CHAPTER 1
INTRODUCTION ON COMPUTER NETWORK

ET4230 – 20161

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Chapter 1: introduction

our goal:

- get "feel" and terminology
- more depth, detail *later* in course
- approach:
  - use Internet as example

overview:

- what's the Internet?
- what's a protocol?
- network edge; hosts, access net, physical media
- network core: packet/circuit switching, Internet structure
- performance: loss, delay, throughput
- security
- protocol layers, service models
- history

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Chapter 1: roadmap

1.1 what *is* the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security

1.7 history

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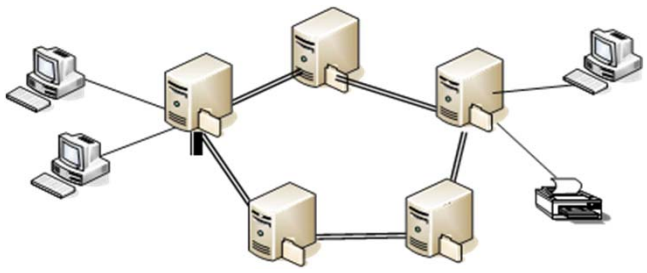
ĐỊNH NGHĨA

- Mạng máy tính:
  - thiết bị mạng (host, server, network devices)
  - phương tiện truyền dẫn vật lý (transmission medium)
  - kiến trúc mạng (network architecture)
    - cấu trúc mạng (Topology)
    - giao thức mạng (Protocols)



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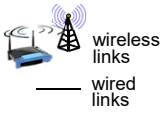
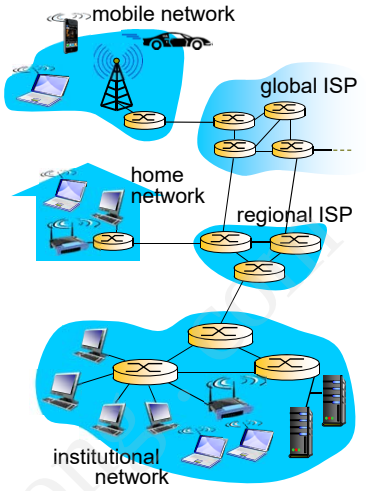
What's the Internet: a component view

- millions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps*



- *communication links*
  - fiber, copper, radio, satellite
  - transmission rate: *bandwidth*

- *Packet switches:* forward packets (chunks of data)
  - *routers* and *switches*



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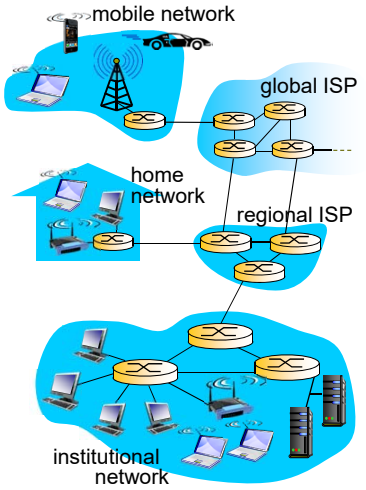
What's the Internet: a protocol view

- *Internet:* "network of networks"
  - Interconnected ISPs
- *protocols* control sending, receiving of msgs
  - e.g., TCP, IP, HTTP, Skype, 802.11
- *Internet standards*
  - RFC: Request for comments
  - IETF: Internet Engineering Task Force



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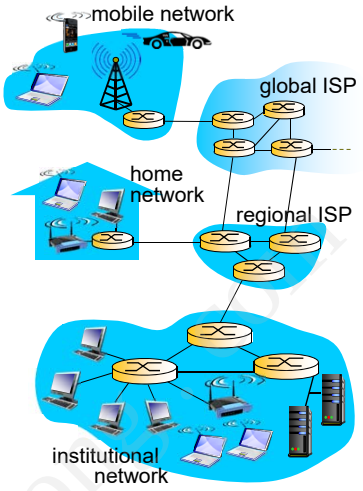
What's the Internet: a service view

- *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



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What's the Internet: goal

- Chia sẻ tài nguyên dùng chung
- Nâng cao độ tin cậy
- Môi trường giao tiếp người – máy
- Giảm chi phí đầu tư phần cứng
- Bảo đảm các tiêu chuẩn thống nhất về tính bảo mật, an toàn dữ liệu

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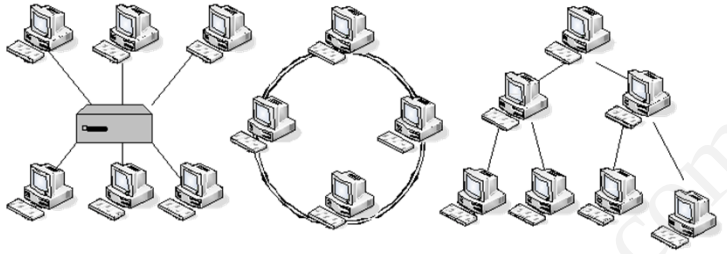
Topology

- Kiểu điểm - điểm (Point to Point)



Các mạng có cấu trúc điểm - điểm (Star, Ring, Tree)

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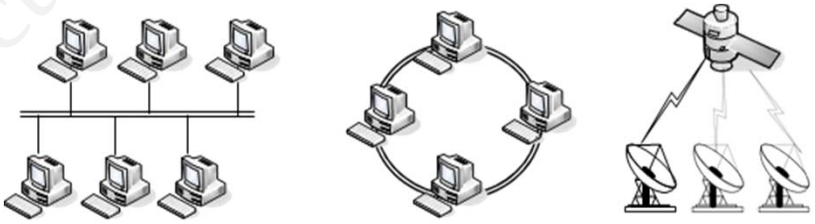
Topology

- Kiểu đa điểm hay quảng bá (Point to Multipoint, Broadcasting)



Các mạng có cấu trúc quảng bá (Bus, Ring, and Satellite)

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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

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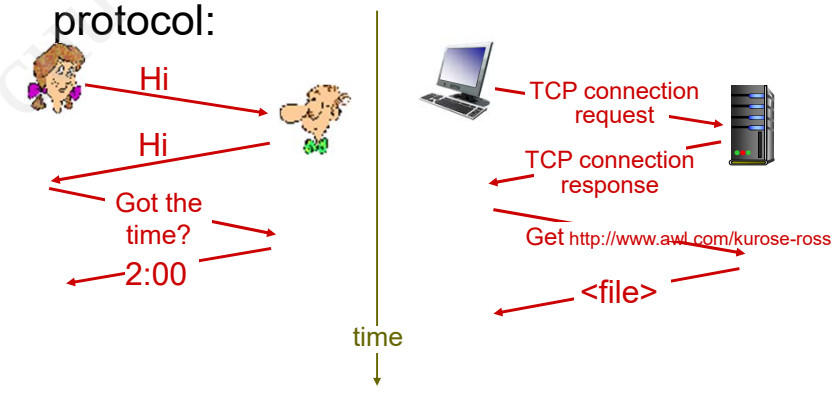
What's a protocol?

a human protocol and a computer network protocol:



Q: other human protocols?

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What's a protocol?

- Chức năng giao thức
  - Encapsulation
  - Fragmentation
  - Connection control
  - Monitoring
  - Flow control
  - Error control
  - Synchronization
  - Addressing

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Chapter 1: roadmap

1.1 what is the Internet?

1.2 network edge

- end systems, access networks, links

1.3 network core

- packet switching, circuit switching, network structure

1.4 delay, loss, throughput in networks

1.5 protocol layers, service models

1.6 networks under attack: security

1.7 history

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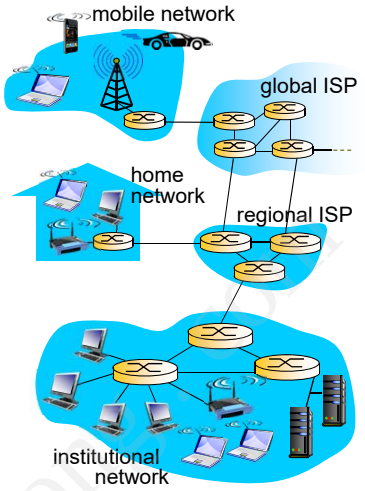
A closer look at network structure

- *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



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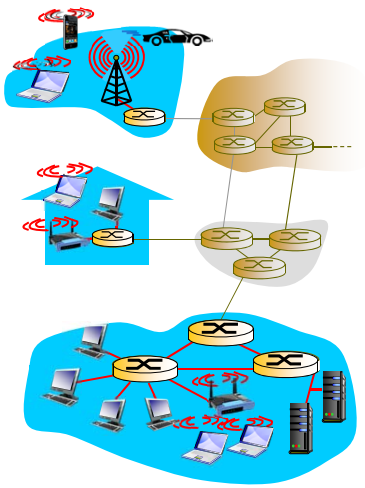
Access networks and physical media

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?
- shared or dedicated?



