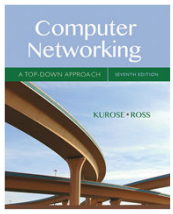
Chapter 1
计算机网络简介
Introduction



Computer Networking: A Top-Down Approach
7th edition
Jim Kurose, Keith Ross
Pearson, 2016

Chapter 1: 简介Introduction

目标 Chapter goal:

- Get "feel," "big picture," introduction to terminology
  - more depth, detail *later* in course
- Approach:
  - use Internet as example

Overview/roadmap:

- 因特网 What *is* the Internet?
- 协议 What *is* a protocol?
- 网络边缘 Network edge: hosts, access network, physical media
- 网络核心 Network core: packet/circuit switching, internet structure
- 性能 Performance: loss, delay, throughput
- 安全 Security
- 协议层和服务模型 Protocol layers, service models
- 计算机网络的历史 History

具体构成描述（硬件和软件）
The Internet: a "Nuts And Bolts" View

Billions of connected computing *devices*:

- *主机 hosts = 端系统 end systems*
- 主机上运行的应用 running *network apps* at Internet's "edge"

包/分组交换机 Packet switches: forward packets (chunks of data)

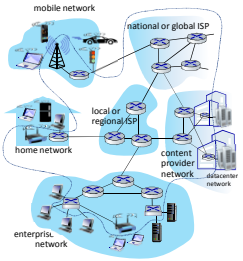
- *routers, switches*

通信链路 Communication links

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

网络 Networks

- collection of devices, routers, links: managed by an organization



世界范围的计算机网络
"Fun" Internet-connected Devices


Amazon Echo

Internet refrigerator


IP picture frame


Pacemaker & Monitor


Tweet-a-watt: monitor energy use


Web-enabled toaster + weather forecaster


Security Camera


Slingbox: remote control cable TV


AR devices


Internet phones

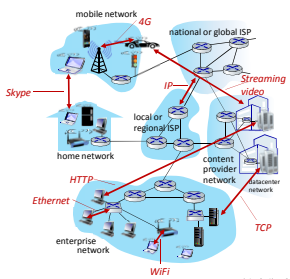

sensorized, bed mattress


Fitbit

Others?

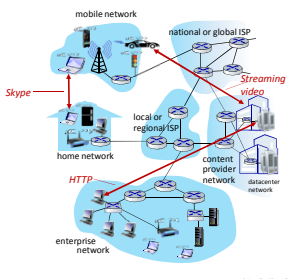
具体构成描述（硬件和软件）
The Internet: a "Nuts And Bolts" View

- *网络的网络 Internet:* "network of networks"
  - Interconnected ISPs
- *协议 protocols* are *everywhere*
  - control sending, receiving of messages
  - e.g., HTTP (Web), streaming video, Skype, TCP, IP, WiFi, 4G, Ethernet
- *互联网标准 Internet standards*
  - RFC: Request for Comments
  - IETF: Internet Engineering Task Force



服务描述
The Internet: a "Service" View

- *基础设施：Infrastructure* that provides services to applications:
  - 大量的应用：Web, steaming video, multimedia teleconferencing, email, games, e-commerce, social media, inter-connected appliances, …
- *编程接口：* provides *programming interface* to distributed applications:
  - "hooks" allowing sending/receiving apps to "connect" to, use Internet transport service
  - provides service options, analogous to postal service



What's a Protocol?

Human protocols:
- "what's the time?"
- "I have a question"
- introductions

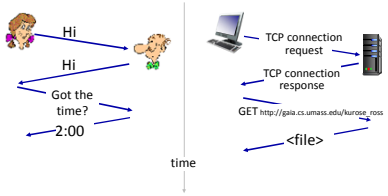
… specific messages sent
… specific actions taken when message received, or other events

Network protocols:
- computers (devices) rather than humans
- all communication activity in Internet governed by protocols

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

What's a Protocol?

A human protocol and a computer network protocol:



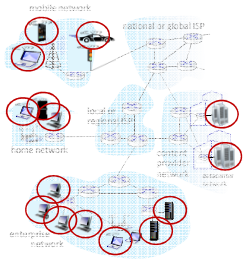
Q: other human protocols?

