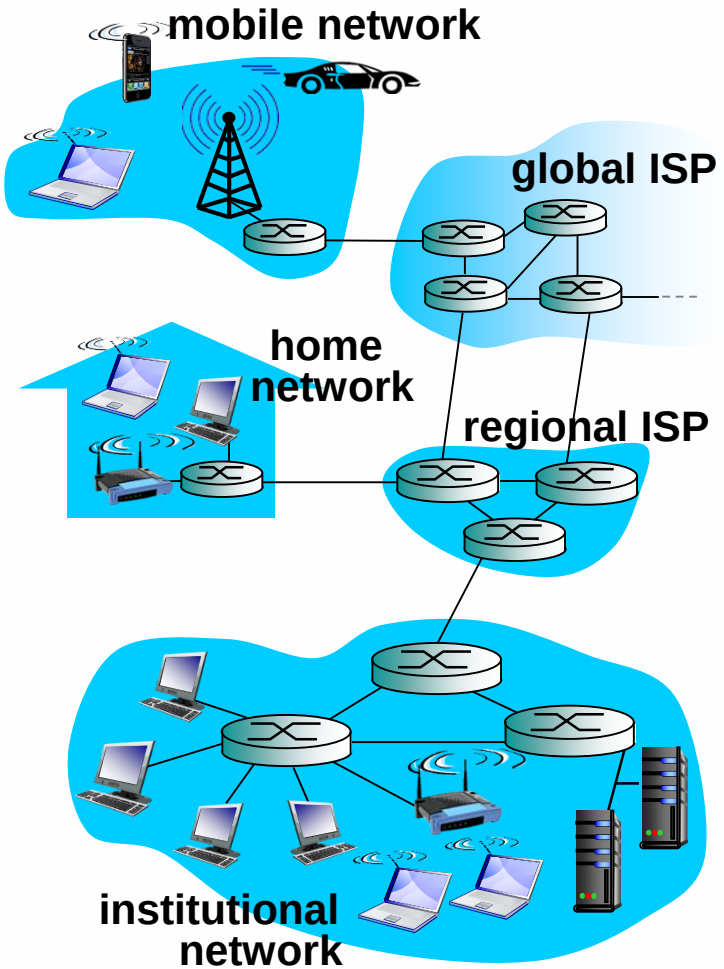
یک پروتکل شبکه‌های کامپیوتری و یک پروتکل انسانی



سوال خودآزمایی: یک پروتکل انسانی دیگر نام ببرید.

ساختار شبکه از نزدیک

- *network edge:*
  - hosts: clients and servers
  - servers often in data centers
- ***access networks, physical media:*** **wired, wireless communication links**



- ***network core:***
  - **interconnected routers**
  - **network of networks**

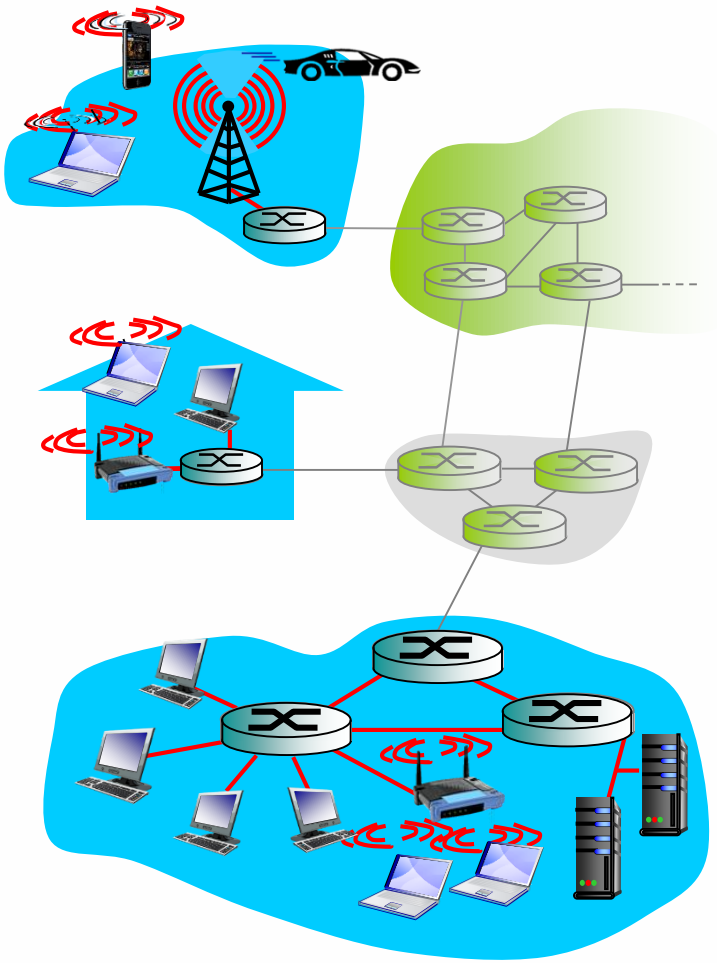
شبکه دسترسی و رسانه‌های فیزیکی

Q: How to connect end systems to edge router?

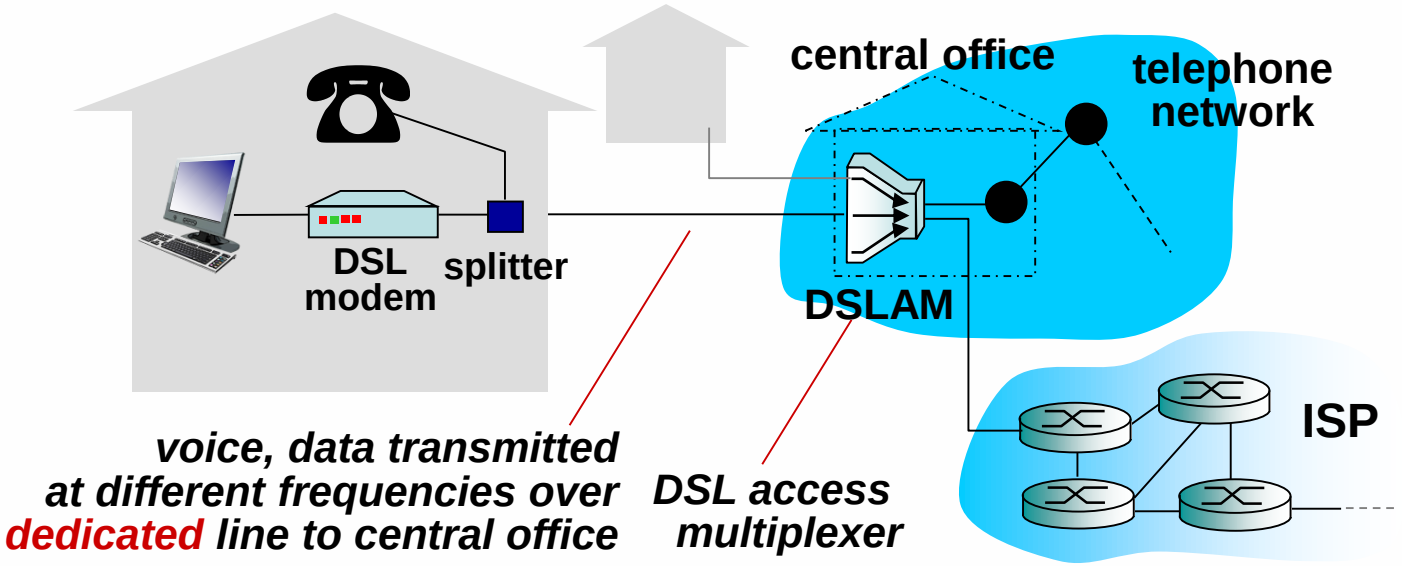
- residential access nets
- institutional access networks (school, company)
- mobile access networks

keep in mind:

- bandwidth (bits per second) of access network?

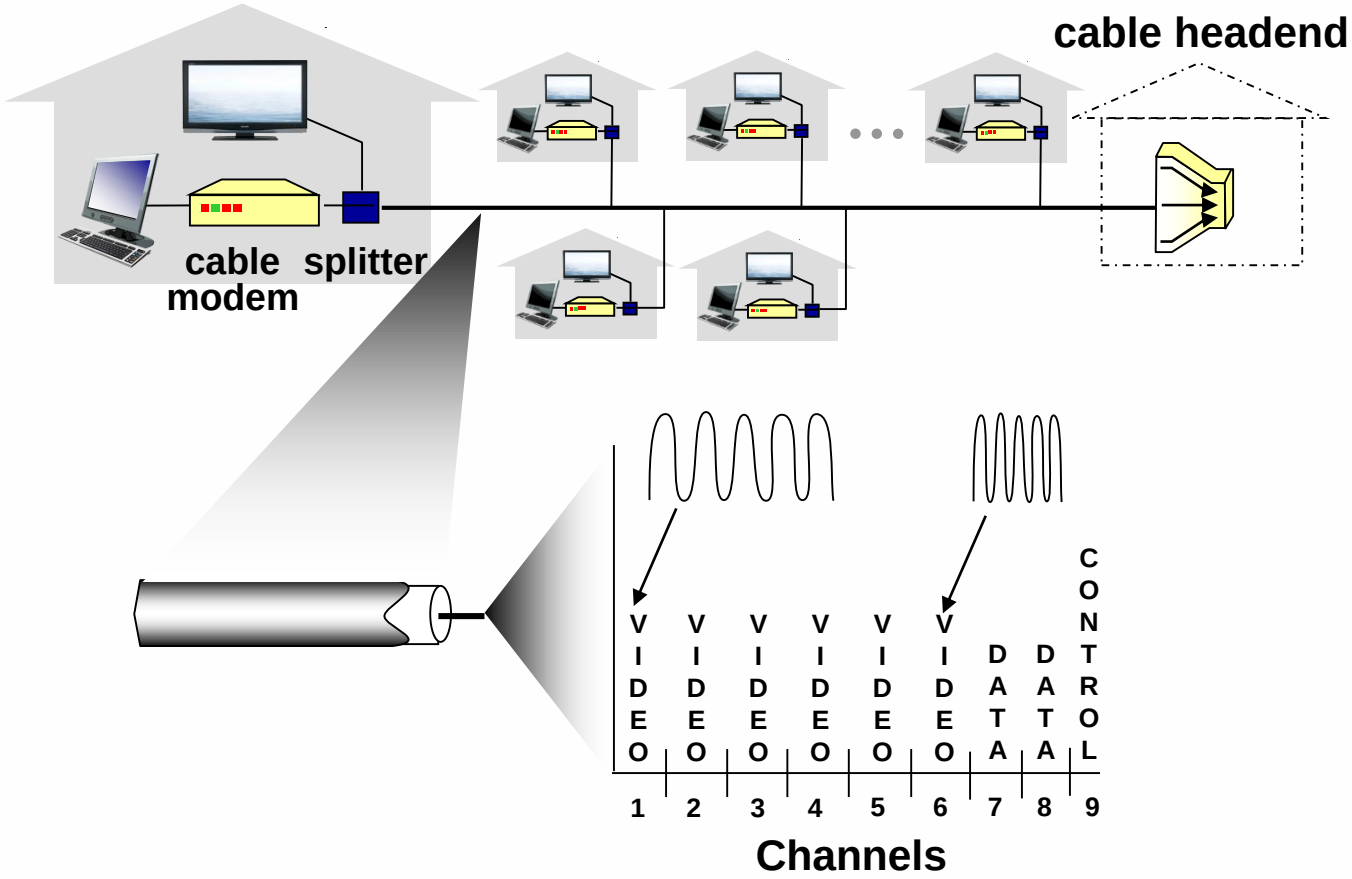


شبکه دسترسی؛ خطوط مشترکان مخابرات (DSL)



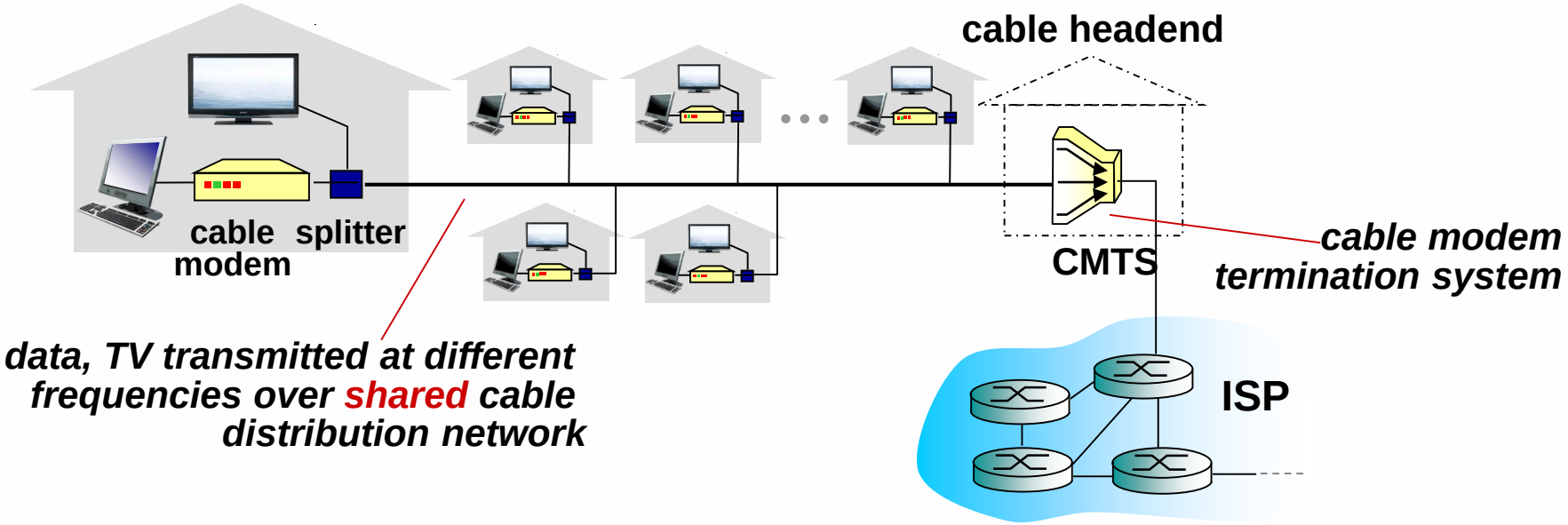
- use *existing* telephone line to central office DSLAM
  - data over DSL phone line goes to Internet
  - voice over DSL phone line goes to telephone net
- < 2.5 Mbps upstream transmission rate (typically < 1 Mbps)
- < 24 Mbps downstream transmission rate (typically < 10 Mbps)