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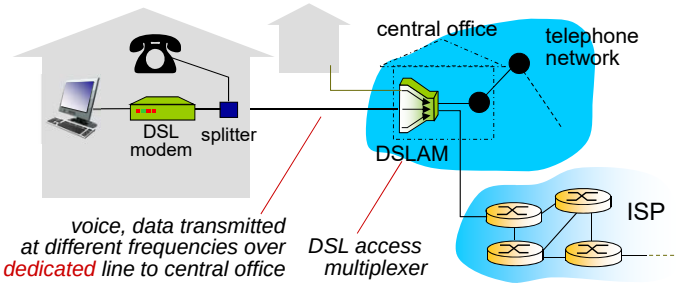
Access net: digital subscriber line (DSL)



- 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)

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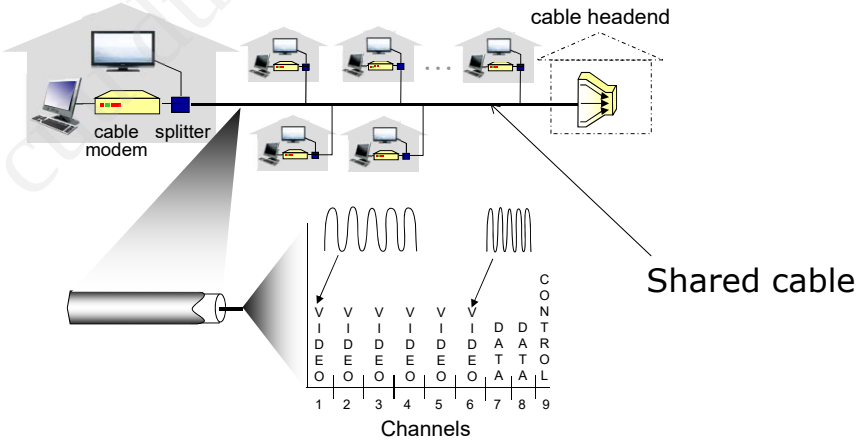
Access net: cable network



frequency division multiplexing: different channels transmitted in different frequency bands

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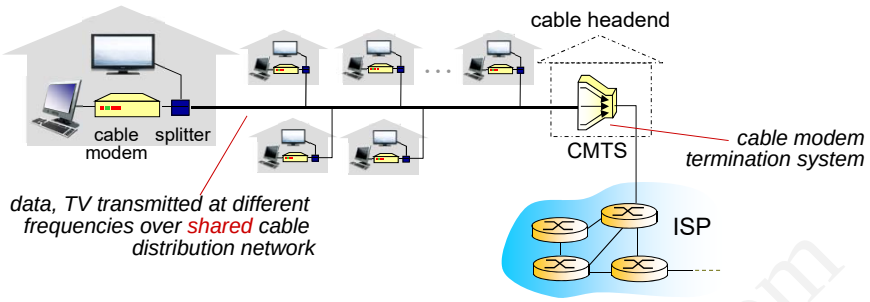
Access net: cable network



- 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

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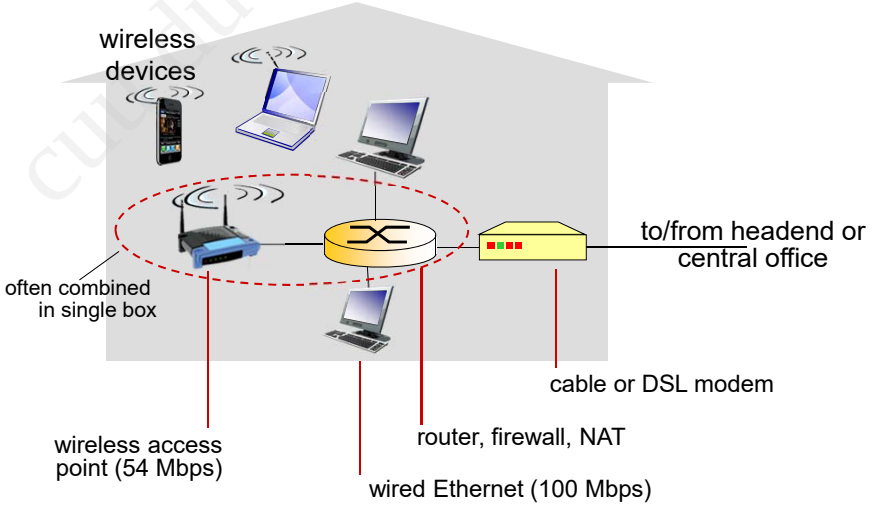
Access net: home network



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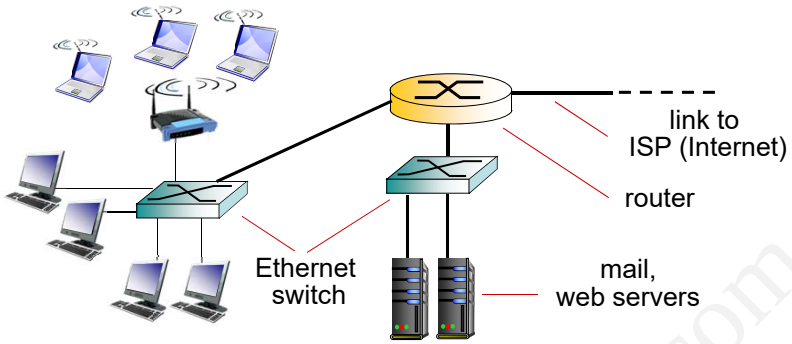
Enterprise access networks (Ethernet)



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

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Wireless access networks

- 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

wide-area wireless access

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

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Physical media

- 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

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Physical media: coax, fiber

twisted pair (TP)

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

coaxial cable:

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

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Physical media: coax, fiber

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

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Physical media: radio, viba, Infrared

- 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

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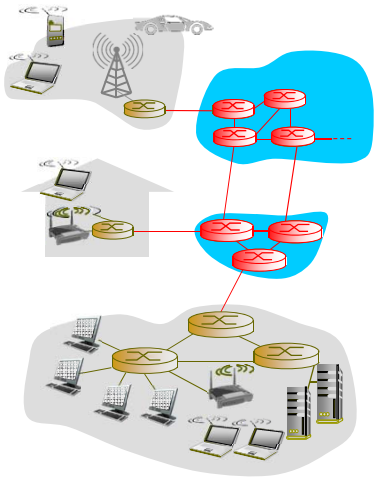
The network core

- 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



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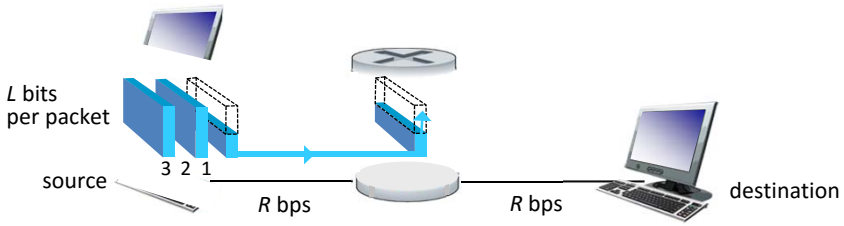
Packet-switching: store-and-forward



- 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

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

one-hop numerical example:

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

more on delay shortly …

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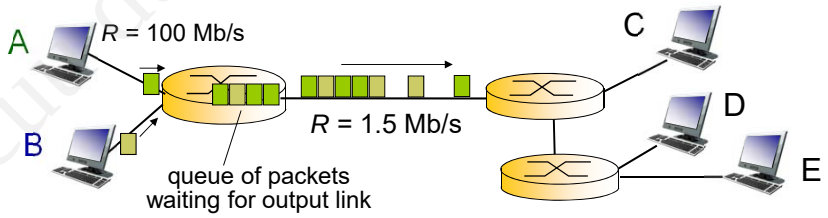
Packet Switching: queueing delay, loss



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

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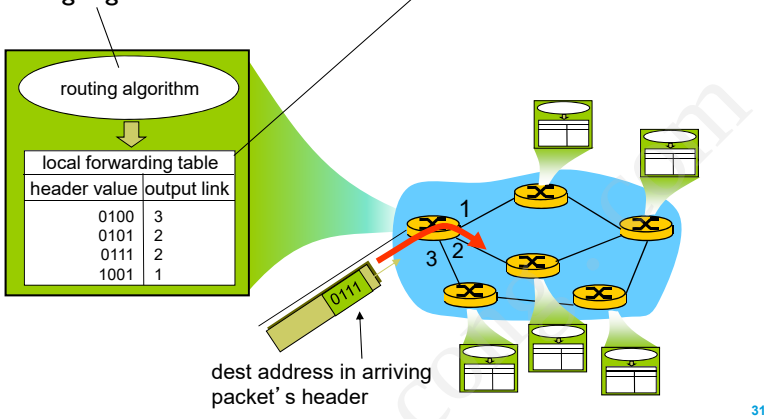
Two key network-core functions

routing: determines source-destination route taken by packets

- *routing algorithms*

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



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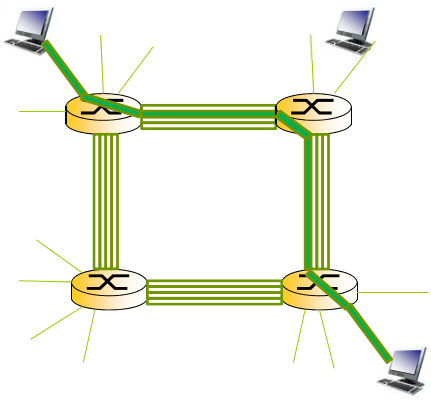
Alternative core: circuit switching