Chapter 1: Roadmap

- What *is* the Internet?
- What *is* a protocol?
- 网络边缘 Network edge: hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

A Closer Look at Internet Structure

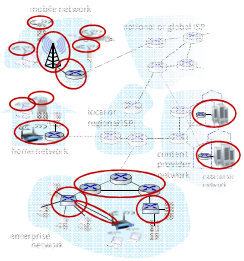
网络边缘 Network edge:
- 主机（端系统）hosts: clients and servers
- 服务器 servers often in data centers



A Closer Look at Internet Structure

Network edge:
- hosts: clients and servers
- servers often in data centers

接入网 Access networks, 物理媒体（媒介） physical media:
- 将端系统物理连接到其边缘路由器（edge router）的网络
- wired, wireless communication links

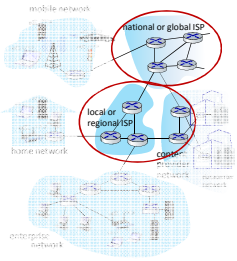


A Closer Look at Internet Structure

Network edge:
- hosts: clients and servers
- servers often in data centers

Access networks, physical media:
- wired, wireless communication links

网络核心 Network core:
- interconnected routers
- network of networks



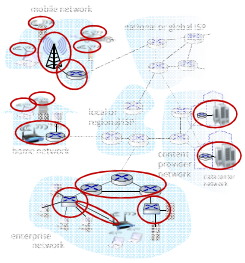
接入网络和物理媒体
Access Networks and Physical Media

Q: How to connect end systems to edge router?

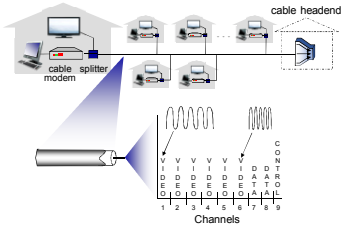
- 家庭接入residential access nets
- 企业接入 Institutional access networks (school, company)
- 无线接入mobile access networks (WiFi, 4G/5G)

What to look for:

- 接入网带宽 bandwidth (bits per second) of access network?
- 共享或专用 shared or dedicated access among users?



家庭接入：电缆接入网
Access Networks: Cable-based Access



frequency division multiplexing (FDM): different channels transmitted in different frequency bands

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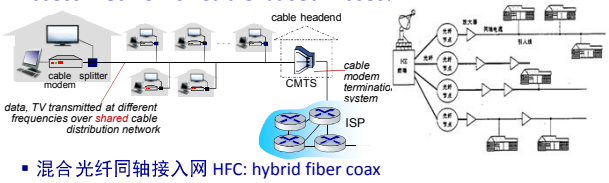
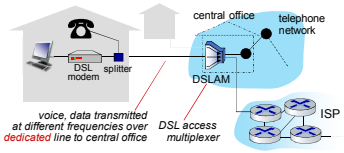


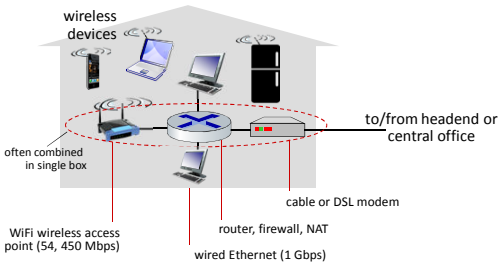
- 混合 光纤同轴接入网 HFC: hybrid fiber coax
  - 是以光纤作为传输骨干，采用模拟传输技术，通过频分复用的方式传输模拟和数字信息的网络
  - asymmetric: up to 40 Mbps – 1.2 Gbs downstream transmission rate, 30-100 Mbps upstream transmission rate
- 电缆、光纤网络将家庭连接到ISP路由器上 network of cable, fiber attaches homes to ISP router，共享的接入网络

家庭接入：数字用户线接入网
Access Networks: Digital Subscriber Line (DSL)



- 使用已有的电话线接入到中心局的DSL接入复用器DSLAM： 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
- 下行传输速率 24-52 Mbps dedicated downstream transmission rate
- 上行传输速率 3.5-16 Mbps dedicated upstream transmission rate