شبکه دسترسی؛ استفاده از کابل تلویزیونی



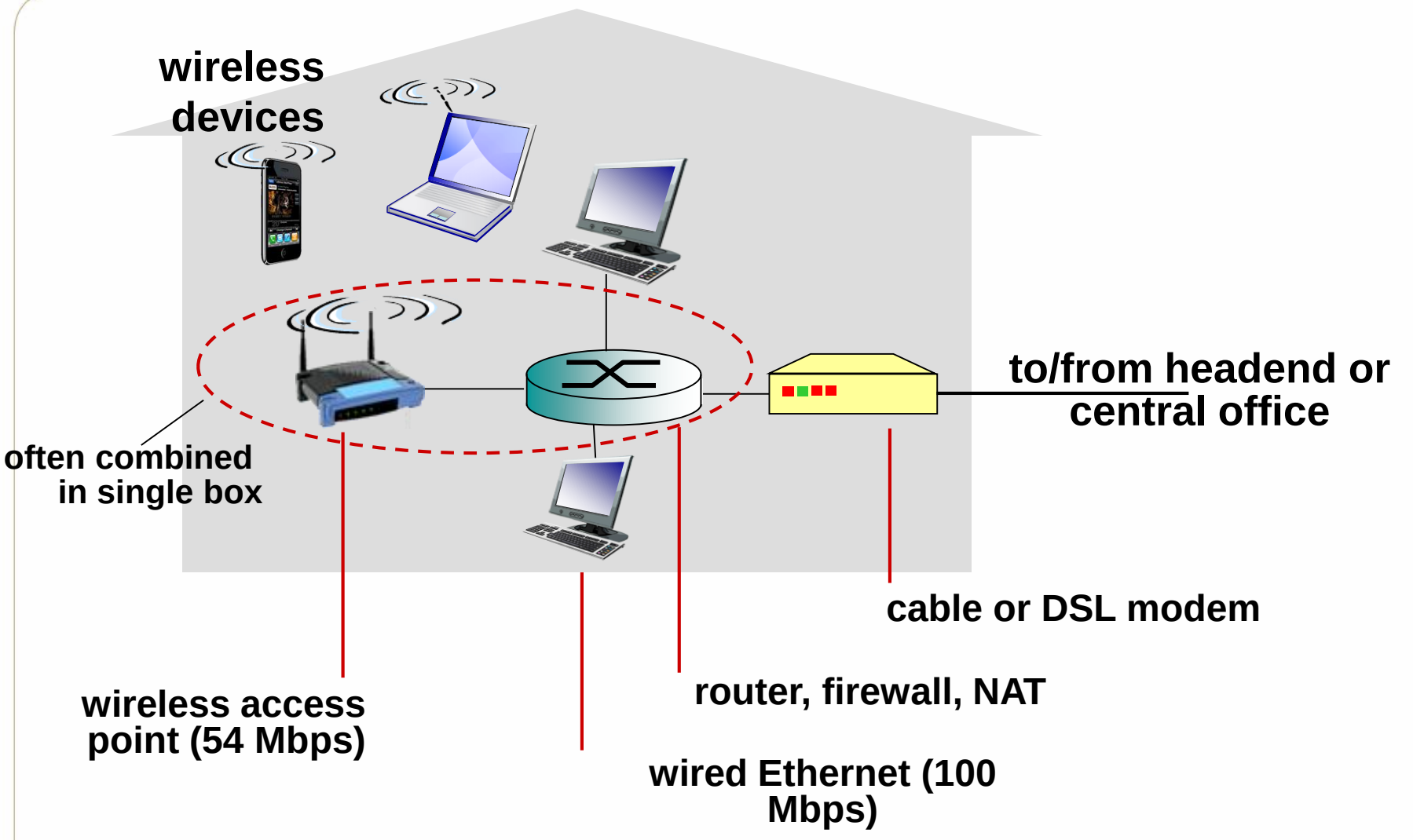
frequency division multiplexing: **different channels transmitted in different frequency bands**

شبکه دسترسی؛ استفاده از کابل تلویزیونی

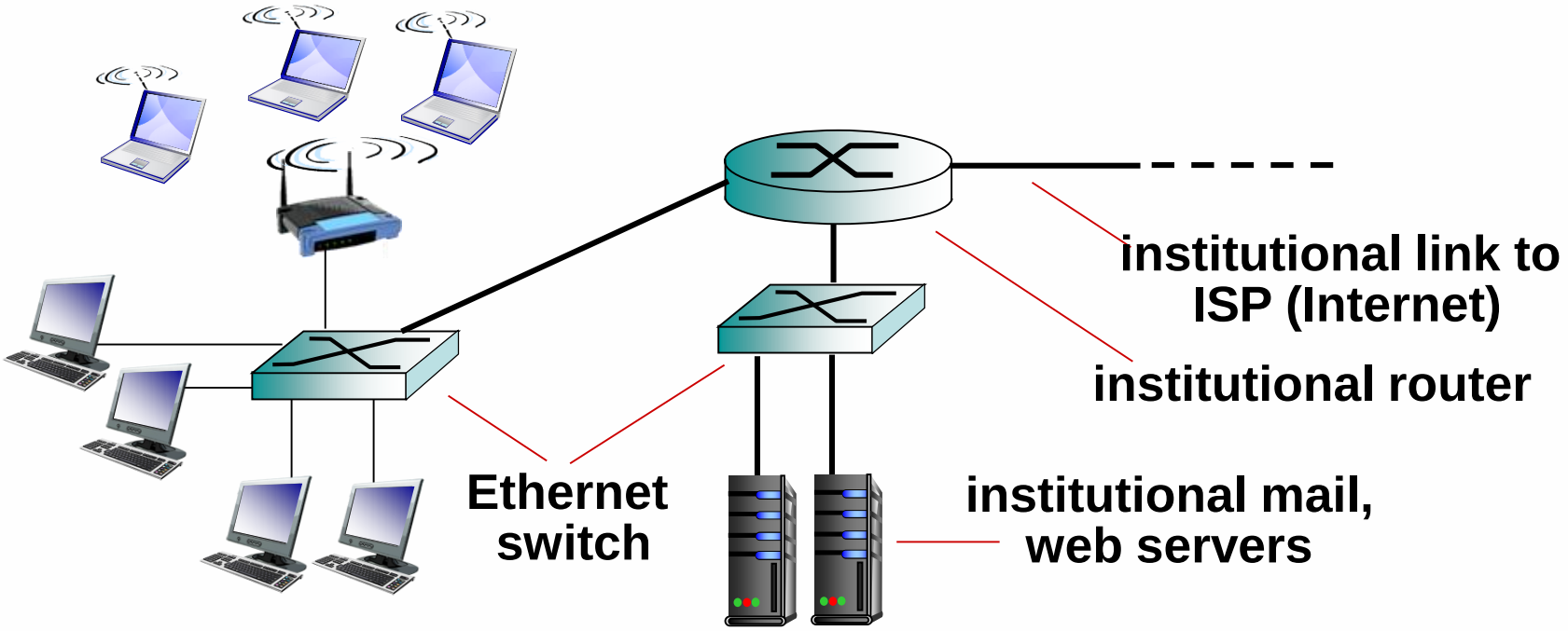


- HFC: hybrid fiber coax
  - asymmetric: up to 30Mbps downstream transmission rate, 2 Mbps upstream transmission rate
- network of cable, fiber attaches homes to ISP router
  - homes *share access network* to cable headend
  - unlike DSL, which has dedicated access to central office

شبکه دسترسی؛ شبکه خانگی



شبکه دسترسی سازمانی؛ اترنت (Ethernet)



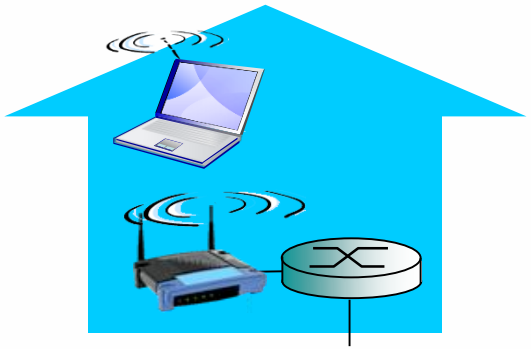
- typically used in companies, universities, etc
- 10 Mbps, 100Mbps, 1Gbps, 10Gbps transmission rates
- today, end systems typically connect into Ethernet switch

شبکه دسترسی بی‌سیم

- shared *wireless* access network connects end system to router
  - via base station aka “access point”

wireless LANs:

- **within building (100 ft)**
- **802.11b/g (WiFi): 11, 54 Mbps transmission rate**



to Internet

wide-area wireless access

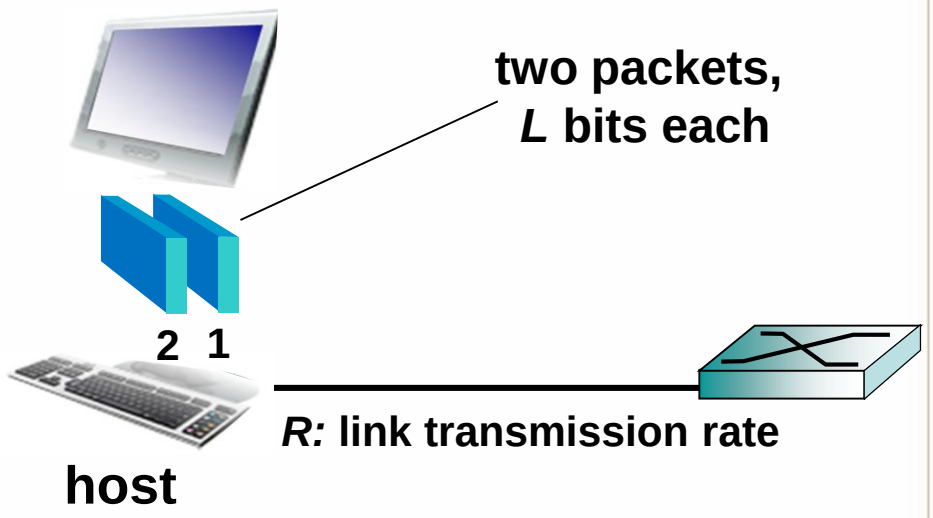
- **provided by telco (cellular) operator, 10’ s km**
- **between 1 and 10 Mbps**
- **3G, 4G: LTE**

to Internet

میزبان (HOST) فرستنده بسته‌های داده

host sending function:

- takes application message
- breaks into smaller chunks, known as *packets*, of length *L* bits
- transmits packet into access network at *transmission rate R*
  - link transmission rate, aka link *capacity, aka link bandwidth*



$$\text{packet transmission delay} = \text{time needed to transmit } L\text{-bit packet into link} = \frac{L \text{ (bits)}}{R \text{ (bits/sec)}}$$

رسانه فیزیکی

- bit: propagates between transmitter/receiver pairs
- physical link: what lies between transmitter & receiver
- guided media:
  - signals propagate in solid media: copper, fiber, coax
- unguided media:
  - signals propagate freely, e.g., radio

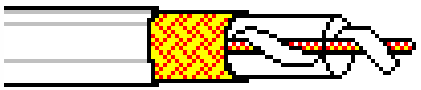
twisted pair (TP)

- two insulated copper wires
  - Category 5: 100 Mbps, 1 Gpbs Ethernet
  - Category 6: 10Gbps

رسانه فیزیکی؛ کابل هم محور و فیبر نوری

coaxial cable:

- two concentric copper conductors
- bidirectional
- broadband:
  - multiple channels on cable
  - HFC



fiber optic cable:

- glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (e.g., 10's-100's Gpbs transmission rate)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