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



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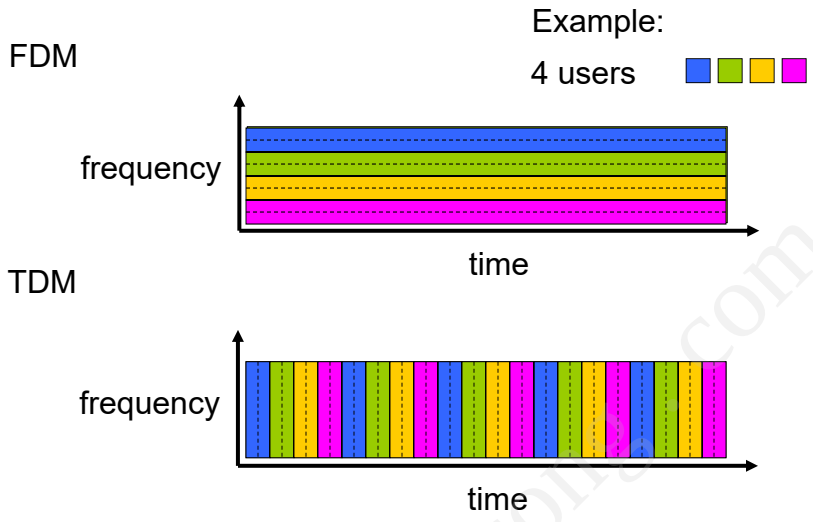
Circuit switching: FDM versus TDM



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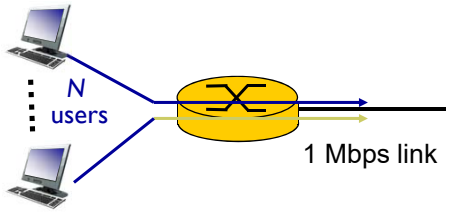
Packet switching versus circuit switching

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 ?

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Packet switching versus circuit switching

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

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

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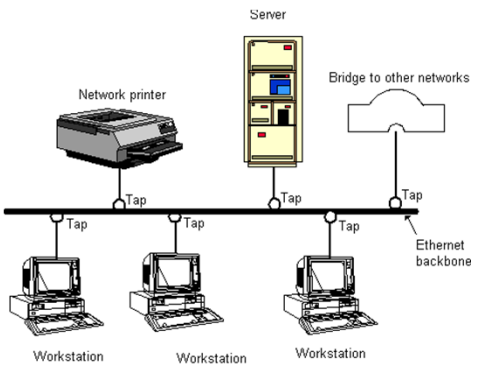
Phân loại mạng máy tính

- Theo khoảng cách
  - Mạng cục bộ LAN (Local Area Networks)



Cấu trúc mạng hình BUS

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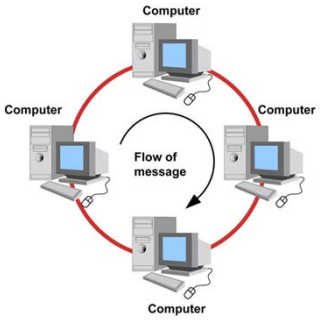
  - Mạng cục bộ LAN (Local Area Networks)



Cấu trúc mạng hình RING

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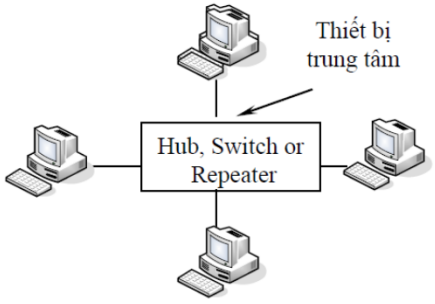

Cấu trúc mạng hình sao

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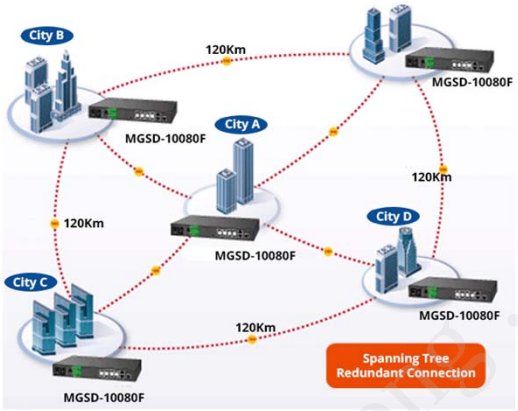
Phân loại mạng máy tính

- Theo khoảng cách
  - Mạng đô thị MAN (Metropolitan Area Networks)



MAN Network Diagram

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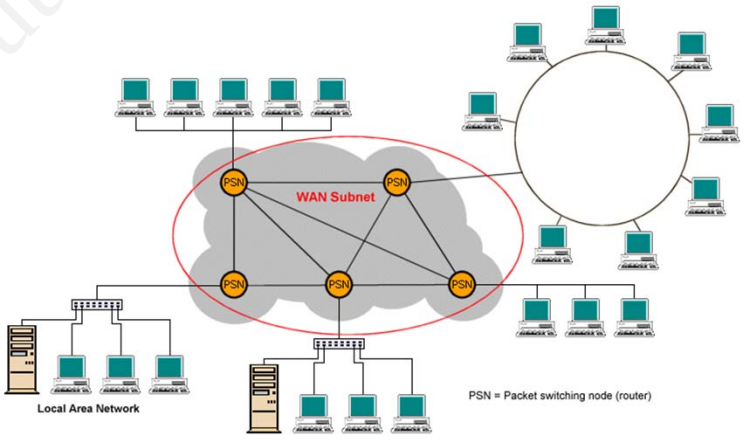
Phân loại mạng máy tính

- Theo khoảng cách
  - Mạng diện rộng WAN (Wide Area Networks)



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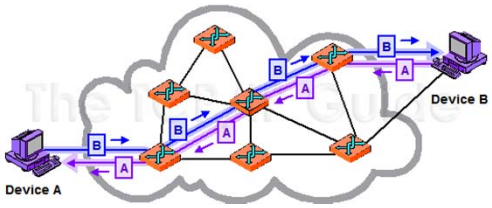
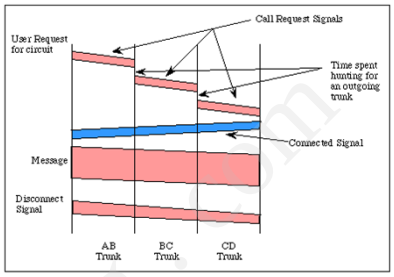
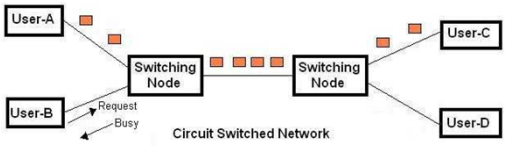
Phân loại mạng máy tính

- Phân loại theo cơ chế chuyển mạch
  - Mạng chuyển mạch kênh (Circuit Switched Networks)







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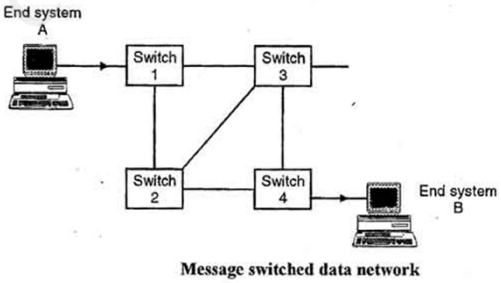
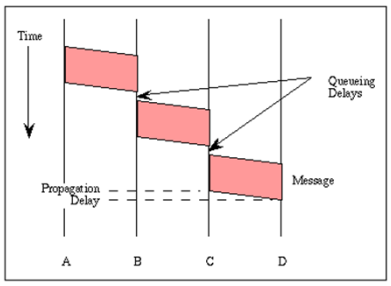
Phân loại mạng máy tính

- Phân loại theo cơ chế chuyển mạch
  - Mạng chuyển mạch thông báo (message-switched network)





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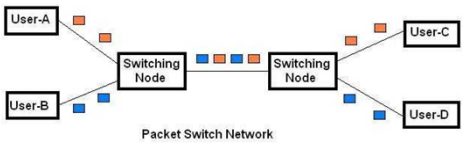
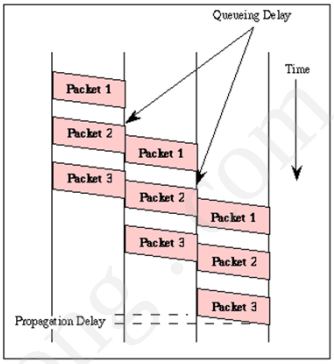
Phân loại mạng máy tính

- Phân loại theo cơ chế chuyển mạch
  - Mạng chuyển mạch gói (Packet Switched Networks)