家庭接入网
Access Networks: Home Networks



无线接入网
Wireless access networks

Shared *wireless* access network connects end system to router

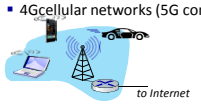
- 通过基站（也称为接入点） via base station aka “access point”

无线本地网络 Wireless local area networks (WLANs)

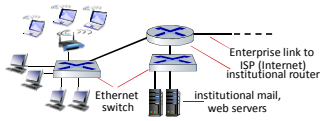
- within building (~30米)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate

广域蜂窝接入网络 Wide-area cellular access networks

- provided by mobile, cellular network operator (10’s km)
- 10’s Mbps
- 4Gcellular networks (5G coming)



企业接入网
Access Networks: Enterprise Networks

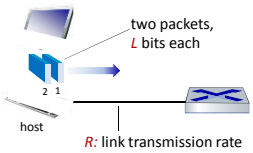


- companies, universities, etc.
- mix of wired, wireless link technologies, connecting a mix of switches and routers (we'll cover differences shortly)
  - 以太网 Ethernet: wired access at 100Mbps, 1Gbps, 10Gbps
  - WiFi: wireless access points at 11, 54, 450 Mbps

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*



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

物理链路
Links: Physical Media

- 比特bit: propagates between transmitter/receiver pairs
- 物理链路physical link: what lies between transmitter & receiver
- 引导型媒体guided media:
  - signals propagate in solid media: copper, fiber, coax
- 非引导型媒体unguided media:
  - signals propagate freely, e.g., radio

双绞线Twisted pair (TP)

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

物理链路
Links: Physical Media

同轴电缆Coaxial cable:

- 两个同心的铜导体two concentric copper conductors
- bidirectional
- broadband:
  - multiple frequency channels on cable
  - 100's Mbps per channel

光纤Fiber optic cable:

- 每个脉冲表示一个比特glass fiber carrying light pulses, each pulse a bit
- high-speed operation:
  - high-speed point-to-point transmission (10's-100's Gbps)
- low error rate:
  - repeaters spaced far apart
  - immune to electromagnetic noise

物理链路Links: Physical Media

无线电Wireless radio

- 电磁频谱中的信号 signal carried in electromagnetic spectrum
- 不需要物理线路 no physical "wire"
- 双向bidirectional
- 依赖传播环境和距离propagation environment effects:
  - 反射reflection
  - 遮挡衰落obstruction by objects
  - 干扰interference

无线电链路类型Radio link types:

- 地面微波terrestrial microwave
  - up to 45 Mbps channels
- 局域Wireless LAN (WiFi)
  - Up to 100's Mbps
- 广域wide-area (e.g., cellular)
  - 4G cellular: ~ 10's Mbps
- 卫星satellite
  - up to 45 Mbps per channel
  - 270 msec end-end delay
  - 同步卫星和近地轨道卫星 geosynchronous versus low-earth-orbit

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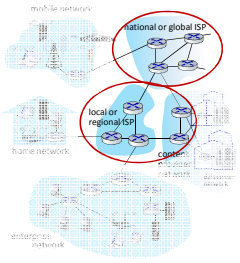
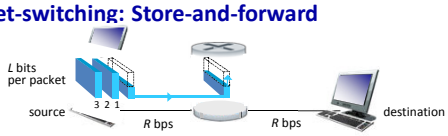
网络核心
The Network Core

- 互联的路由器mesh of interconnected routers
- 分组交换packet-switching: hosts break application-layer messages（报文） into *packets*（分组）
  - forward packets from one router to the next, across links on path from source to destination
  - each packet transmitted at full link capacity



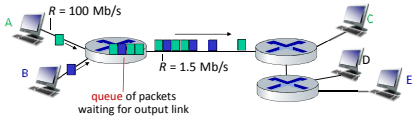
分组交换：存储转发
Packet-switching: Store-and-forward



- 传输延迟Transmission delay: takes *L*/*R* seconds to transmit (push out) *L*-bit packet into link at *R* bps
- 存储转发*Store and forward: entire* packet must arrive at router before it can be transmitted on next link
- 上图中的端端延迟*End-end delay:* 2*L*/*R* (above), assuming zero propagation delay (more on delay shortly)