رسانه فیزیکی؛ ارتباط رادیویی

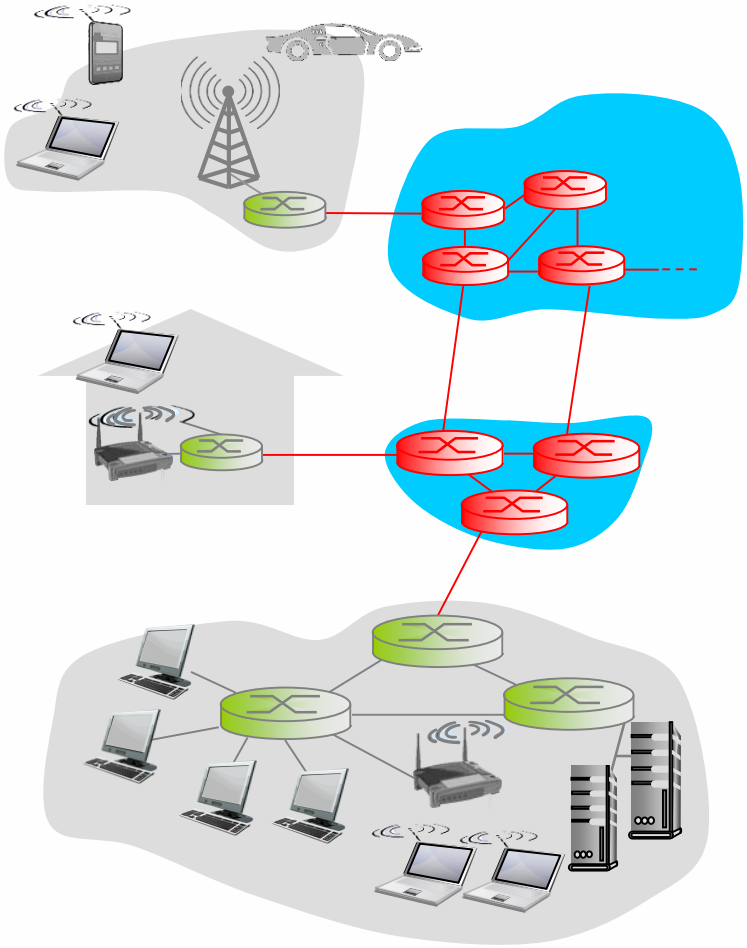
- signal carried in electromagnetic spectrum
- no physical “wire”
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

radio link types:

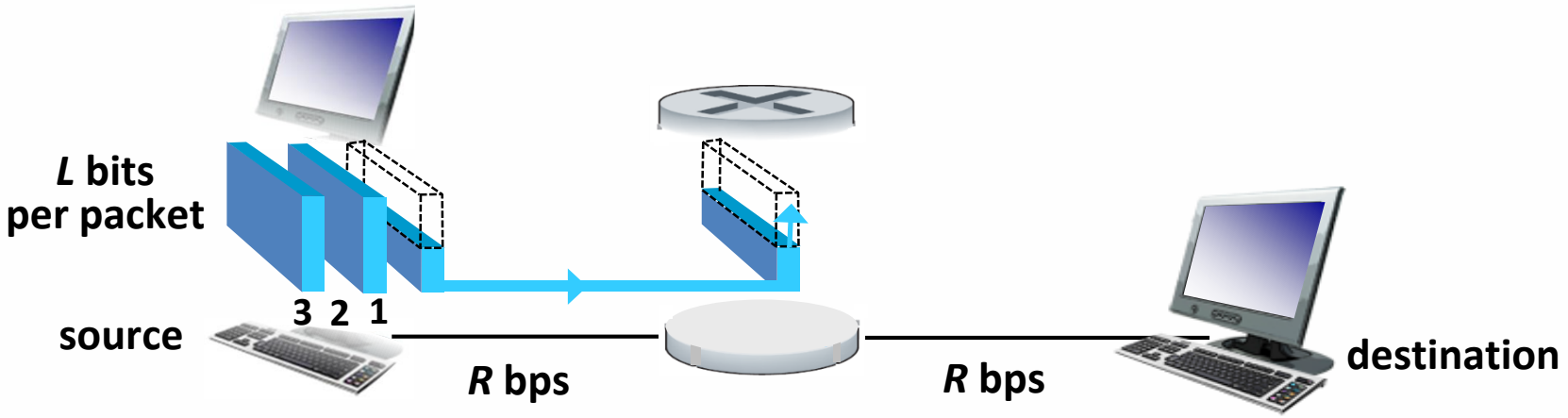
- **terrestrial microwave**
  - **e.g. up to 45 Mbps channels**
- **LAN (e.g., WiFi)**
  - **11Mbps, 54 Mbps**
- **wide-area (e.g., cellular)**
  - **3G cellular: ~ few Mbps**
- **satellite**
  - **Kbps to 45Mbps channel (or multiple smaller channels)**
  - **270 msec end-end delay**
  - **geosynchronous versus low altitude**

هسته شبکه

- mesh of interconnected routers
- packet-switching: hosts break application-layer messages into *packets*
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



سوئیچ بسته؛ ذخیره و هدایت



- takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- *store and forward:* entire packet must arrive at router before it can be transmitted on next link

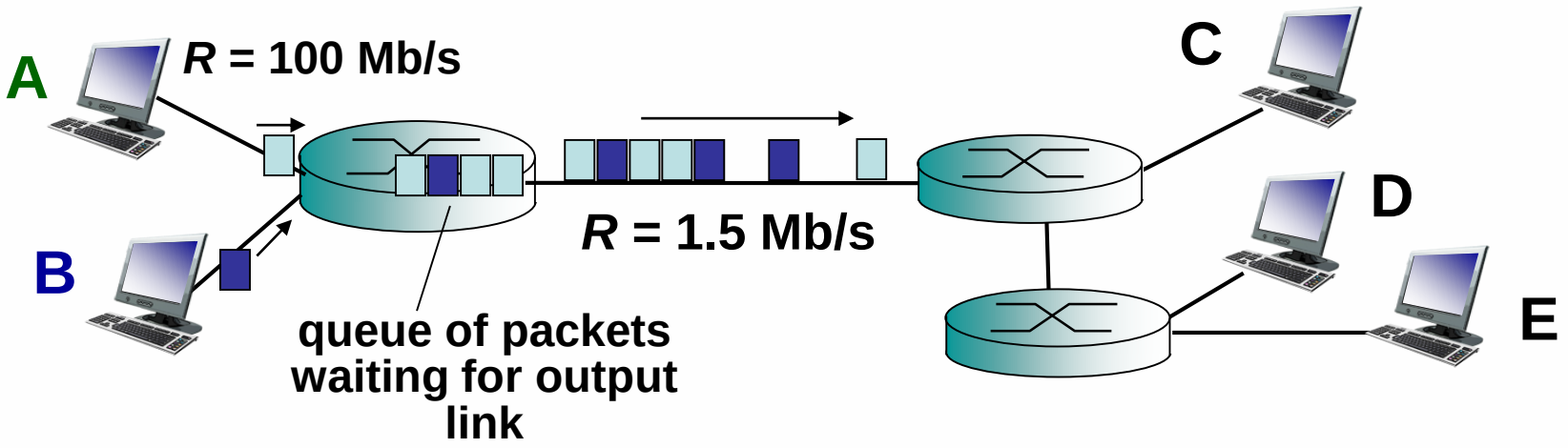
one-hop numerical example:

- *L* = 7.5 Mbits
- *R* = 1.5 Mbps
- one-hop transmission delay = 5 sec

- **end-end delay = 2*L*/*R* (assuming zero propagation delay)**

more on delay shortly …

سوئیچ بسته؛ تاخیر صف و تلفات



queuing and loss:

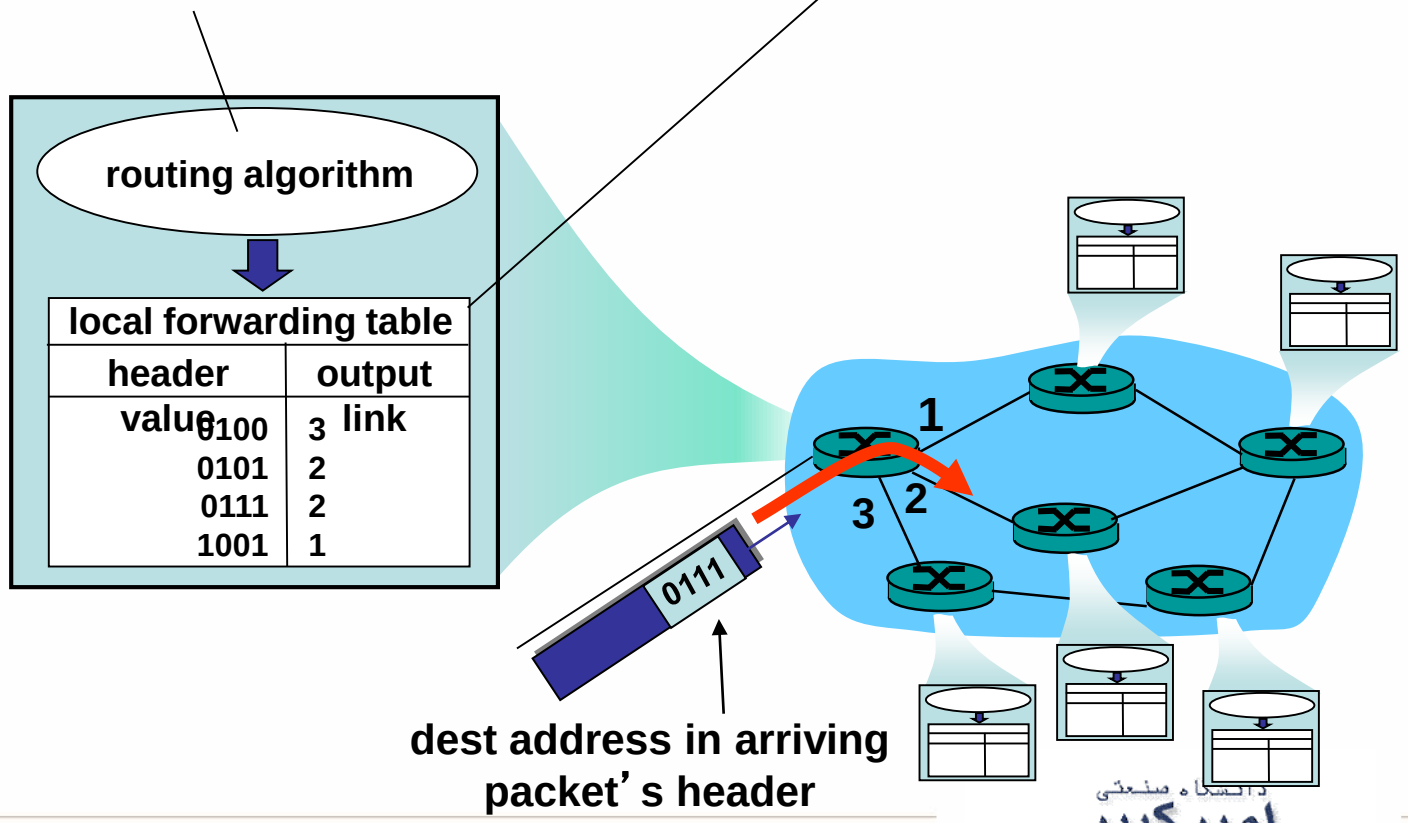
- If arrival rate (in bits) to link exceeds transmission rate of link for a period of time:
  - packets will queue, wait to be transmitted on link
  - packets can be dropped (lost) if memory (buffer) fills up

دو عملکرد کلیدی هسته شبکه

routing: **determines source-destination route taken by packets**

- ***routing algorithms***

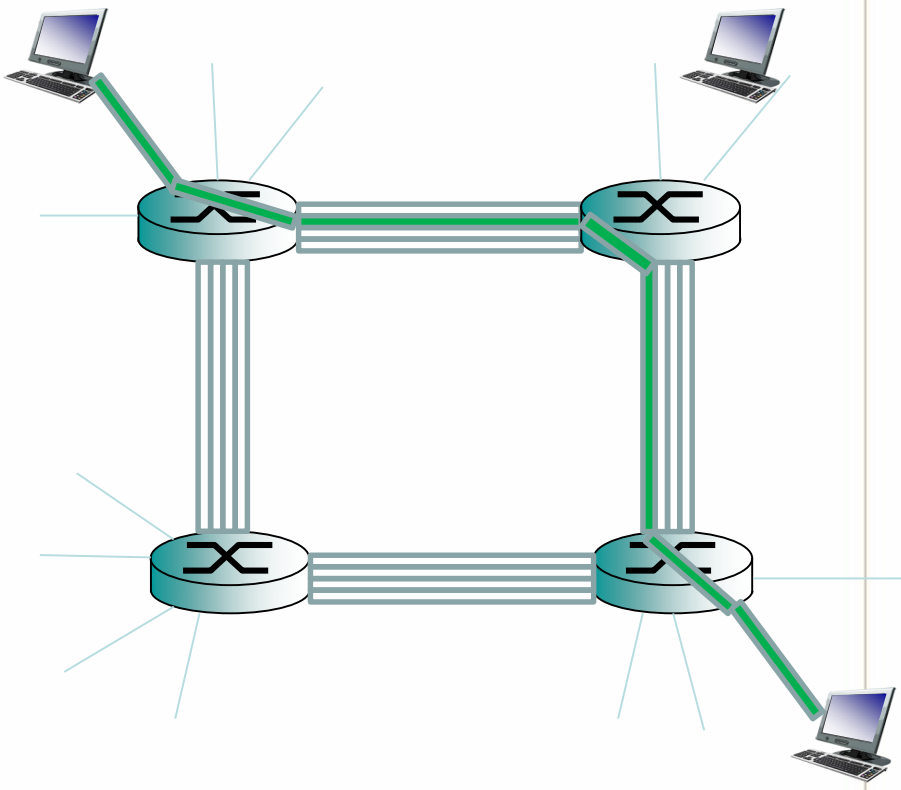
forwarding: move packets from router's input to appropriate router output