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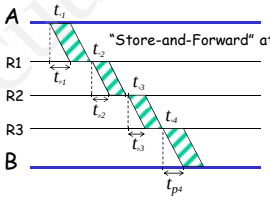
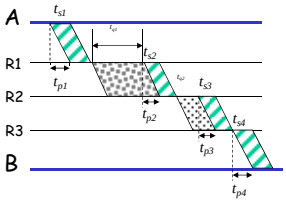
  - Mạng chuyển mạch gói (Packet Switched Networks)



$$\min(d_{e2e}) = \sum_{i=1}^{n} (t_{p_i} + t_{s_i})$$



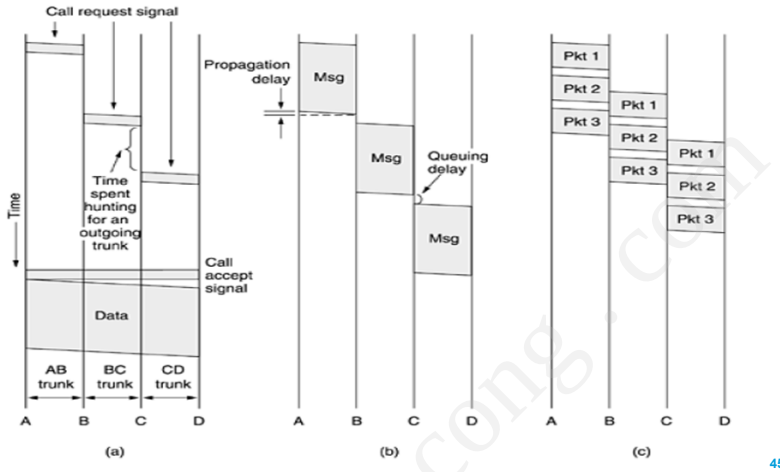
$$d_{e2e} = \sum_{i=1}^{n} (t_{p_i} + t_{s_i} + t_{q_i})$$

Trong điều kiện tải cao, các gói đi vào nút mạng phải đợi trong hàng đợi trước khi được gửi ra đầu ra

44

Phân loại mạng máy tính

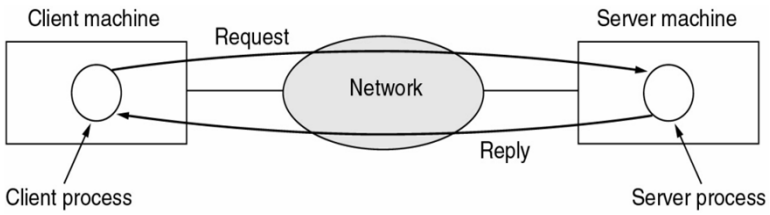
- Phân loại theo cơ chế chuyển mạch
  - So sánh các cơ chế chuyển mạch (bài tập)



45

Phân loại mạng máy tính

- Phân loại theo mô hình xử lý dữ liệu
  - Mô hình Client-Server

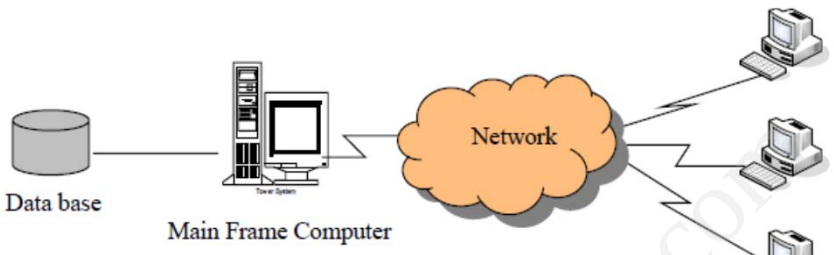


Mô hình chủ /khách (Client / Server)

46

Phân loại mạng máy tính

- Phân loại theo mô hình xử lý dữ liệu
  - Mô hình Client-Server



Hình 1.10 Ví dụ mô hình Client-Server 2 lớp
1. Trình duyệt Browser gửi yêu cầu cho Web Server.
2. Web Server trả kết quả về cho trình duyệt

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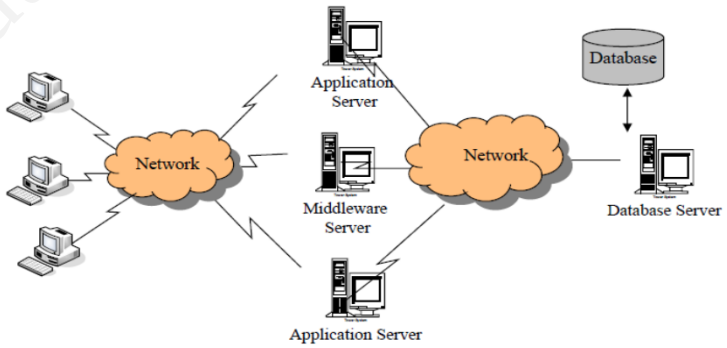
Phân loại mạng máy tính

- Phân loại theo mô hình xử lý dữ liệu
  - Mô hình Client-Server



Mô hình Client-Server nhiều lớp

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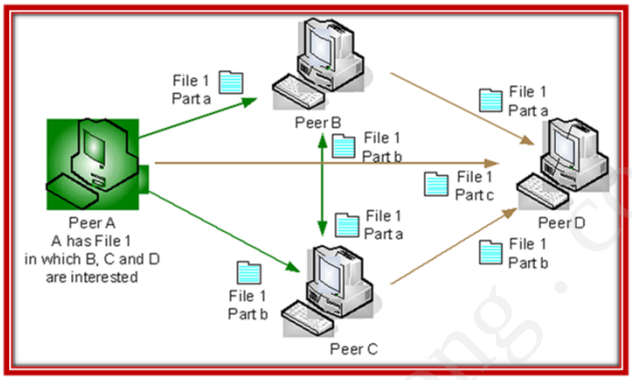
Phân loại mạng máy tính

- Phân loại theo mô hình xử lý dữ liệu
  - Mô hình ngang hàng (Peer-to-Peer)



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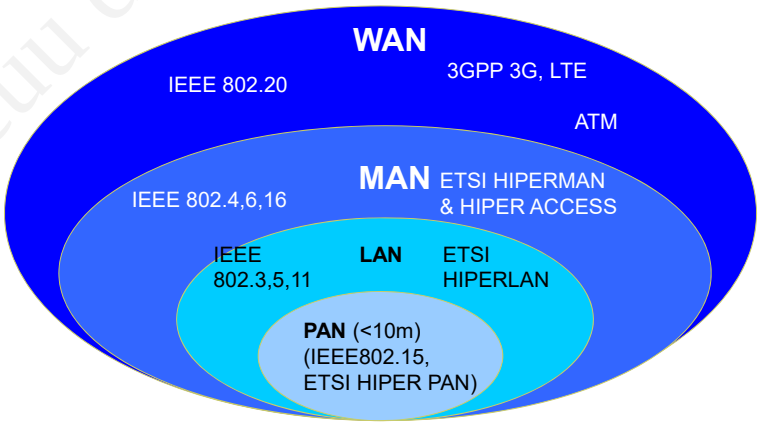
Kích cỡ mạng



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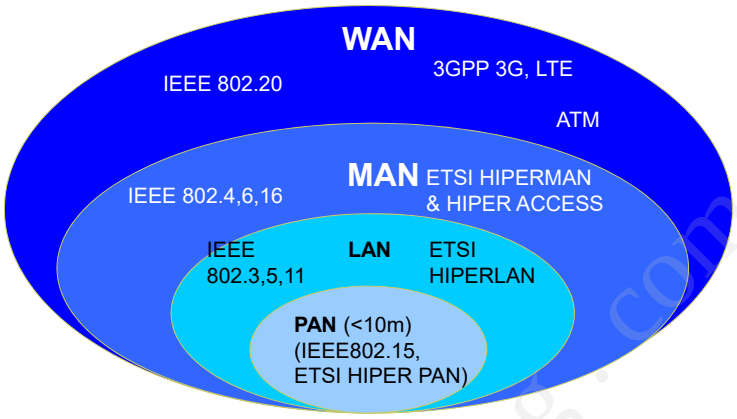
Một số mạng điển hình



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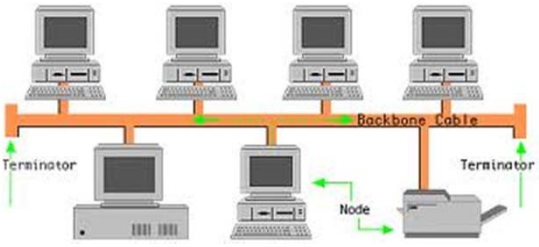
Một số mạng điển hình

- IEEE 802
  - IEEE 802.3: Chuẩn mạng LAN/MAN – Ethernet
  - IEEE 802.4: Chuẩn mạng LAN – Token Bus, chủ yếu được sử dụng trong công nghiệp (GM)

IEEE 802



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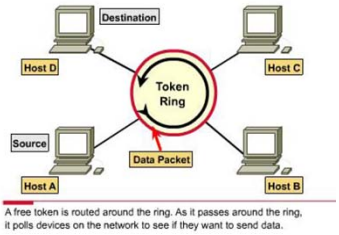
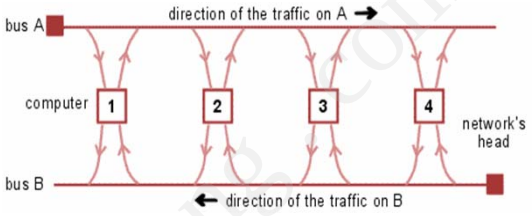
Một số mạng điển hình

- IEEE 802
  - IEEE 802.5: chuẩn mạng LAN – Token Ring được phát triển bởi IBM
  - IEEE 802.6: chuẩn mạng MAN – DQDB (Distributed Queue Dual Bus) với tốc độ 150Mbit/s trên khoảng cách 160km



A free token is routed around the ring. As it passes around the ring, it polls devices on the network to see if they want to send data.