One-hop numerical example:
- *L* = 10 Kbits
- *R* = 100 Mbps
- one-hop transmission delay = 0.1 msec

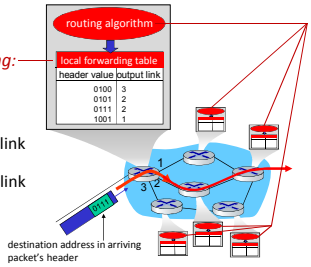
分组交换：排队时延和分组丢失
Packet-switching: queueing delay, loss



Packet queuing and loss: if arrival rate (in bps) to link exceeds transmission rate (bps) of link for a period of time:
- packets will queue, waiting to be transmitted on output link
- packets can be dropped (lost) if memory (buffer) in router fills up

网络核心的两个主要功能
Two key network-core functions

转发Forwarding:
- *local* action: move arriving packets from router's input link to appropriate router output link

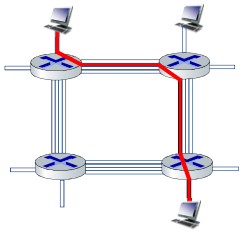


路由Routing:
- *global* action: determine source-destination paths taken by packets
- routing algorithms

电路交换
Alternative to packet-switching: circuit switching

在电路交换网络中，在端系统通信会话期间，预留了端系统沿路径通信所需要的资源

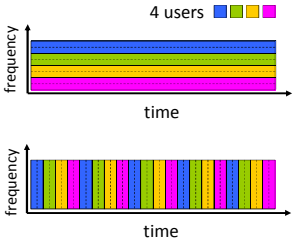
end-end resources allocated to, reserved for "call" between source and destination
- in diagram, each link has four circuits.
  - call gets 2nd circuit in top link and 1st circuit in right link.
- dedicated resources: no sharing
  - circuit-like (guaranteed) performance
- circuit segment idle if not used by call (no sharing)
- commonly used in traditional telephone networks



电路交换中的复用
Circuit switching: FDM and TDM

频分复用
Frequency Division Multiplexing (FDM)
- optimal, electromagnetic frequencies divided into (narrow) frequency bands
- each call allocated its own band throughout call, can transmit at max rate of that (narrow) frequency band

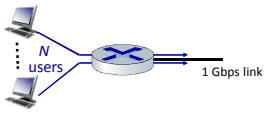
时分复用
Time Division Multiplexing (TDM)
- time divided into slots
- each call allocated periodic slot(s), can transmit at maximum rate of (wider) frequency band, but only during its time slot(s)



分组交换与电路交换的对比
Packet switching versus Circuit switching

packet switching allows more users to use network!

Example:
- 1 Gb/s link
- each user:
  - 100 Mb/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 ?

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/interactive

分组交换与电路交换的对比
Packet switching versus Circuit switching

Is packet switching a "winner"?

- great for "bursty" data – sometimes has data to send, but at other times not
  - resource sharing
  - simpler, no call setup
- excessive congestion possible: packet delay and loss due to buffer overflow
  - protocols needed for reliable data transfer, congestion control
- *Q:* How to provide circuit-like behavior?
  - bandwidth guarantees traditionally used for audio/video applications

是不是跟我们日常中的某些问题有些类似？

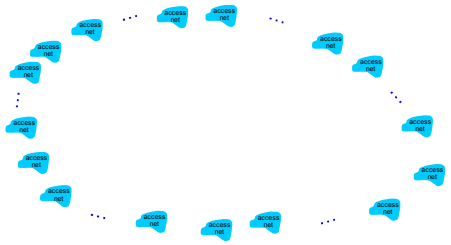
Q: human analogies of reserved resources (circuit switching) versus on-demand allocation (packet switching)?