آلترناتیوهای مختلف هسته؛ سوئیچ مدار

end-end resources allocated to, reserved for “call” between source & dest:

- In diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call *(no sharing)*
- Commonly used in traditional telephone networks

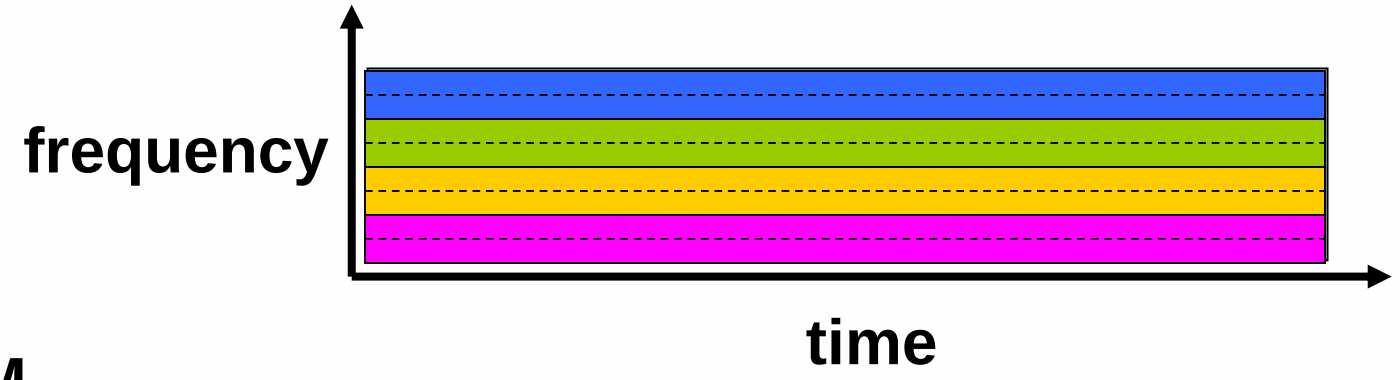


سوئیچ مدار؛ مقایسه FDM و TDM

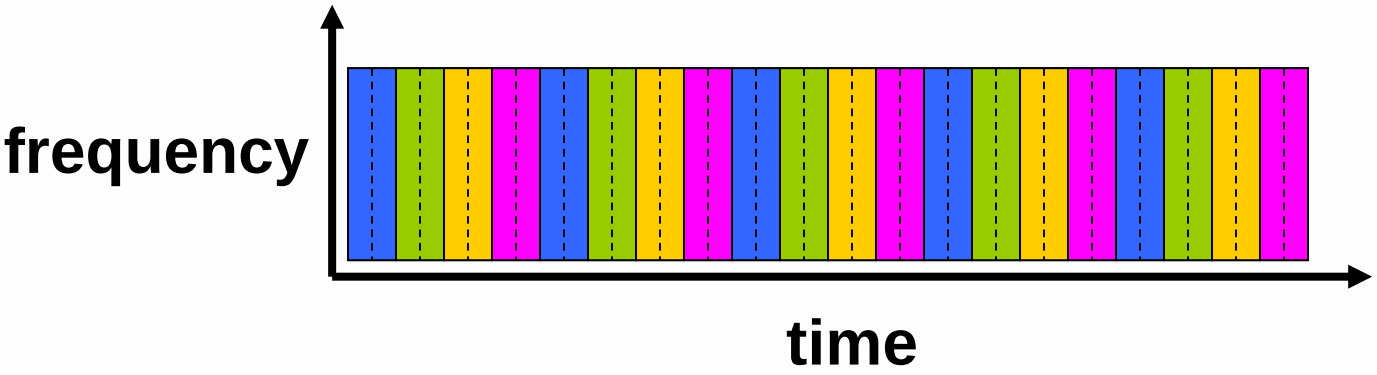
Example:

4 users

FDM



TDM

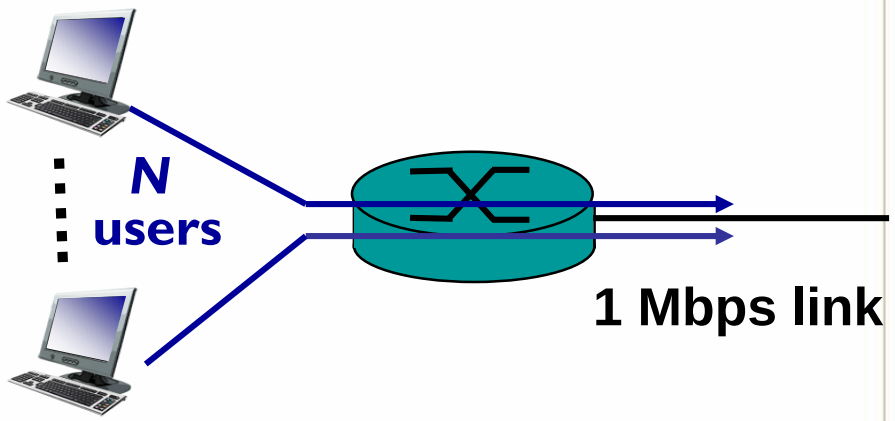


مقایسه سوئیچ مدار و سوئیچ بسته

packet switching allows more users to use network!

example:

- 1 Mb/s link
- each user:
  - 100 kb/s when “active”
  - active 10% of time



- *circuit-switching:*
  - 10 users
- *packet switching:*
  - with 35 users, probability > 10 active at same time is less than .0004 *

Q: how did we get value 0.0004?

Q: what happens if > 35 users ?

مقایسه سوئیچ مدار و سوئیچ بسته

is packet switching a “slam dunk winner?”

- great for bursty data
  - resource sharing
  - simpler, no call setup
- excessive congestion possible: 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 7)

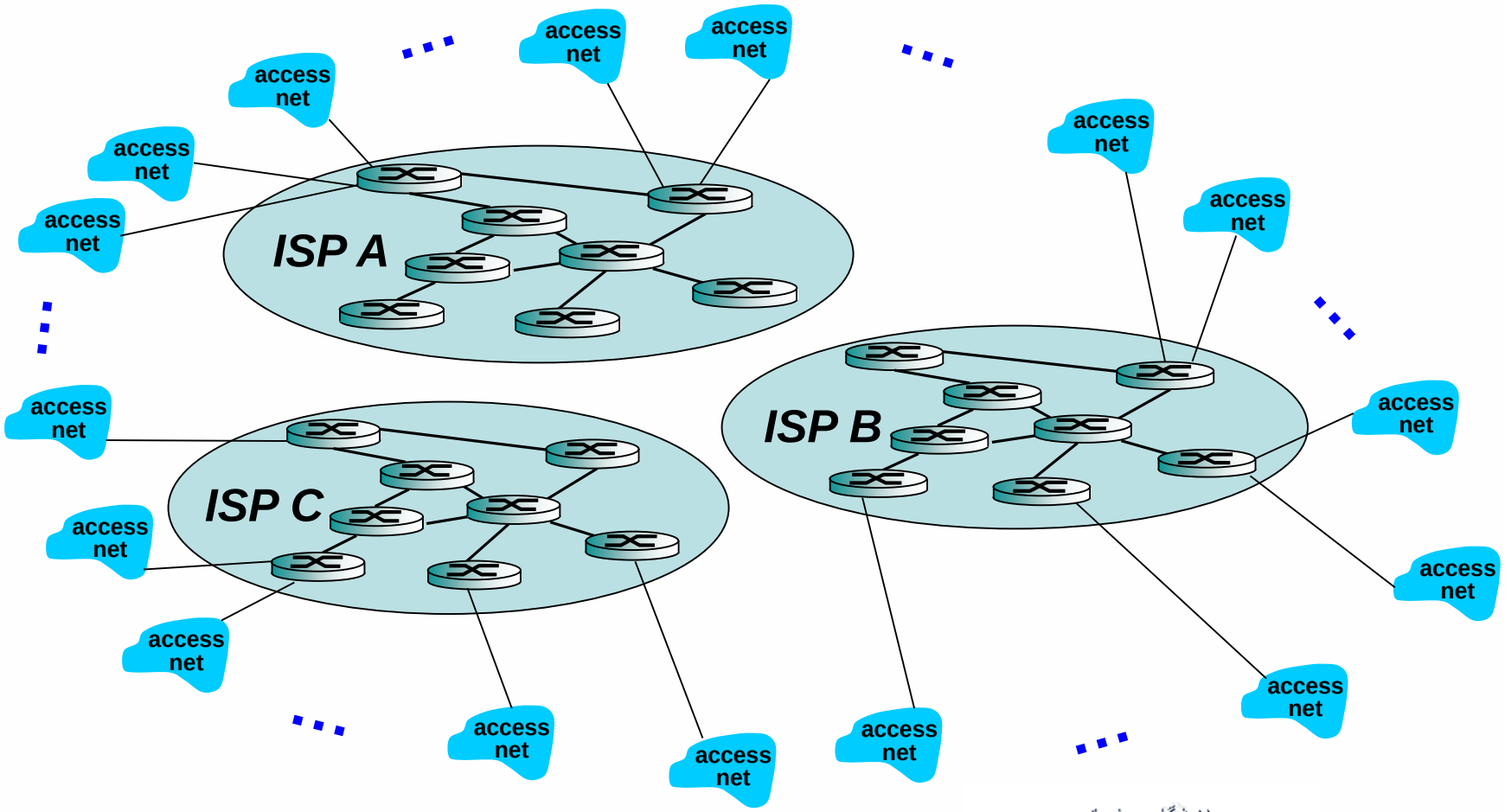
Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet-switching)?

ساختار اینترنت؛ شبکه شبکه‌ها

- End systems connect to Internet via access ISPs (Internet Service Providers)
  - Residential, company and university ISPs
  - Access ISPs in turn must be interconnected.
  - So that any two hosts can send packets to each other
  - Resulting network of networks is very complex
  - Evolution was driven by economics and national policies
- Let's take a stepwise approach to describe current Internet structure

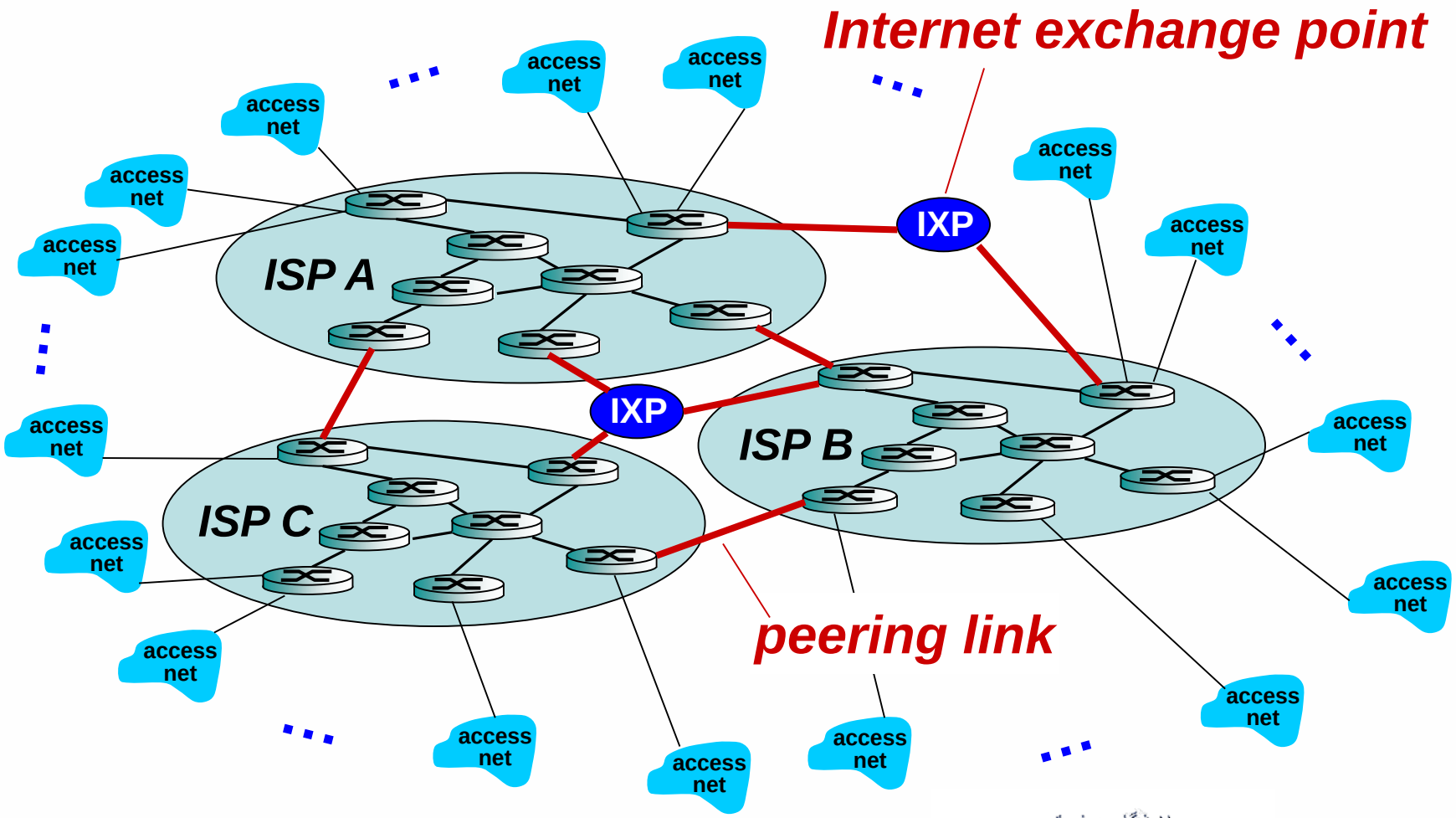
ساختار اینترنت؛ شبکه شبکه‌ها

But if one global ISP is viable business, there will be competitors ….