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Một số mạng điển hình

- IEEE 802
  - IEEE 802.11: chuẩn mạng LAN không dây
  - IEEE 802.15: chuẩn mạng cá nhân không dây (Wireless Personal Area Network - WPAN)
    - IEEE 802.15.1: BlueTooth
    - IEEE 802.15.3: High rate WPAN (11 – 55Mbit/s): sử dụng cho các ứng dụng multimedia
    - IEEE 802.15.4: Low rate WPAN/ZigBee: cho các ứng dụng tiêu thụ ít năng lượng, tốc độ thấp (Wireless Sensor Network)

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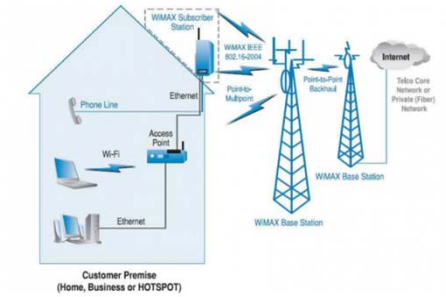
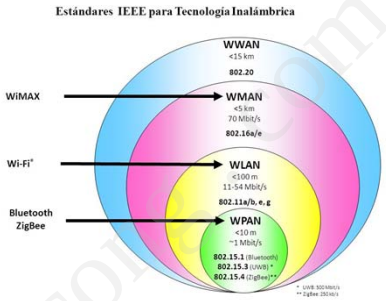
Một số mạng điển hình

- IEEE 802
  - IEEE 802.16: Chuẩn mạng WMAN – WiMAX
    - IEEE 802.16-2004: WiMAX cố định
    - IEEE 802.16e-2005: WiMAX di động
  - IEEE 802.20: WWAN – Mobile Broadband Wireless Access (MBWA), tầm phủ sóng lớn hơn WiMAX (< 15km)





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Một số mạng điển hình

- 3GPP
  - 3G/HSPA (High Speed Packet Access)
  - LTE (Long Term Evolution)
- ATM Forum
  - ATM

3GPP A GLOBAL INITIATIVE

The ATM Forum

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Internet structure: network of networks

- 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

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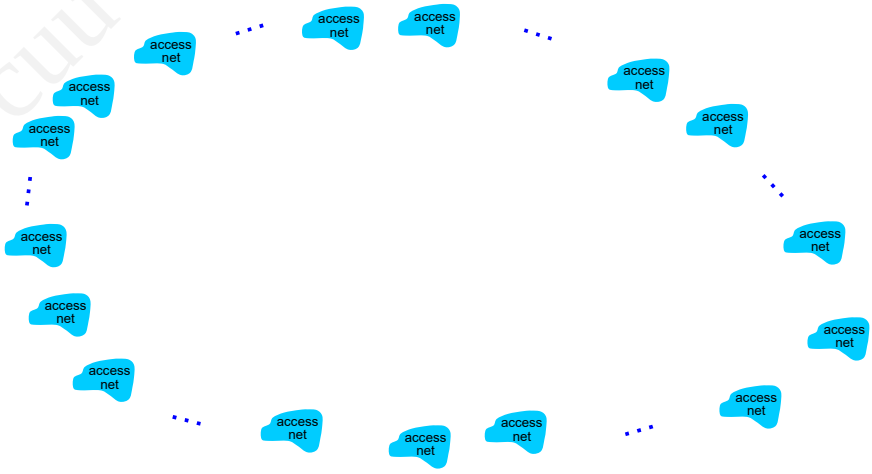
Internet structure: network of networks

Question: given *millions* of access ISPs, how to connect them together?



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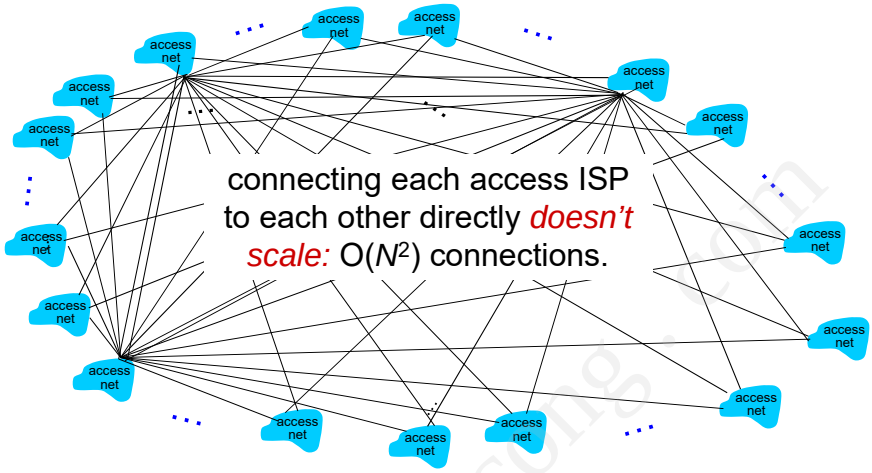
Internet structure: network of networks

Option: connect each access ISP to every other access ISP?



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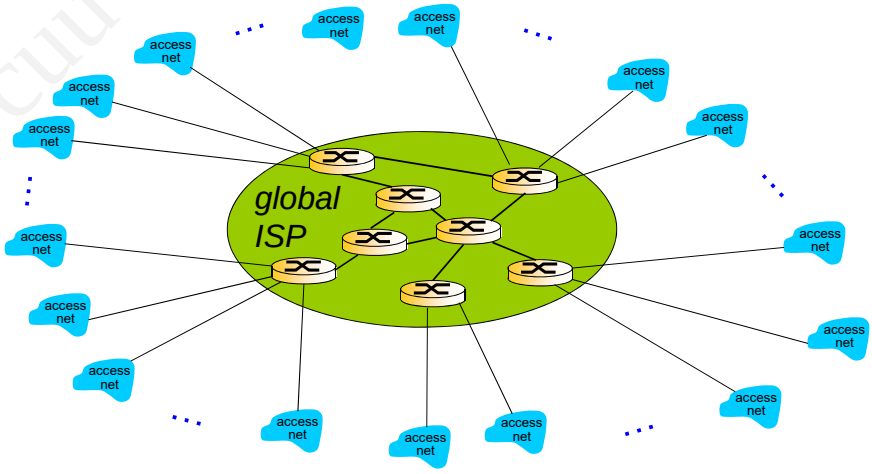
Internet structure: network of networks

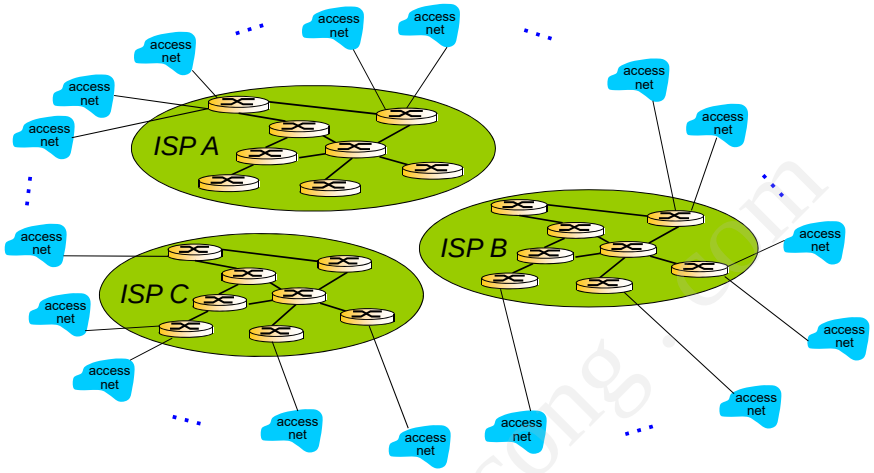
Option: connect each access ISP to a global transit ISP? Customer and provider ISPs have economic agreement.



60

Internet structure: network of networks

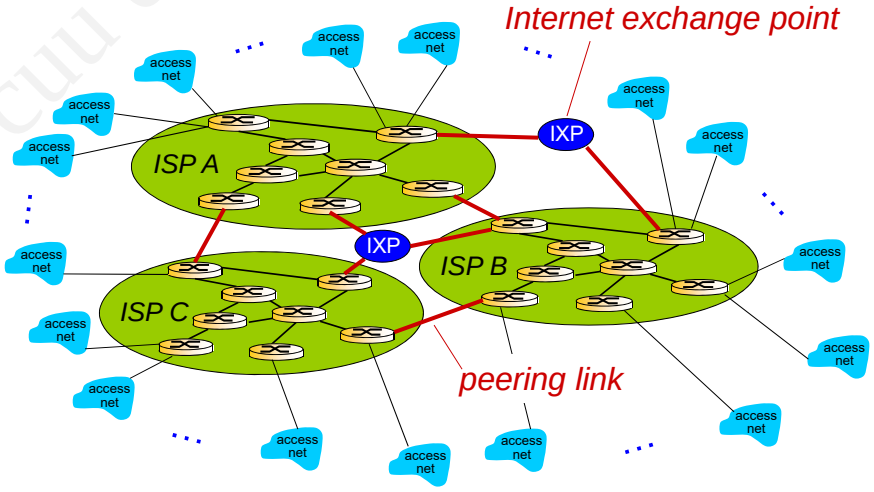
But if one global ISP is viable business, there will be competitors ….