网络结构：网络的网络
Internet Structure: a "Network of Networks"

- Hosts connect to Internet via access Internet Service Providers (ISPs)
  - residential, enterprise (company, university, commercial) 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

网络结构：网络的网络
Internet Structure: a "Network of Networks"

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



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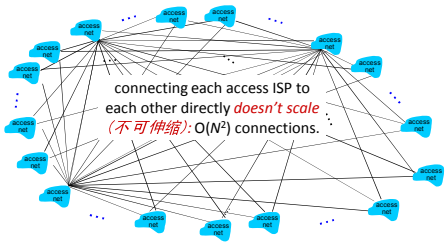
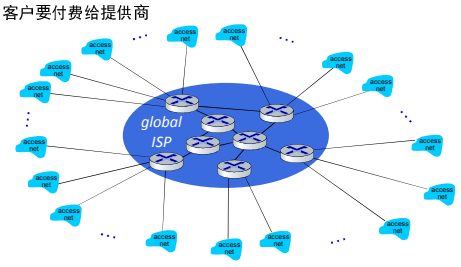


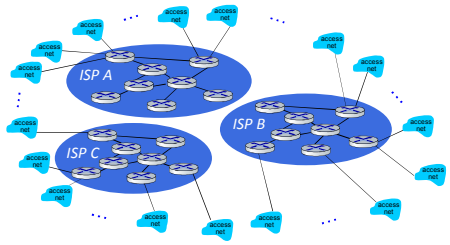
网络结构：网络的网络
Internet Structure: a "Network of Networks"

用单一的全球传输ISP(被称作提供商）互联 所有接入ISP（被称作客户）客户要付费给提供商



网络结构：网络的网络
Internet Structure: a "Network of Networks"

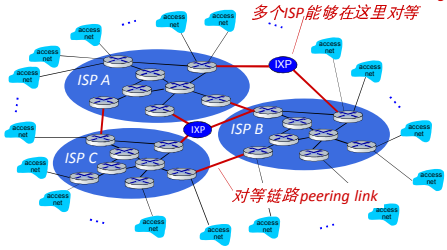
But if one global ISP is viable business, there will be competitors ….



网络结构：网络的网络
Internet Structure: a "Network of Networks"

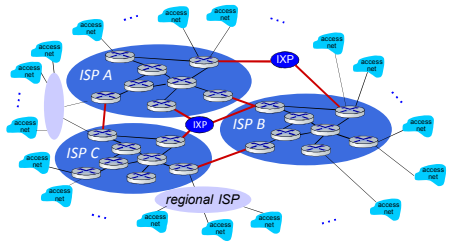
But if one global ISP is viable business, there will be competitors …. who will want to be connected

网络交换点Internet exchange point，多个ISP能够在这里对等



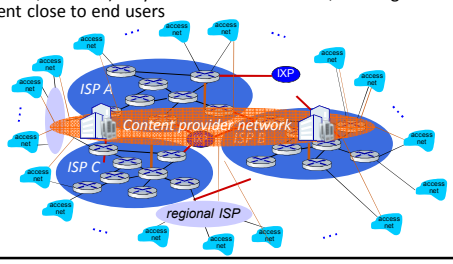
网络结构：网络的网络
Internet Structure: a "Network of Networks"

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



网络结构：网络的网络
Internet Structure: a "Network of Networks"

… 以及 内容提供商网络content provider networks (e.g., Google, Microsoft, Akamai) may run their own network, to bring services, content close to end users



网络结构：网络的网络
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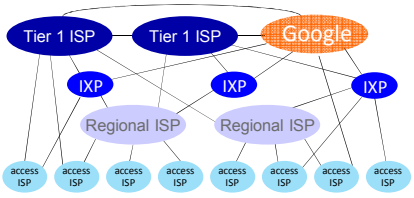


At "center": small # of well-connected large networks

- "tier-1" commercial ISPs (e.g., Level 3, Sprint, AT&T, NTT), national & international coverage
- content provider networks (e.g., Google, Facebook): private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

Tier-1 ISP Network Map: Sprint (2019)

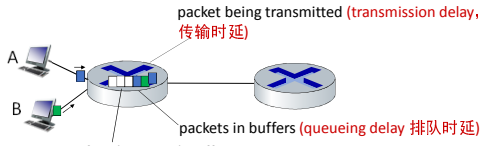
Chapter 1: Roadmap

- What *is* the Internet?
- What *is* a protocol?
- Network edge: hosts, access network, physical media
- Network core: packet/circuit switching, internet structure
- 性能 Performance: loss, delay, throughput
- Security
- Protocol layers, service models
- History