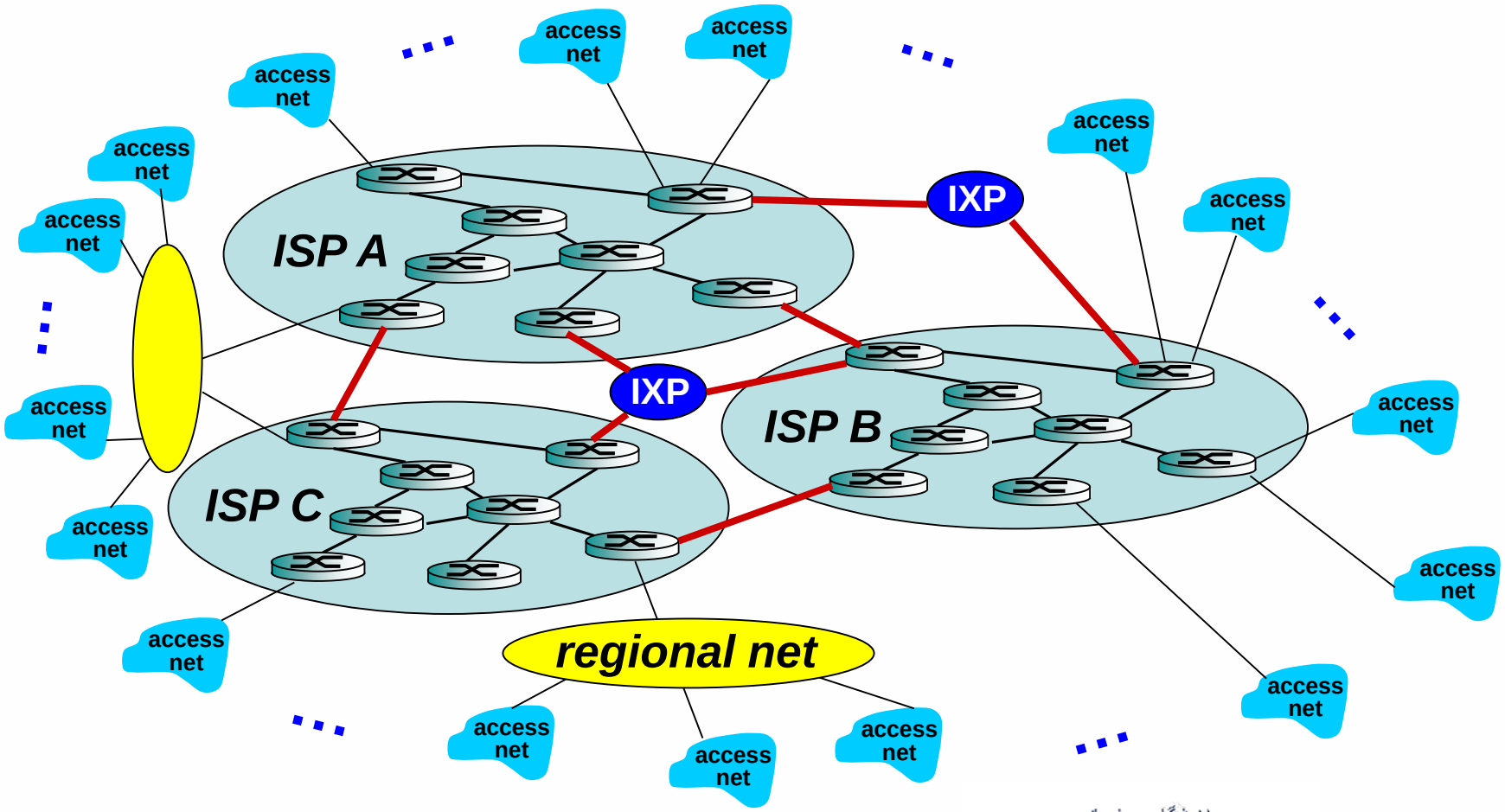
ساختار اینترنت؛ شبکه شبکه‌ها

But if one global ISP is viable business, there will be competitors …. which must be interconnected