61

Internet structure: network of networks

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



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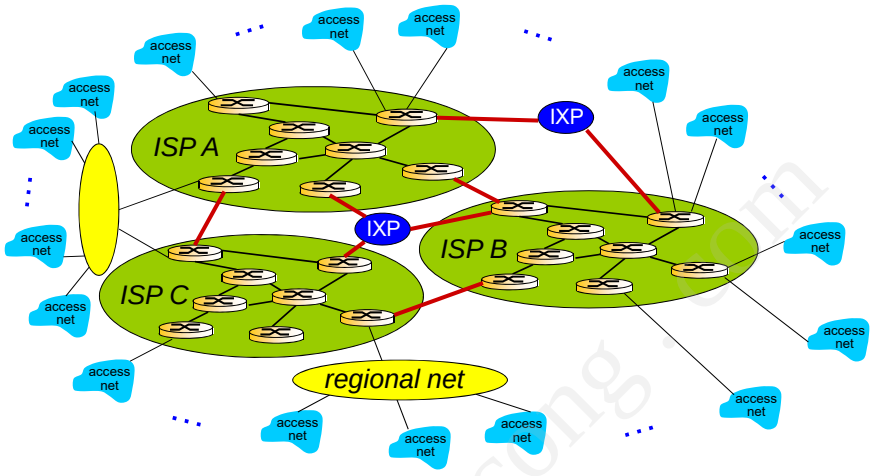
Internet structure: network of networks

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



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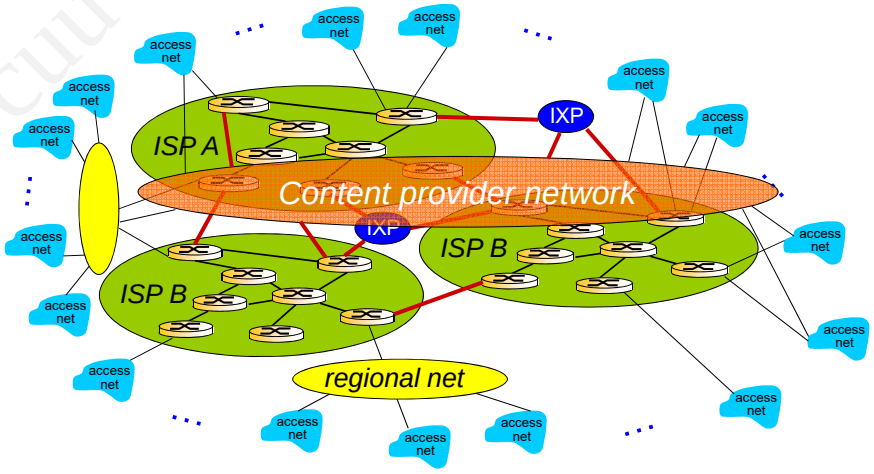
Internet structure: network of networks

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



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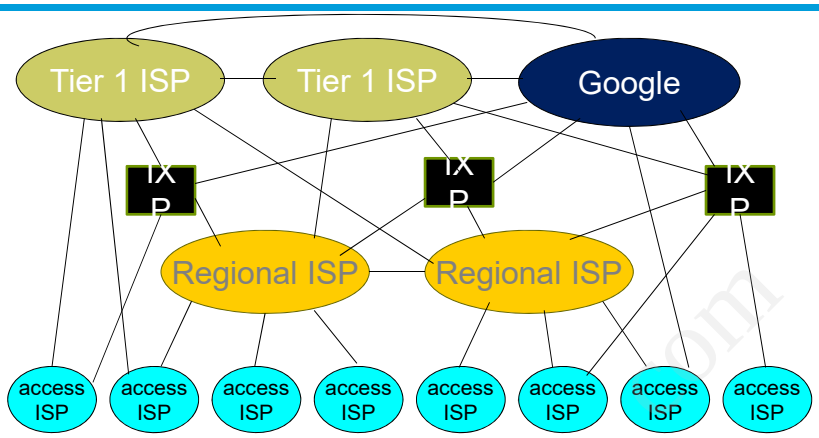
Internet structure: network of networks



- 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

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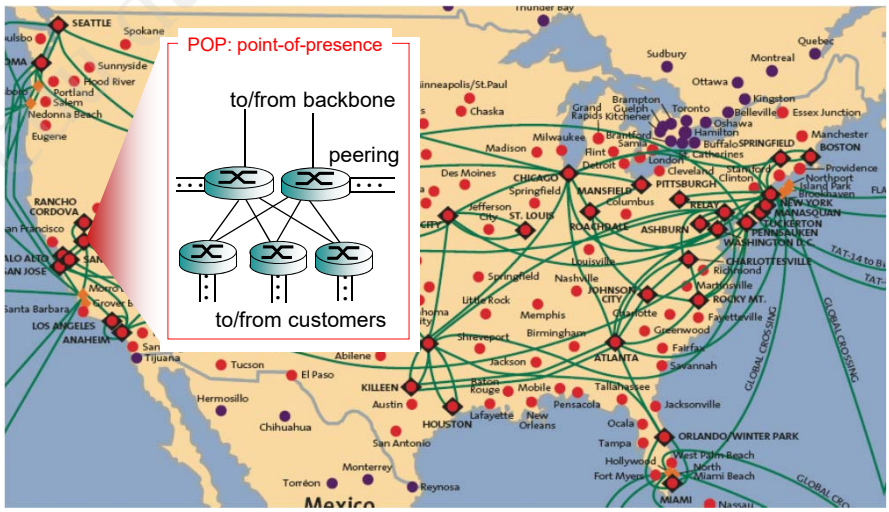
Tier-1 ISP: e.g., Sprint



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Một số khái niệm

- Băng thông: Số lượng bit có thể truyền đi trên một đơn vị thời gian
  - Thường được biểu diễn qua tốc độ dữ liệu tối đa (maximum data rate)
- Trễ lan truyền (propagation delay): thời gian để tín hiệu lan truyền trên kênh vật lý:
  - $t_p=l/v_c$; v_c là vận tốc lan truyền của tín hiệu
    - Phụ thuộc vào môi trường truyền dẫn
    - Electromagnetic signal (light) travels in the medium -- 2 x 108 m/s in fiber.
  - l: Chiều dài của đường truyền vật lý giữa 2 nút mạng (m)

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Một số khái niệm

- Thời gian phục vụ gói (transmission time): thời gian gửi hết một gói tin từ bit đầu tiên đến bit cuối cùng lên kênh truyền
  - $t_s=L/C$
    - Dung lượng kênh truyền C (bit/s) (link capacity)
  - A function of bandwidth
  - If bandwidth is B, transmission time is 1/B.
  - If bandwidth is 10 Mbps, the transmission time is $1/(10 \times 10^6)$ = 1 ms.
- Trễ hàng đợi t_q (Queuing delay): thời gian một gói phải lưu lại trong hàng đợi ở nút mạng trung gian
  - How long does it have to wait ?
    - Dependent on the load on the network -- how many packets are traversing that router

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Một số khái niệm

- Trễ từ đầu cuối đến đầu cuối (end-to-end delay d_{e2e}: trễ từ khi gửi một gói tin ở đầu phát cho đến khi nó được nhận ở đầu thu
- Round Trip Time
  - **RTT** is the length of time it takes for a small packet to be sent plus the length of time it takes for an acknowledgment of that packet to be received (*excluding the transmission time of the packet*)
  - if forward delay = backward delay, RTT = 2 * Latency (typically assumed -- although not always accurate)

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Một số khái niệm

- Thông lượng (Throughput):
  - Định nghĩa hiệu quả sử dụng kênh truyền
  - Throughput = Transfer size/ Transfer time.
  - What is the transfer time ?
    - RTT + (Transfer size/Bandwidth)
    - (ignoring queuing delays).
  - Ví dụ:
    - 1 MB file over a 1 Gbps network with RTT 100 milliseconds.
    - Transfer time = 100 ms + (1 MB/1Gbps) = 100 ms + 8 ms = 108 ms.
    - Effective throughput = 1 MB/108 ms = 74.1 Mbps.
  - Nhận xét: Impact of data size
    - If data size increases, (Transfer size/Bandwidth) increases become much larger than RTT, in that case, Throughput ~ (Transfer size /(Transfer size/Bandwidth) ~ Bandwidth!