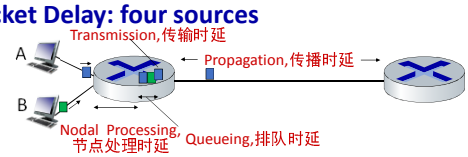
丢包和时延是如何发生的
How do loss and delay occur?

packets *queue* in router buffers

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



分组的四种时延
Packet Delay: four sources

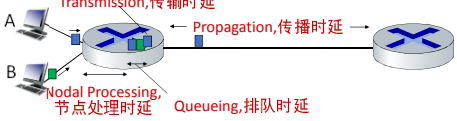


$d_{nodal} = d_{proc} + d_{queue} + d_{trans} + d_{prop}$

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

分组的四种时延
Packet Delay: four sources



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

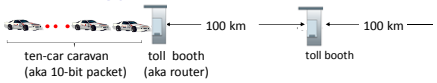
d_{trans}: transmission delay:
- *L*: packet length (bits)
- *R*: link *bandwidth (bps)*
- $d_{trans} = L/R$

d_{prop}: propagation delay:
- *d*: length of physical link
- *s*: propagation speed (~$2x10^8$ m/sec)
- $d_{prop} = d/s$

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

* Check out the online interactive exercises: http://gaia.cs.umass.edu/kurose_ross

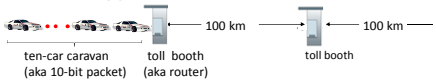
传输和传播时延的类比
Caravan Analogy



- 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

传输和传播时延的类比
Caravan Analogy

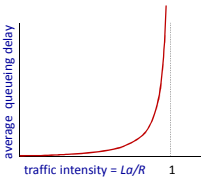


- suppose cars now "propagate" at 1000 km/hr
- and suppose toll booth now takes one min to service a car
- *Q:* Will cars arrive to 2nd booth before all cars serviced at first booth?

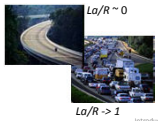
A: Yes! after 7 min, first car arrives at second booth; three cars still at first booth

排队时延
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 is more than can be serviced - average delay infinite!



真实的网络时延和路由是怎样的？
"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 (with time-to-live field value of *i*)
  - router *i* will return packets to sender
  - sender measures time interval between transmission and reply