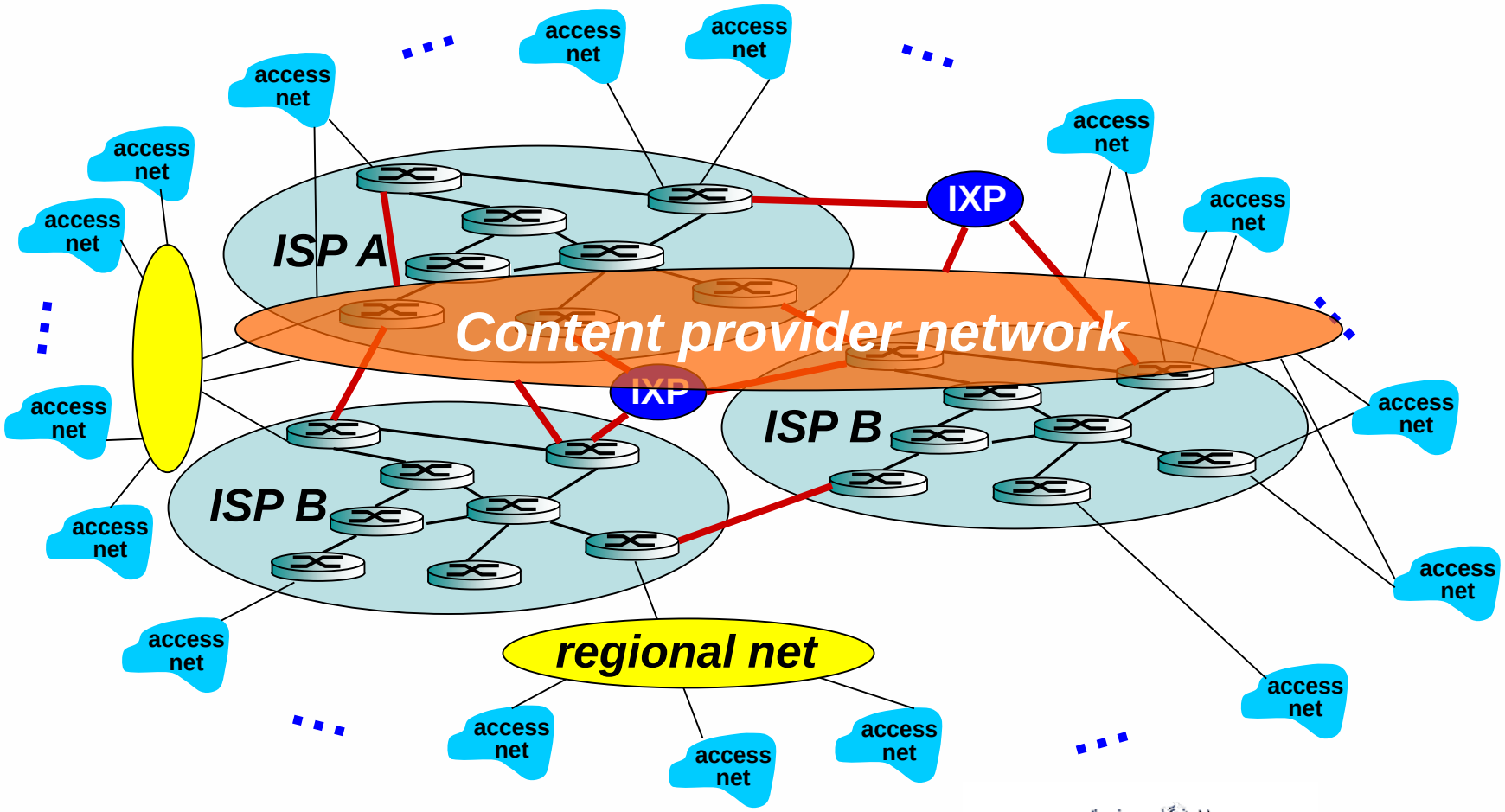
ساختار اینترنت؛ شبکه شبکه‌ها

… and regional networks may arise to connect access nets to ISPS

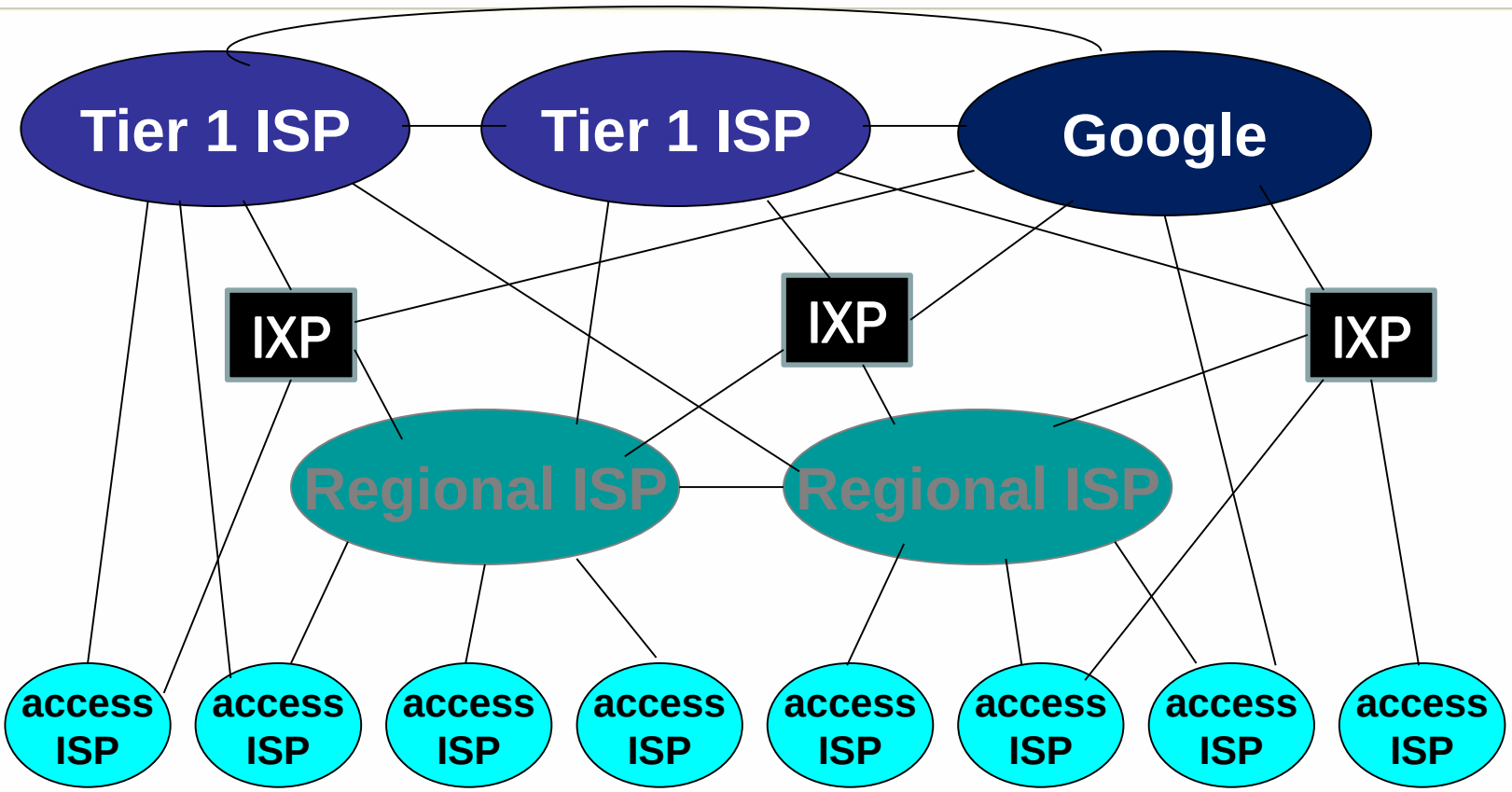


ساختار اینترنت؛ شبکه شبکه‌ها

… and content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



ساختار اینترنت؛ شبکه شبکه‌ها

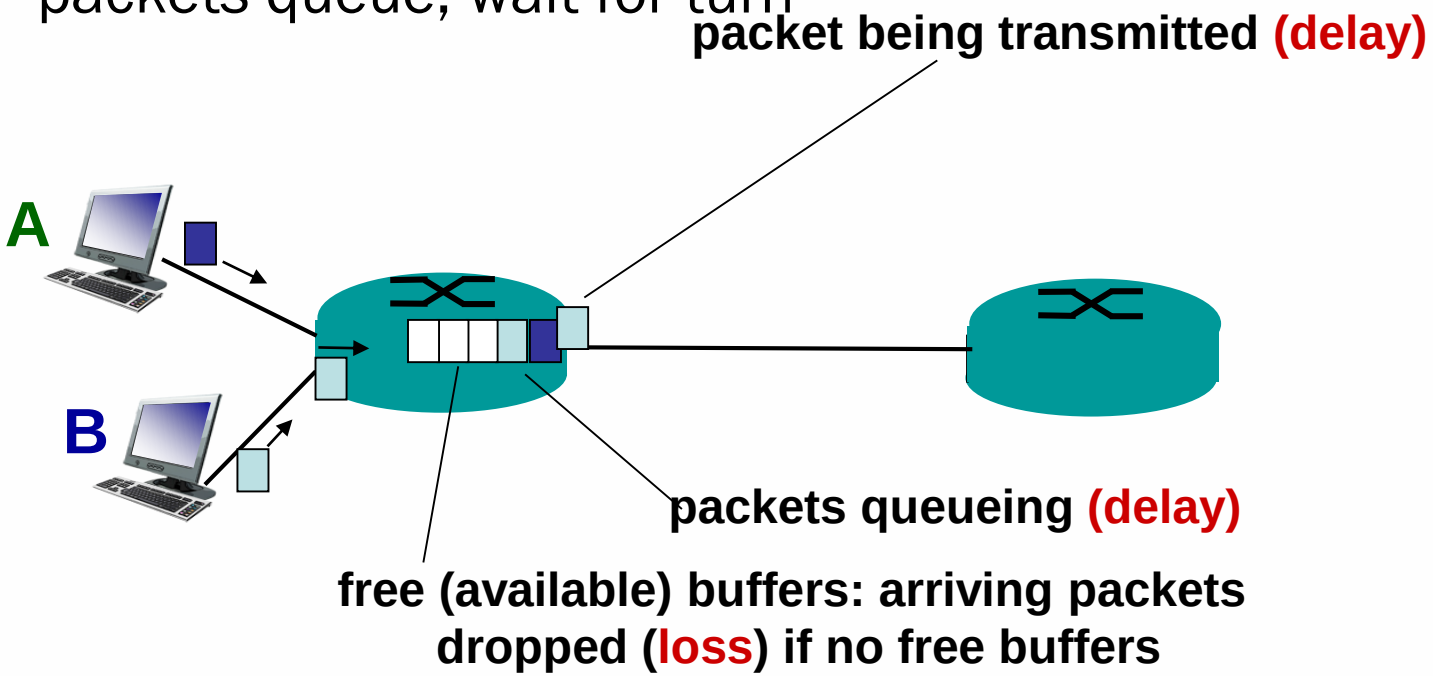


- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
  - content provider network (e.g, Google): private network that connects it data centers to Internet, often bypassing tier-1, regional ISPs

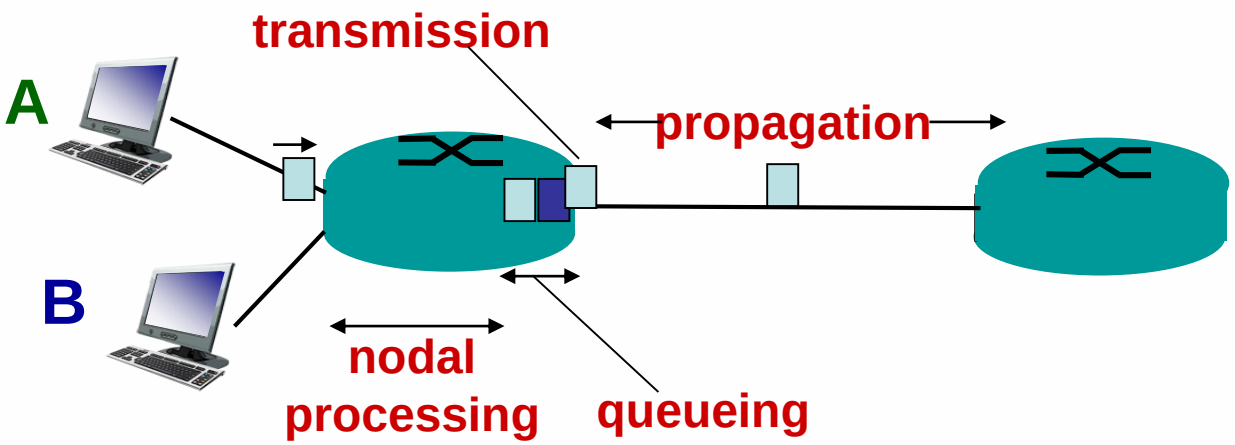
چگونه تاخیر و تلفات اتفاق می‌افتند؟

packets *queue* in router buffers

- packet arrival rate to link (temporarily) exceeds output link capacity
- packets queue, wait for turn



چهار عامل تاخیر بسته‌ها



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

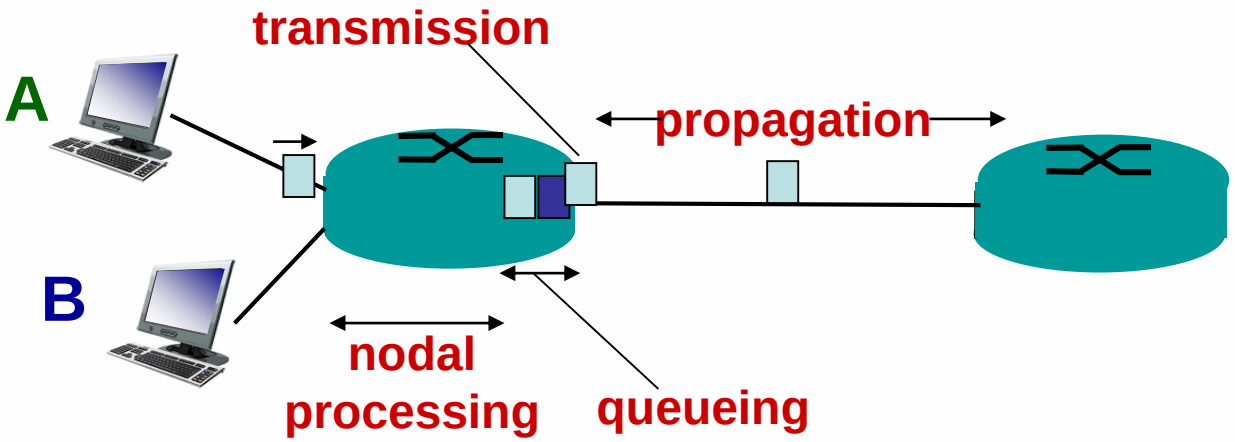
d_{proc}: nodal processing

- check bit errors
- determine output link
- typically < msec

d_{queue}: queueing delay

- **time waiting at output link for transmission**
- **depends on congestion level of router**

چهار عامل تاخیر بسته‌ها



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

d_{trans}: transmission delay:

- *L*: packet length (bits)
- *R*: link *bandwidth (bps)*
- $d_{trans} = L/R$

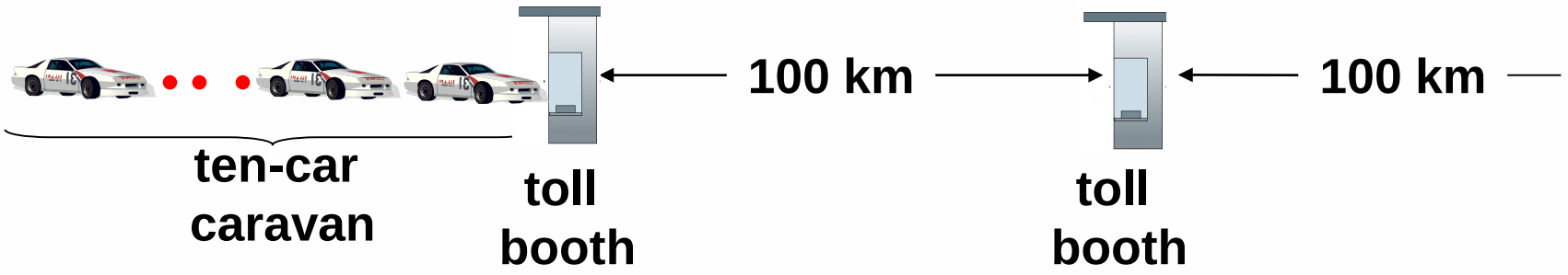
d_{prop}: propagation delay:

- *d*: length of physical link
- *s*: propagation speed in medium (~2×10^8 m/sec)
- $d_{prop} = d/s$

d_{trans} and d_{prop} *very* different

* Check out the Java applet for an interactive animation on trans vs. prop delay

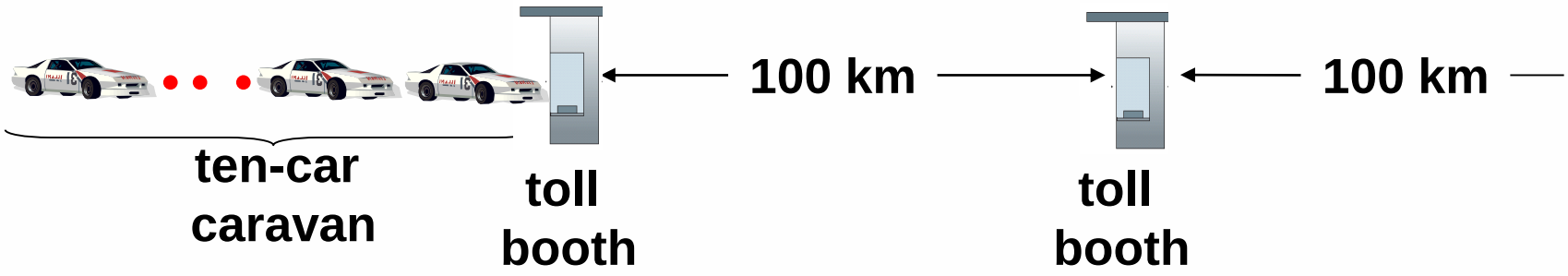
مشابهت با کاروانی از ماشین‌ها



- cars “propagate” at 100 km/hr
- toll booth takes 12 sec to service car (bit transmission time)
- car~bit; caravan ~ packet
- *Q:* How long until caravan is lined up before 2nd toll booth?

- time to “push” entire caravan through toll booth onto highway = 12*10 = 120 sec
- time for last car to propagate from 1st to 2nd toll both: 100km/(100km/hr)= 1 hr
- *A:* 62 minutes

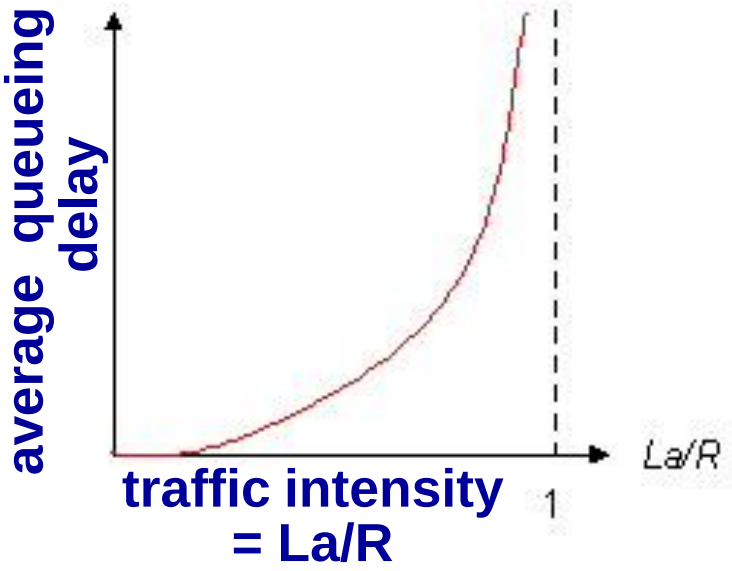
مشابهت با کاروانی از ماشین‌ها(ادامه)



- suppose cars now “propagate” at 1000 km/hr
- and suppose toll booth now takes one min to service a car
- *Q:* Will cars arrive to 2nd booth before all cars serviced at first booth?
  - *A: Yes!* after 7 min, 1st car arrives at second booth; three cars still at 1st booth.

تاخیر صف (بررسی دوباره)

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



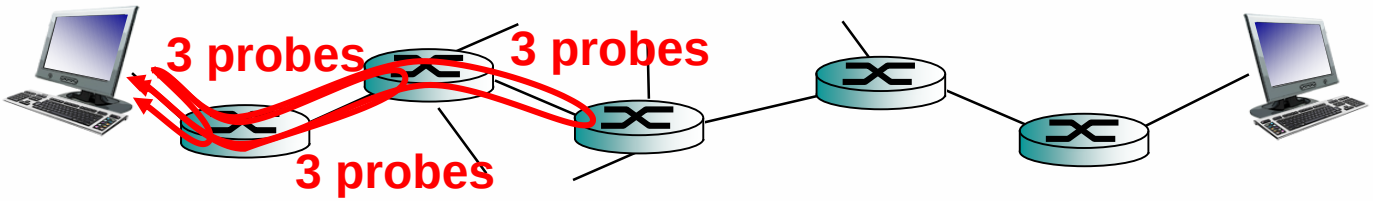
- ***La/R* ~ 0: avg. queueing delay small**
- ***La/R* -> 1: avg. queueing delay large**
- ***La/R* > 1: more "work" arriving than can be serviced, average delay infinite!**

La/R ~ 0

La/R -> 1

تاخیر "واقعی" در اینترنت و مسیریاب‌ها

- what do “real” Internet delay & loss look like?
- 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.