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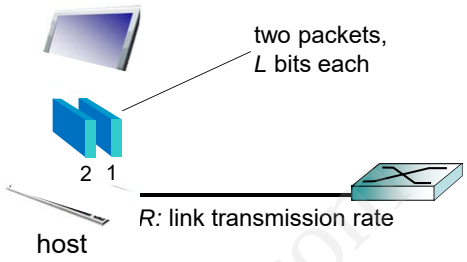
Host: sends *packets* of data

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*



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

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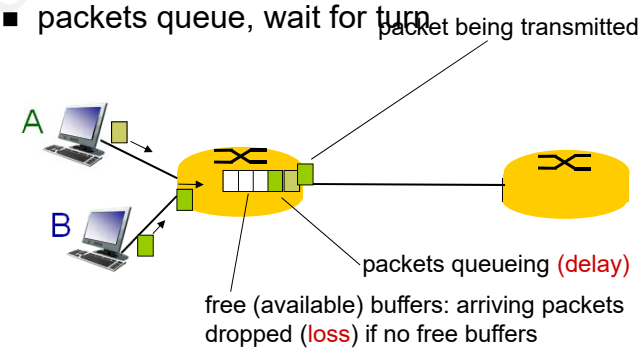
How do loss and delay occur?

packets *queue* in router buffers

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



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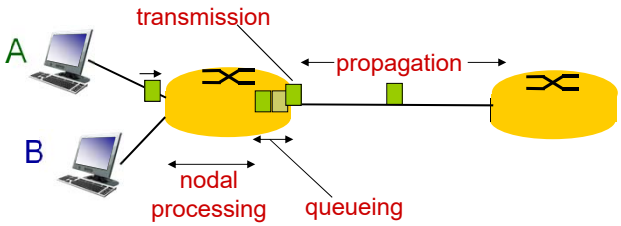
Four sources of packet delay



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

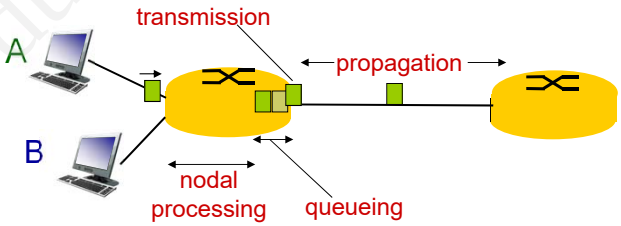
d_{proc}: nodal processing

- 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

Four sources of packet delay



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

d_{trans}: transmission delay:

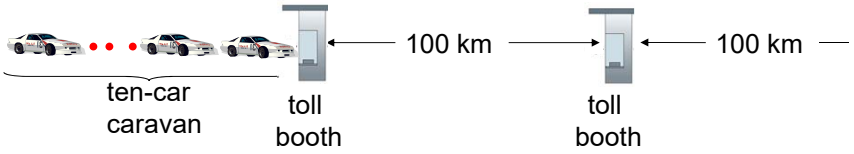
- L: packet length (bits)
- R: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:

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

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

Caravan analogy



- 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

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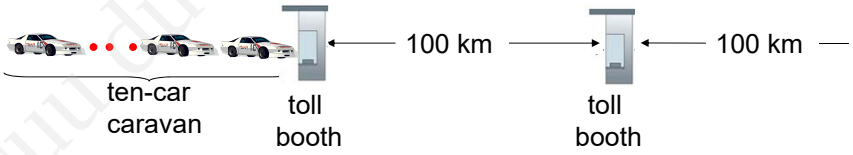
Caravan analogy (more)



- 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.

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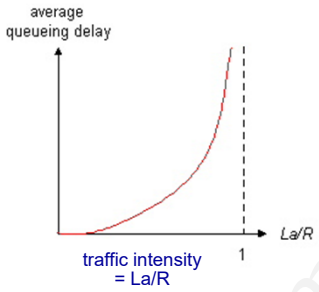
Queueing delay (revisited)

- *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

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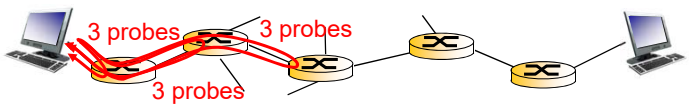
"Real" Internet delays and routes

- 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.



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"Real" Internet delays, routes

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)

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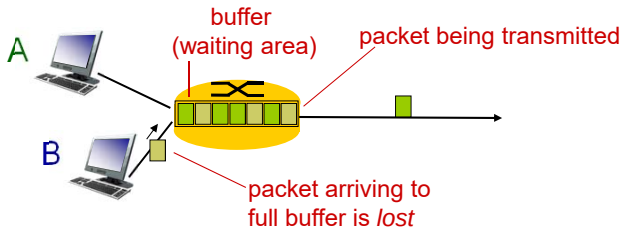
Packet loss

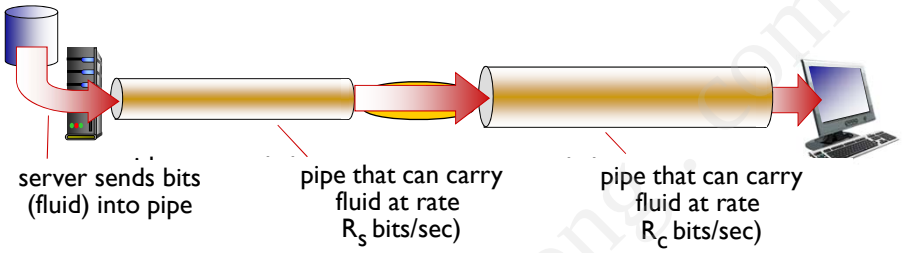
- queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- lost packet may be retransmitted by previous node, by source end system, or not at all



80

Throughput

- *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



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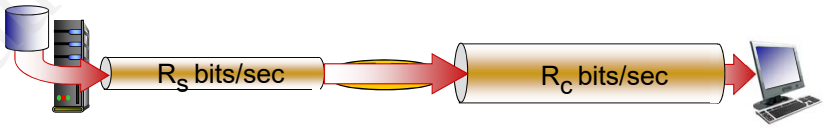
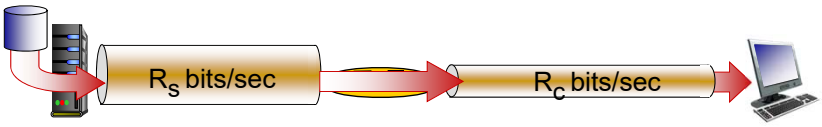
Throughput (more)

- $R_s < R_c$ 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

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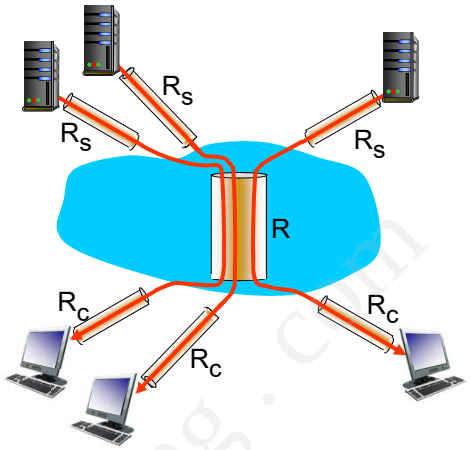
Throughput: Internet scenario

- 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

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Bài tập

- Compare the delay in sending an *x* -bit message over a *k* -hop path in a circuit-switched network and in a (lightly loaded) packet-switched network. The circuit setup time is *s* sec, the propagation delay is *d* sec per hop, the packet size is *p* bits, and the data rate is *b* bps. Under what conditions does the packet network have a lower delay?
- Suppose that *x* bits of user data are to be transmitted over a *k*-hop path in a packet-switched network as a series of packets, each containing *p* data bits and *h* header bits, with x >> (*p* + *h*). The bit rate of the lines is *b* bps and the propagation delay is negligible. What value of *p* minimizes the total delay?
- A LMDS (Local Multipoint Distribution Service), each sector has its own 36-Mbps channel. According to queuing theory, if the channel is 50% loaded, the queuing time will be equal to the download time. Under these conditions, how long does it take to download a 5-KB Web page? How long does it take to download the page over a 1-Mbps ADSL line? Over a 56-kbps modem?