真实的网络时延和路由是怎样的？
"Real" Internet Delays and 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
```

3 delay measurements to border1-rt-fa5-1-0.gw.umass.edu

trans-oceanic link

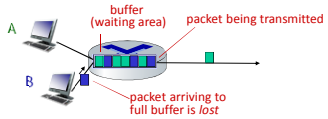
looks like delays *decrease*! Why?

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

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

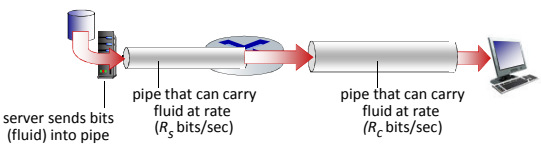
丢包
Packet loss

- 队列只有有限的容量 queue (aka buffer) preceding link in buffer has finite capacity
- packet arriving to full queue dropped (aka lost)
- 丢失的分组基于端到端原则进行重传 lost packet may be retransmitted by previous node, by source end system, or not at all



吞吐量
Throughput

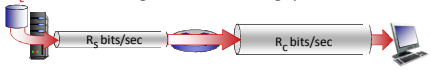
- *throughput:* rate (bits/time unit) at which bits are being sent from sender to receiver
  - *瞬时吞吐量instantaneous:* rate at given point in time
  - *平均吞吐量average:* rate over longer period of time



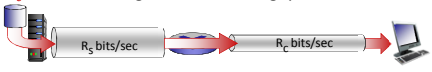
R_s 服务器与路由器之间的链路速率，R_c 客户与路由器之间的链路速率

吞吐量
Throughput

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

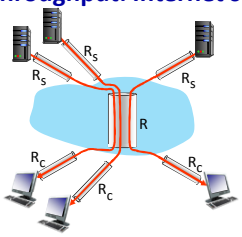


$R_s > R_c$ What is average end-end throughput?



瓶颈链路
bottleneck link
link on end-end path that constrains end-end throughput

吞吐量
Throughput: Internet scenario



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

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

* Check out the online interactive exercises for more examples: http://gaia.cs.umass.edu/kurose_ross/

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网络安全
Network security

- 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!

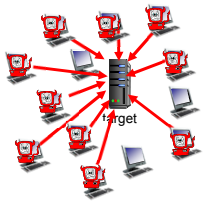
Bad guys: put malware into hosts via Internet

- malware can get in host from:
  - *病毒virus: 需要某种形式的用户交互来感染用户设备的恶意软件* self-replicating infection by receiving/executing object (e.g., e-mail attachment)
  - *蠕虫worm: 无须任何明显用户交互就能进入设备的恶意软件* 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 or distributed denial of service (DDoS) attacks

Bad guys: attack server, network infrastructure

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

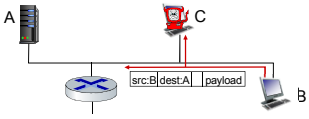
1. select target
2. break into hosts around the network (see botnet)
3. send packets to target from compromised hosts



网络嗅探
Bad guys can sniff packets

packet "sniffing":

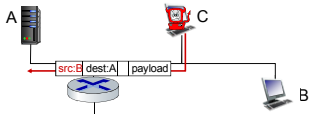
- broadcast media (shared Ethernet, wireless)
- 混杂模式的网络接口promiscuous network interface reads/records all packets (e.g., including passwords!) passing by



Wireshark software is a (free) packet-sniffer

网络地址伪装
Bad guys can use fake addresses

IP spoofing: send packet with false source address



… lots more on security (throughout, Chapter 8)

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- 协议层和服务模型Protocol layers, service models
- History

协议分层和参考模型
Protocol "Layers" and Reference Models

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?

航线系统例子
Example: Organization of Air Travel

票务ticket (购买purchase)	票务ticket (投诉complain)
行李baggage (托运check)	行李baggage (认领claim)
登机口gates (登机load)	登机口gates (离机unload)
从跑道起飞runway takeoff	从跑道着陆runway landing
按路线飞行airplane routing	按路线飞行airplane routing

按路线飞行airplane routing

airline travel: a series of steps, involving many services

航线系统例子
Example: Organization of Air Travel

ticket (purchase)	*ticketing service*	ticket (complain)
baggage (check)	*baggage service*	baggage (claim)
gates (load)	*gate service*	gates (unload)
runway takeoff	*runway service*	runway landing
airplane routing	*routing service*	airplane routing

layers: each layer implements a service
- via its own internal-layer actions
- relying on services provided by layer below

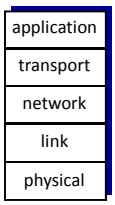
Q: describe in words the service provided in each layer above

为何要分层
Why Layering?

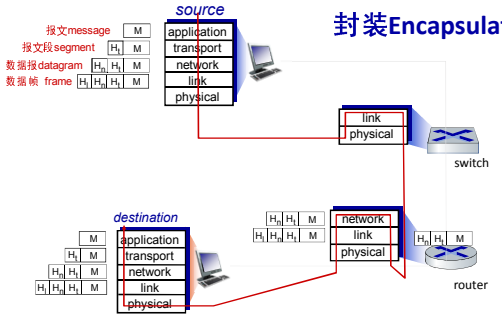
dealing with complex systems:
- explicit structure allows identification, relationship of complex system's pieces
  - layered *reference model* for discussion
- modularization eases maintenance, updating of system