تاخیر "واقعی" در اینترنت و مسیریاب‌ها

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

3 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
```

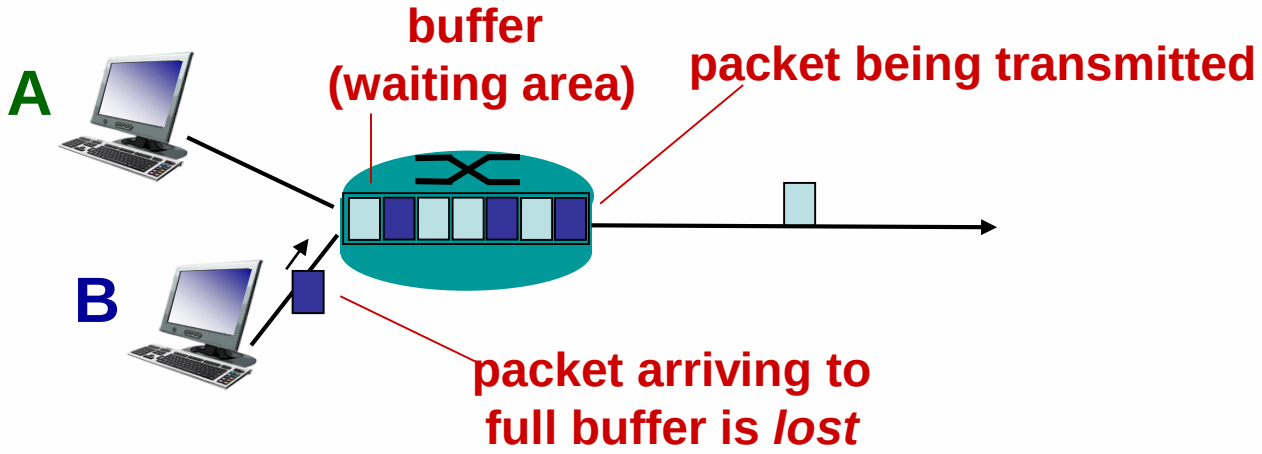
trans-oceanic link

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

*** Do some traceroutes from exotic countries at www.traceroute.org**

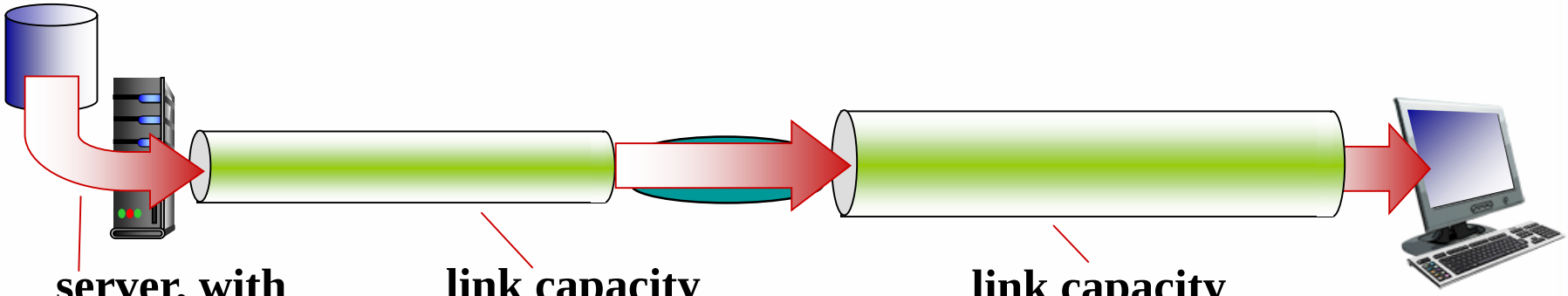
تلفات بسته

- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



بازده

- *throughput:* rate (bits/time unit) at which bits transferred between sender/receiver
  - *instantaneous:* rate at given point in time
  - *average:* rate over longer period of time



server, with file of F bits to send to client

server sends bits (fluid) into pipe

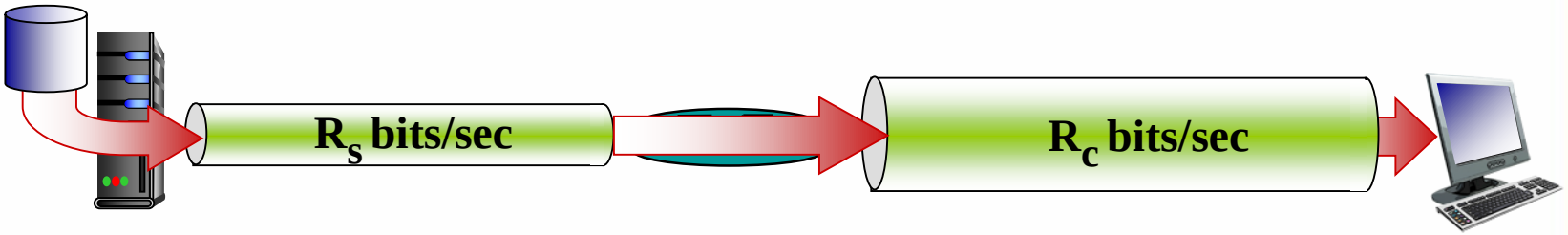
link capacity R_s bits/sec

pipe that can carry fluid at rate R_s bits/sec)

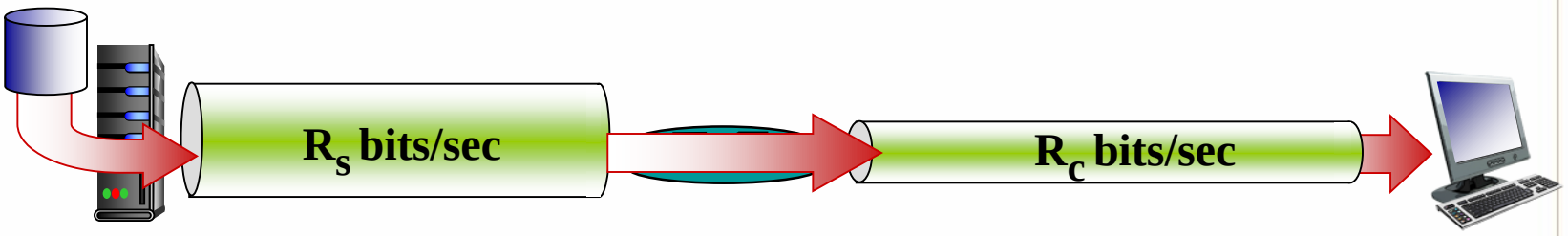
link capacity R_c bits/sec

pipe that can carry fluid at rate R_c bits/sec)

- $R_s < R_c$ What is average end-end throughput?



- $R_s > R_c$ **What is average end-end throughput?**

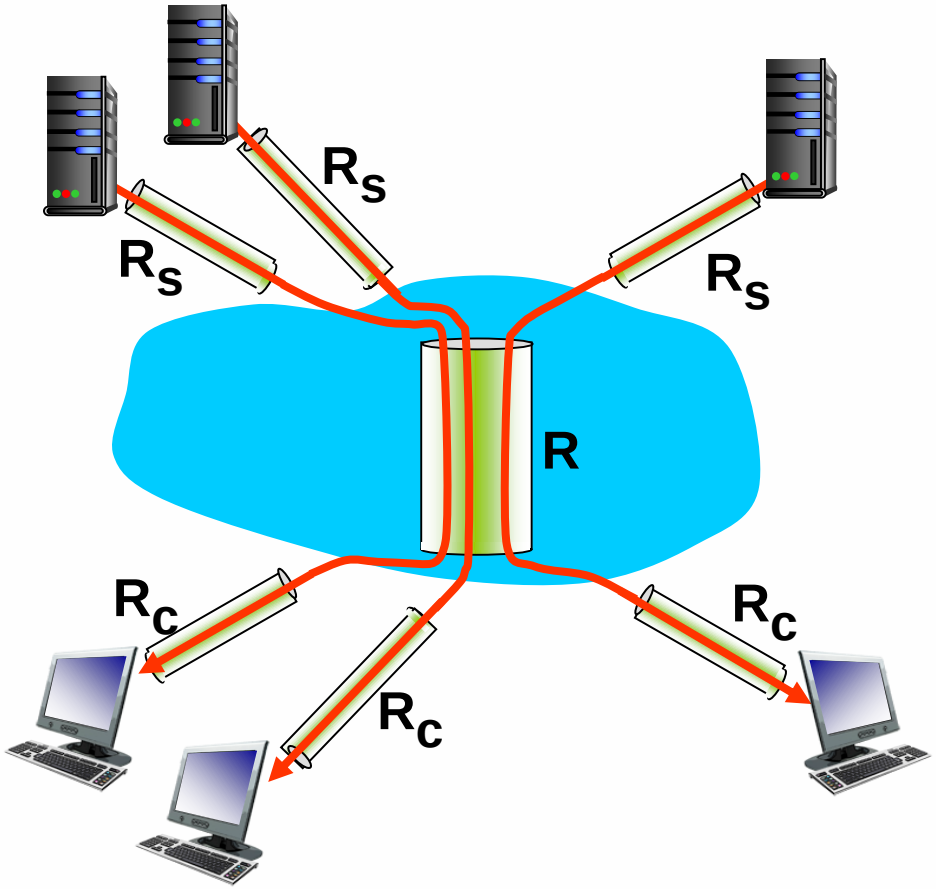


bottleneck link

link on end-end path that constrains end-end throughput

بازده: سناریوی اینترنت

- per-connection end-end throughput: $\min(R_c,R_s,R/10)$
- in practice: R_c or R_s is often bottleneck



10 connections (fairly) share backbone bottleneck link R bits/sec

پروتکل لایه‌ها

Networks are complex, with many "pieces":

- hosts
- routers
- links of various media
- applications
- protocols
- hardware, software

Question:

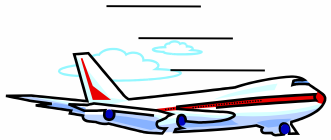
is there any hope of *organizing* structure of network?

…. or at least our discussion of networks?

ساختار مسافرت هوایی

- a series of steps

لایه‌بندی عملیات خطوط هوایی



ticket (purchase)			ticket (complain)	ticket
baggage (check)			baggage (claim	baggage
gates (load)			gates (unload)	gate
runway (takeoff)			runway (land)	takeoff/landing
airplane routing	airplane routing	airplane routing	airplane routing	airplane routing
departure airport	intermediate air-traffic control centers		arrival airport	

layers: each layer implements a service

- via its own internal-layer actions
- relying on services provided by layer below

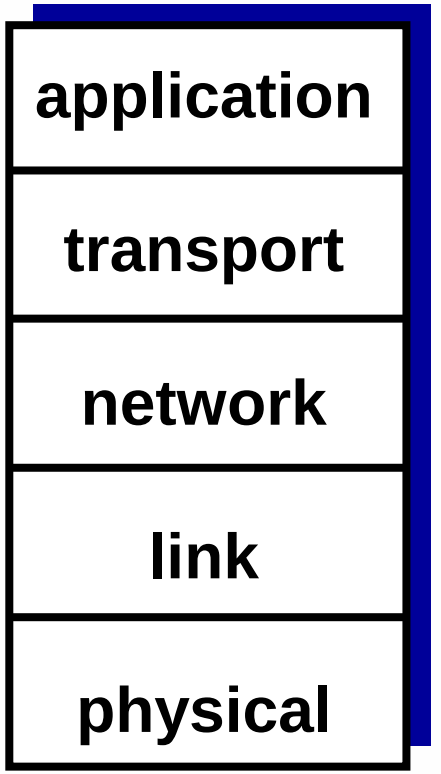
چرا لایه بندی؟

dealing with complex systems:

- explicit structure allows identification, relationship of complex system's pieces
  - layered *reference model* for discussion
- modularization eases maintenance, updating of system
  - change of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system
- layering considered harmful?

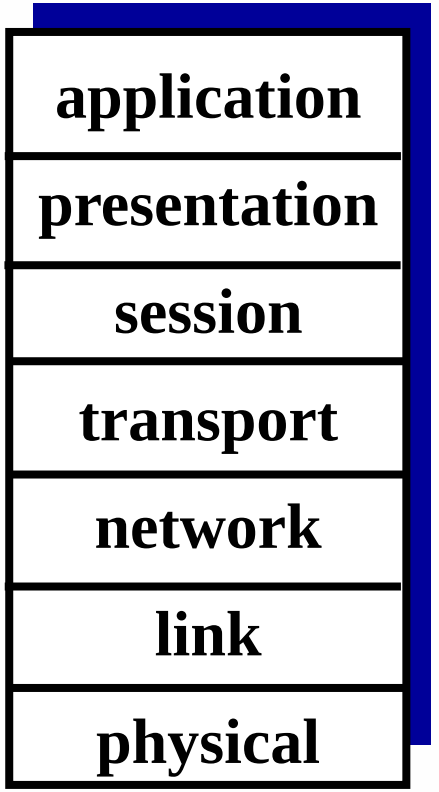
پشته پروتکل اینترنت

- *application:* supporting network applications
  - FTP, SMTP, HTTP
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.111 (WiFi), PPP
- *physical:* bits “on the wire”

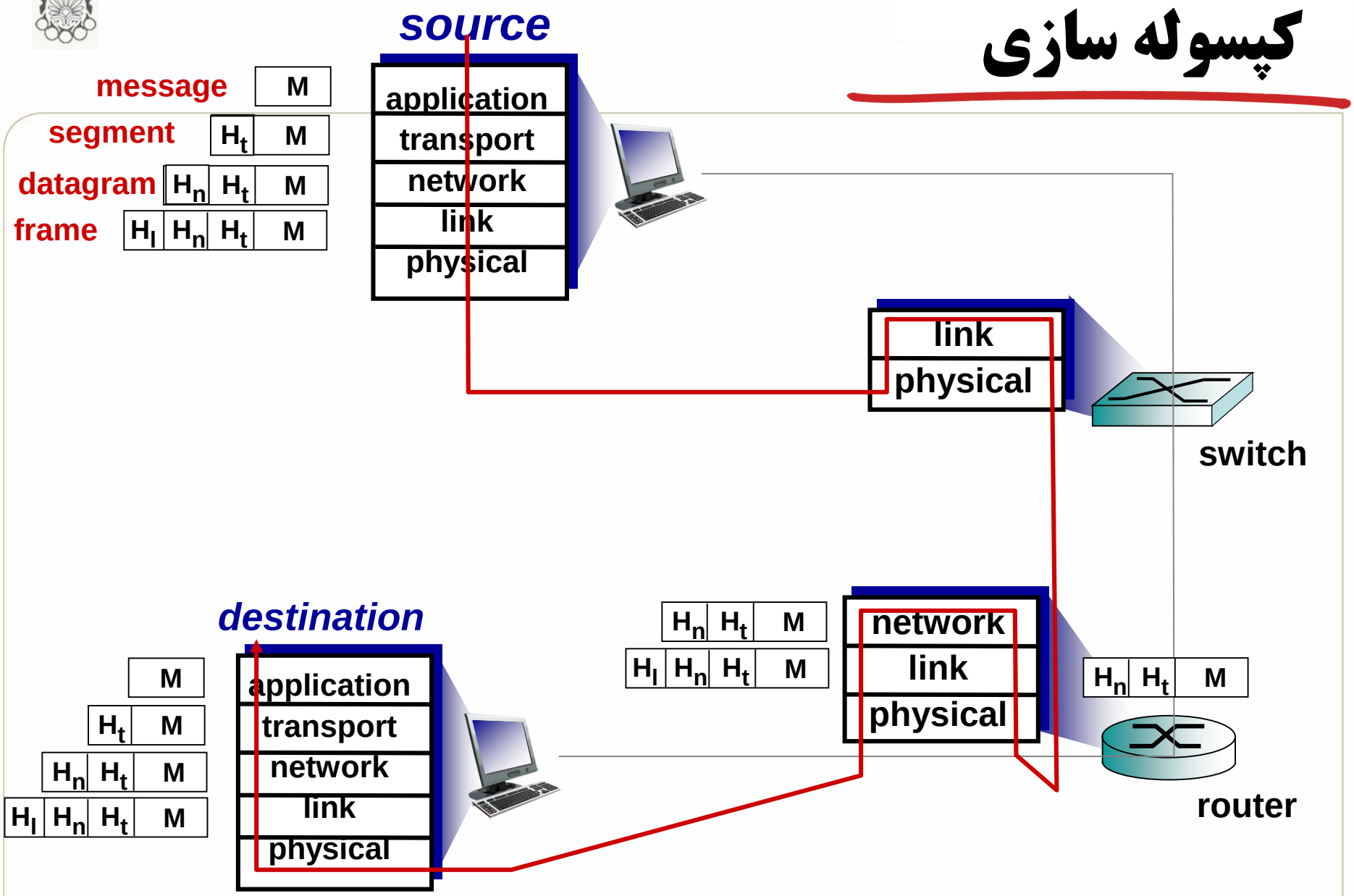


مدل مرجع ISO/OSI