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Internet history

- Bắt đầu từ một thí nghiệm của dự án của ARPA
- Một liên kết giữa hai nút mạng (IMP tại UCLA và IMP tại SRI).
  - ARPA: Advanced Research Project Agency
  - UCLA: University California Los Angeles
  - SRI: Stanford Research Institute
  - IMP: Interface Message Processor

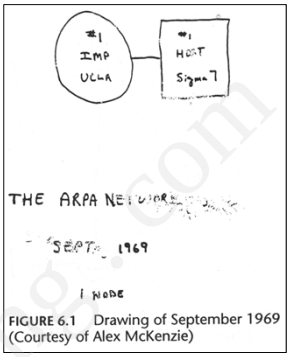
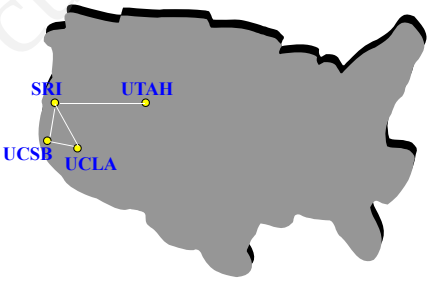


FIGURE 6.1 Drawing of September 1969 (Courtesy of Alex McKenzie)

Internet history

- 3 tháng sau: một mạng hoàn chỉnh với 4 nút, 56kbps



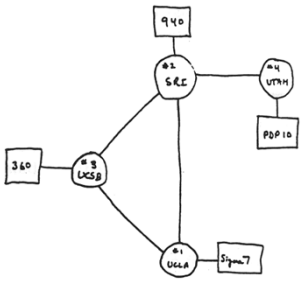
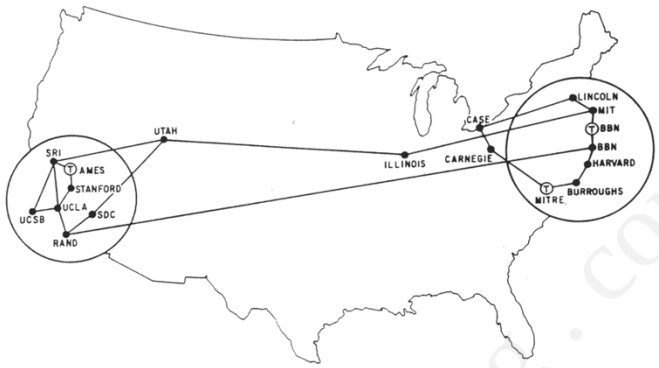


FIGURE 6.2 Drawing of 4 Node Network (Courtesy of Alex McKenzie)

Internet history

- ARPANET thời kỳ đầu, 1971: tốc độ phát triển 1 nút/tháng



MAP 4 September 1971

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Internet history

- Sự mở rộng của ARPANET, 1974: vượt quá 3.000.000 gói tin/ngày

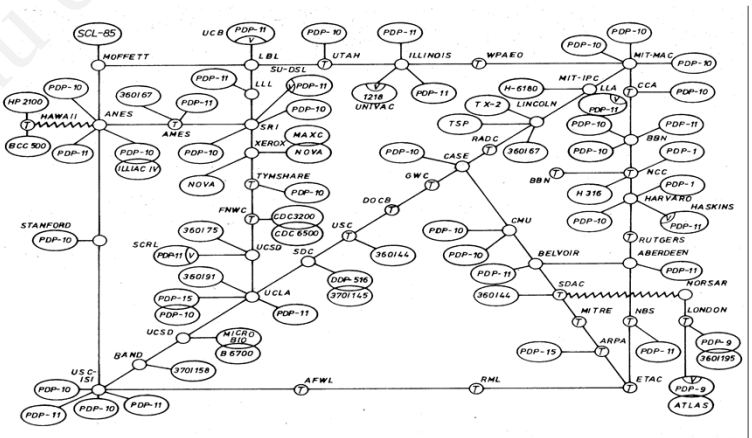

Abb. 4 ARPA NETwork, topologische Karte. Stand Juni 1974.

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Internet history

- Thập niên 1970:
  - Từ đầu 1970 xuất hiện các mạng riêng:
    - ALOHAnet tại Hawaii
    - DECnet, IBM SNA, XNA
  - 1974: Cerf & Kahn – nguyên lý kết nối các hệ thống mở (Turing Awards)
  - 1976: Ethernet, Xerox PARC

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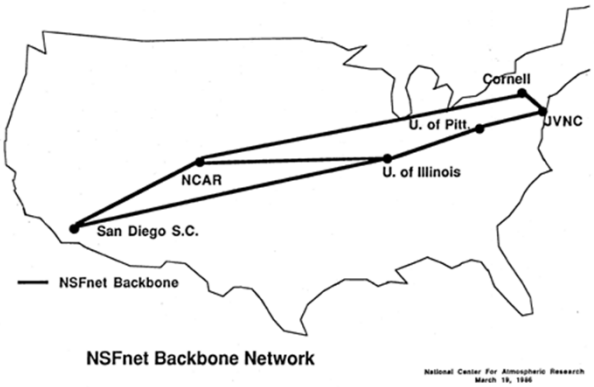
Internet history

- 1981: Xây dựng mạng NSFNET
  - NSF: National Science Foundation: Phục vụ cho nghiên cứu khoa học, do sự quá tải của ARPANET



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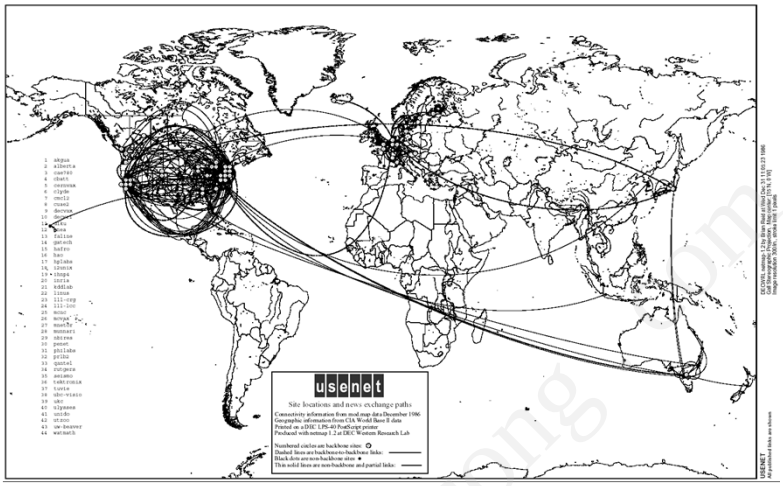
Internet history

- 1986: Nối kết USENET& NSFNET



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Internet history

- Thêm nhiều mạng mới nối vào: MFENET, HEPNET (Dept. Energy), SPAN (NASA), BITnet, CSnet, NSFnet, Minitel …
- TCP/IP được chuẩn hóa và phổ biến vào 1980
- Berkeley tích hợp TCP/IP vào BSD Unix
- Dịch vụ: FTP, Mail, DNS …

- Thập niên 90: Web và thương mại hóa Internet
- Đầu 90: ARPAnet chỉ là một phần của Internet
- Đầu 90: Web
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic, Netscape
- Cuối 90: Thương mại hóa Internet

Cuối 1990's – 2000's:

- Nhiều ứng dụng mới: chat, chia sẻ file P2P…
- E-commerce, Yahoo, Amazon, Google…
- > 50 triệu máy trạm, > 100 triệu NSD
- Vấn đề an toàn an ninh thông tin!
  - Internet dành cho tất cả mọi người
  - Tất cả các dịch vụ phải quan tâm tới vấn đề này

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Internet history

2005-present

- ~750 million hosts
  - Smartphones and tablets
- Aggressive deployment of broadband access
- Increasing ubiquity of high-speed wireless access
- Emergence of online social networks:
  - Facebook: soon one billion users
- Service providers (Google, Microsoft) create their own networks
  - Bypass Internet, providing "instantaneous" access to search, emai, etc.
- E-commerce, universities, enterprises running their services in "cloud" (eg, Amazon EC2)

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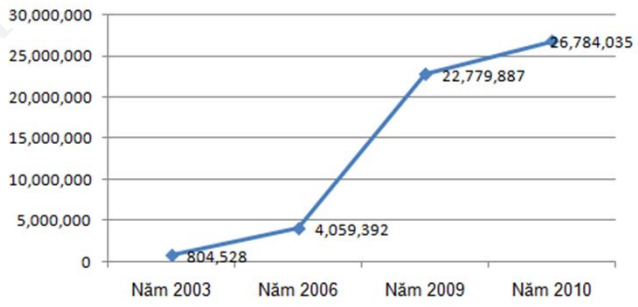
Internet history

- Phát triển Internet ở Việt Nam



Bản đồ số lượng người dùng Internet ở Việt Nam qua các năm

https://vi.wikipedia.org/wiki/Internet_tại_Việt_Nam

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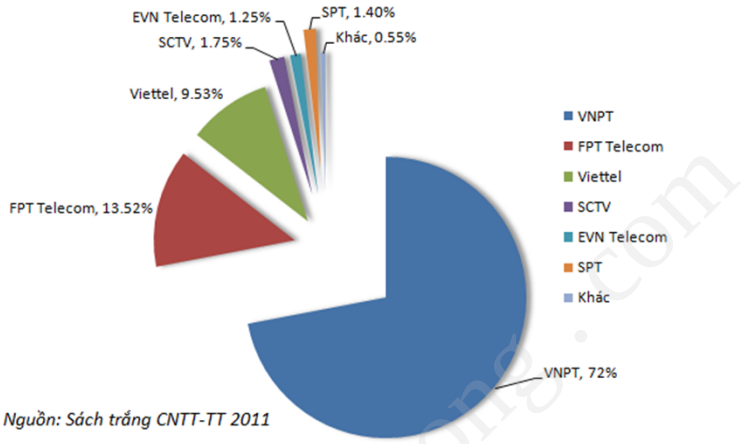
Internet history

- Thị phần thuê bao dịch vụ truy cập Internet của các doanh nghiệp (tính đến tháng 12/2010)



Nguồn: Sách trắng CNTT-TT 2011

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Introduction: summary

covered a "ton" of material!

- Internet overview
- what's a protocol?
- network edge, core, access network
  - packet-switching versus circuit-switching
  - Internet structure
- performance: loss, delay, throughput
- layering, service models
- security
- history

you now have:

- context, overview, "feel" of networking
- more depth, detail *to follow!*

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