  - change in layer's service *implementation*: transparent to rest of system
  - e.g.,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

网络协议栈
Internet Protocol Stack

- *应用层 application:* supporting network applications
  - IMAP, SMTP, HTTP
- *传输层 transport:* process-process data transfer
  - TCP, UDP
- *网络层 network:* routing of datagrams from source to destination
  - IP, routing protocols
- *数据链路层 link:* data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- *物理层 physical:* bits "on the wire"



封装Encapsulation



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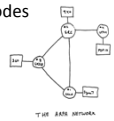
Internet History

20世纪60年代 1961-1972: Early packet-switching principles

- 1961排队论 : Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964分组交换: Baran - packet-switching in military nets
- 1967美国高级研究计划署 **ARPAnet** conceived by Advanced Research Projects Agency
- 1969第一台分组交换机在加州大学洛杉矶分校安装,年底有四个节点: first ARPAnet node operational

- 1972ARPAnet成长到有15个节点:
  - ARPAnet public demo
  - NCP (Network Control Protocol) first host-host protocol
  - first e-mail program
  - ARPAnet has 15 nodes



Internet History

网络互联和专用网络1972-1980: Internetworking and proprietary nets

- 1970 夏威夷岛上的微波网络 ALOHAnet satellite network in Hawaii
- 1974网络的网络: Cerf and Kahn - architecture for interconnecting networks
- 1976共享广播网络的以太网协议: Ethernet at Xerox PARC
- late70's专用网络体系结构: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Vint Cerf 与 Bob Kahn - 互联网之父

Cerf and Kahn's 开放网络体系结构的系 统设计原则
Cerf and Kahn's internetworking principles:

- 最简单化,自治原则-网络独立运作,与其他网络互连时无须进行内部改动minimalism, autonomy - no internal changes required to interconnect networks
- best-effort service model
- stateless routing
- decentralized control

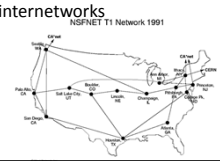
define today's Internet architecture

Internet History

网络的激增 1980-1990: new protocols, a proliferation of n额tworks

- **1983: deployment of TCP/IP**
- 1982: smtp e-mail protocol defined
- 1983: DNS defined for name-to-IP-address translation
- 1985: ftp protocol defined
- 1988: TCP congestion control

- new national networks: CSnet（计算机科学网）, BITnet（美国大学间网络）, NSFnet, Minitel（法国）
- **100,000 hosts** connected to internetworks



Internet History

网络爆炸1990, 2000s: commercialization, the Web, new applications

- early 1990s: ARPAnet不复存在
- 1991: NSF 解除了对NSFnet用于商业目的的限制，1995年退役
- early 1990s: Web （Berners-Lee，1989 Web之父）
  - hypertext [Bush 1945, Nelson 1960's]
  - HTML, HTTP: Berners-Lee
  - 1994: Mosaic communications , later Netscape
  - late 1990s: commercialization of the Web

late 1990s – 2000s:

- more killer apps: instant messaging, P2P file sharing
- network security to forefront
- est. 50 million host, 100 million+ users
- backbone links running at Gbps

Internet History

2005-present: more new applications, Internet is "everywhere"

- ~18B devices attached to Internet (2017)
  - rise of smartphones (iPhone: 2007)
- aggressive deployment of broadband access
- increasing ubiquity of high-speed wireless access: 4G/5G, WiFi
- emergence of online social networks:
- Facebook: ~ 2.5 billion users
- service providers (Google, FB, Microsoft) create their own networks
  - bypass commercial Internet to connect "close" to end user, providing "instantaneous" access to search, video content, …
- enterprises run their services in "cloud" (e.g., Amazon Web Services, Microsoft **A**zure)

Chapter 1: Summary

We've covered a "ton" of material!

- 网络简介Internet overview
- 协议 what's a protocol?
- 网络边缘、接入网和网络核心network edge, access network, core
  - packet-switching versus circuit-switching
  - Internet structure
- 性能 performance: loss, delay, throughput
- 网络分层和服务模型 layering, service models
- 网络安全 security
- 计算机网络的历史history

You now have:

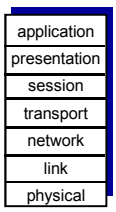
- context, overview, vocabulary, "feel" of networking
- more depth, detail, *and fun* to follow*!*

Additional Chapter 1 slides

ISO/OSI Reference Model

Two layers not found in Internet protocol stack!

- *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?



The seven layer OSI/ISO reference model

Wireshark