- *presentation:* allow applications to interpret meaning of data, e.g., encryption, compression, machine-specific conventions
- *session:* synchronization, checkpointing, recovery of data exchange
- Internet stack "missing" these layers!
  - these services, *if needed*, must be implemented in application
  - needed?



کپسوله سازی


source
message
M
segment
H_t M
datagram
H_n H_t M
frame
H_l H_n H_t M
application
transport
network
link
physical
link
physical
switch
destination
M
H_t M
H_n H_t M
H_l H_n H_t M
application
transport
network
link
physical
H_n H_t M
H_l H_n H_t M
network
link
physical
H_n H_t M
router

امنیت شبکه

- field of network security:
  - how bad guys can attack computer networks
  - how we can defend networks against attacks
  - how to design architectures that are immune to attacks
- Internet not originally designed with (much) security in mind
  - *original vision:* “a group of mutually trusting users attached to a transparent network” ☺
  - Internet protocol designers playing “catch-up”
  - security considerations in all layers!

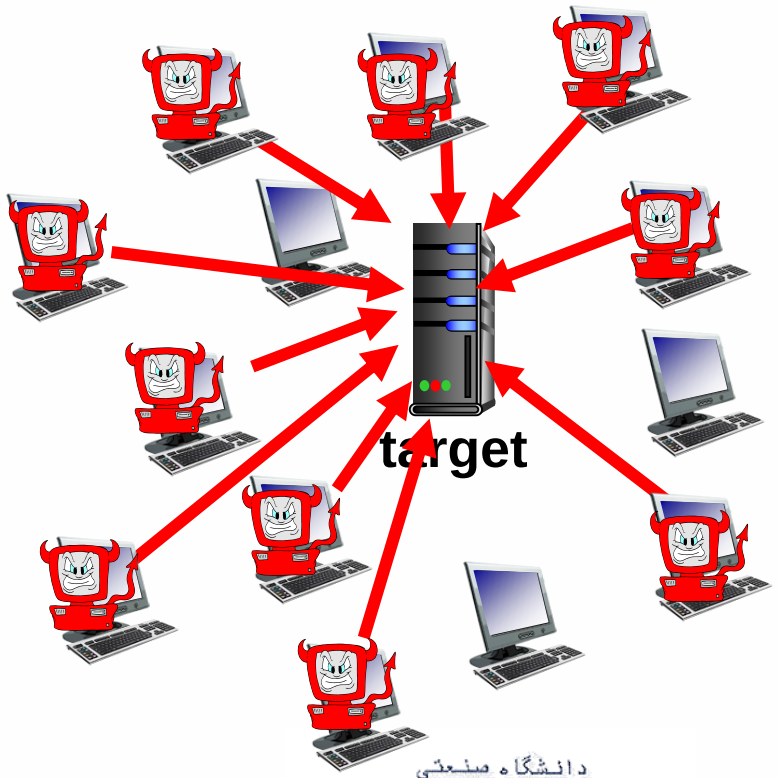
آدم بدها : نصب بدافزار در میزبان از طریق اینترنت

- malware can get in host from:
  - *virus:* self-replicating infection by receiving/executing object (e.g., e-mail attachment)
  - *worm:* self-replicating infection by passively receiving object that gets itself executed
- spyware malware can record keystrokes, web sites visited, upload info to collection site
- infected host can be enrolled in botnet, used for spam. DDoS attacks

آدم بدها : حمله به شبکه، سرویس یا زیرساخت

Denial of Service (DoS): attackers make resources (server, bandwidth) unavailable to legitimate traffic by overwhelming resource with bogus traffic

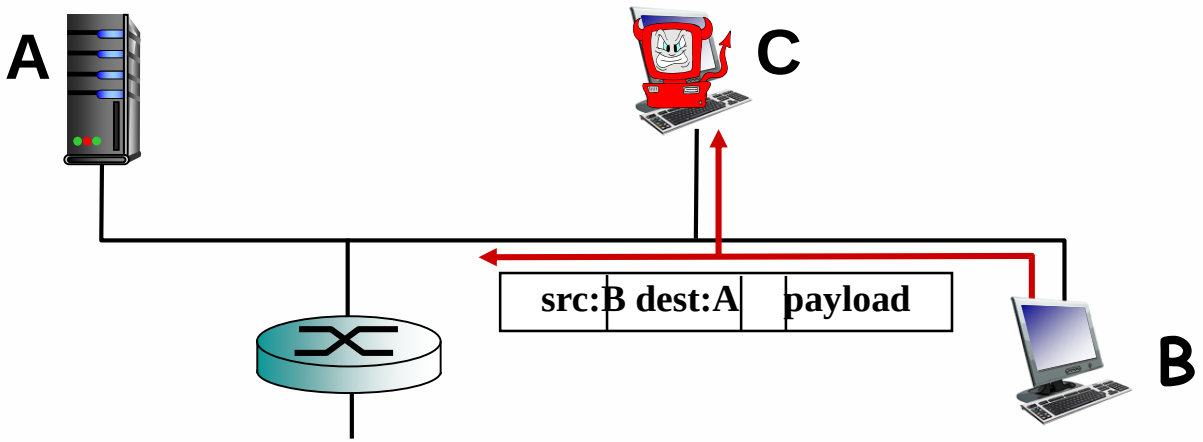
1. **select target**
2. **break into hosts around the network (see botnet)**
3. **send packets to target from compromised hosts**



آدم بدها ممکن است بسته‌ها را شنود کنند

packet "sniffing":

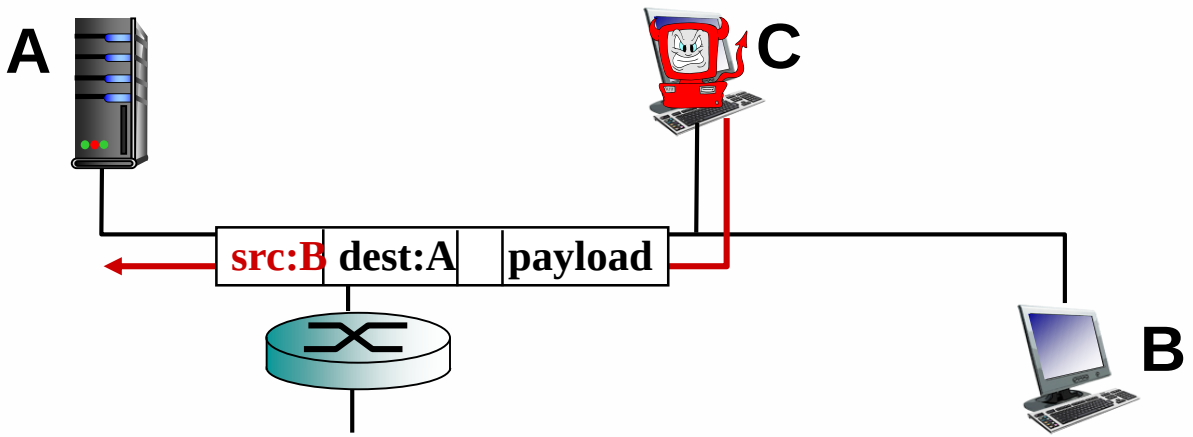
- broadcast media (shared ethernet, wireless)
- promiscuous network interface reads/records all packets (e.g., including passwords!) passing by



- **wireshark software used for end-of-chapter labs is a (free) packet-sniffer**

آدم بدها ممکن است از آدرس‌های جعلی استفاده کنند

IP spoofing: send packet with false source address



خلاصه فصل اول

این فصل حجم زیادی از مطالب را پوشش داد:

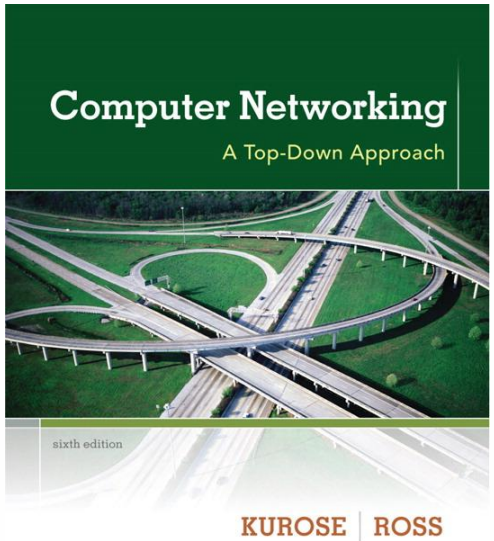
- توصیف کلی اینترنت
- تعریف پروتکل
- لبه‌های شبکه) هسته شبکه و شبکه دسترسی
  - **سوئیچ بسته و سوئیچ مدار**
  - **ساختار اینترنت**
- کارآیی: تلفات، تاخیر، بازده
- لایه بندی، مدل های سرویس
- امنیت
- تاریخچه

دانسته های شما در پایان این فصل:

- دانش کلی از شبکه
- علاقه به دانستن مطالب بطور عمیق‌تر

منابع

این پاورپوینت از روی پاورپوینت مربوط به فصل یک کتاب تهیه شده است



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6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012