

Chapter I

Introduction

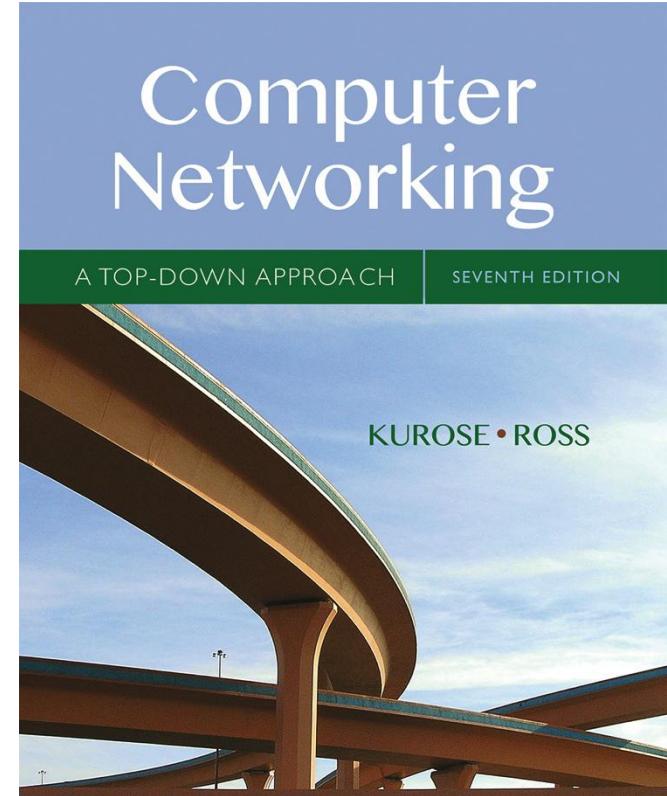
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*Computer
Networking: A Top
Down Approach*

7th edition
Jim Kurose, Keith Ross
Pearson/Addison Wesley
April 2016

Chapter 1: Introduction

Our goal:

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

Chapter 1: roadmap

1.1 What is the Internet?

1.2 Network edge

- end systems, access networks, links

1.3 Network core

- circuit switching, packet switching, network structure

1.4 Delay, loss and throughput in packet-switched networks

1.5 Protocol layers, service models

1.6 Networks under attack: security

1.7 History

1.1 What is the Internet?

- 将从以下两个角度描述因特网是什么：
 - ❖ 因特网的具体构成
 - ❖ 因特网的功能

1.1.1 因特网的具体构成



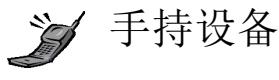
桌面机



服务器



笔记本



手持设备



无线链路

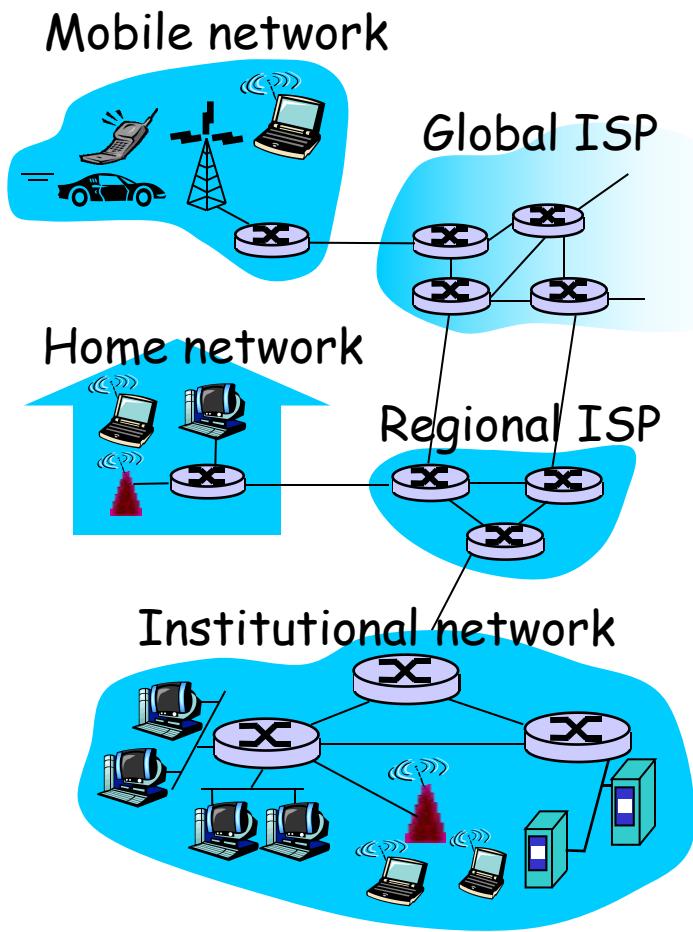


有线链路



路由器

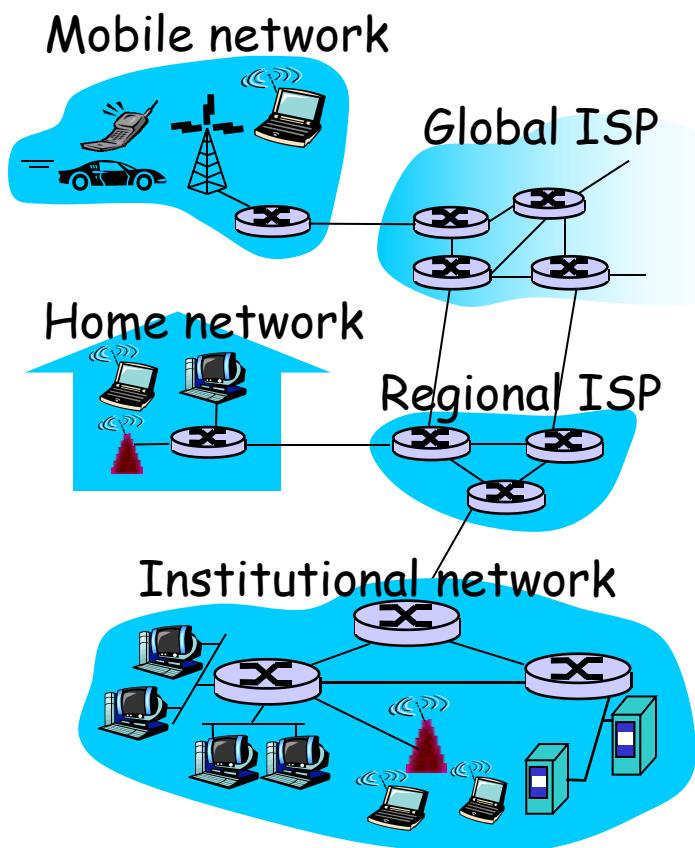
- **终端:**
 - 称 主机 (**host**) 或端系统 (**end system**)
 - **运行应用程序**
- **通信链路:**
 - 光纤, 铜线, 电磁波
 - 主要指标为传输速率,也称带宽(**bandwidth**)
- **交换设备:**
 - 转发分组 (**packet**)
 - 路由器和交换机



因特网的具体构成（续）

□ Internet Service Provider:

- ❖ ISP是由交换设备和通信链路组成的网络，为终端提供因特网接入服务
- ❖ 不同层次的ISP: 本地ISP, 地区ISP, 全球ISP
- ❖ 每个ISP是自治的



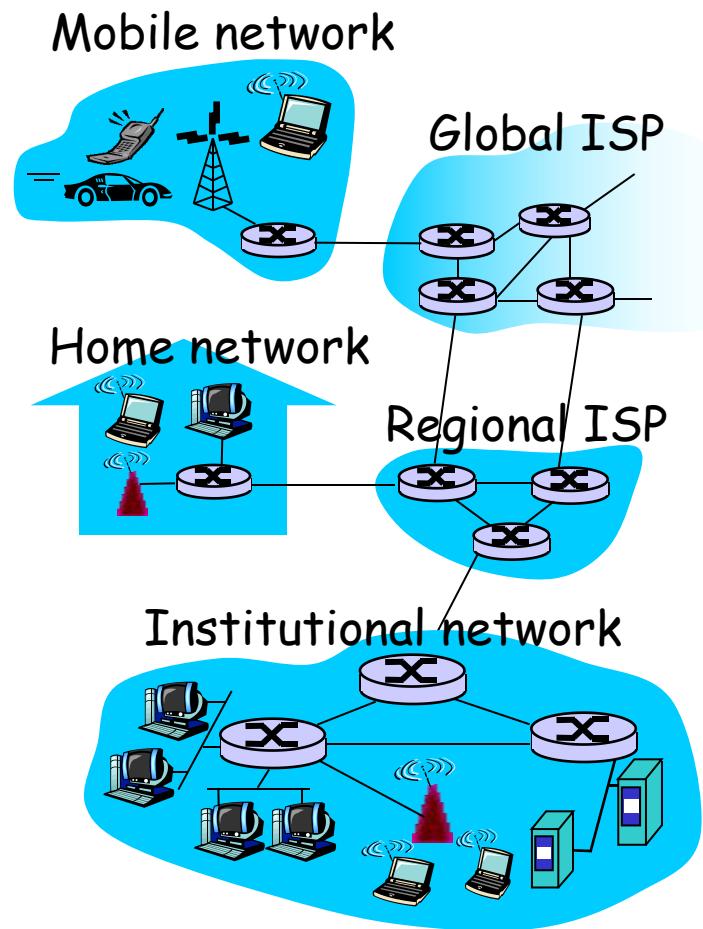
因特网的具体构成（续）

□ 协议规定了设备之间通信需要遵循的规则：

- ❖ 终端与终端之间
- ❖ 终端与交换设备之间
- ❖ 交换设备与交换设备之间

□ 因特网协议标准：

- ❖ 由IETF组织统一管理，以RFC xxx文档的形式发布
- ❖ 因特网中最核心的两个协议是TCP和IP，因特网协议统称为TCP/IP协议族



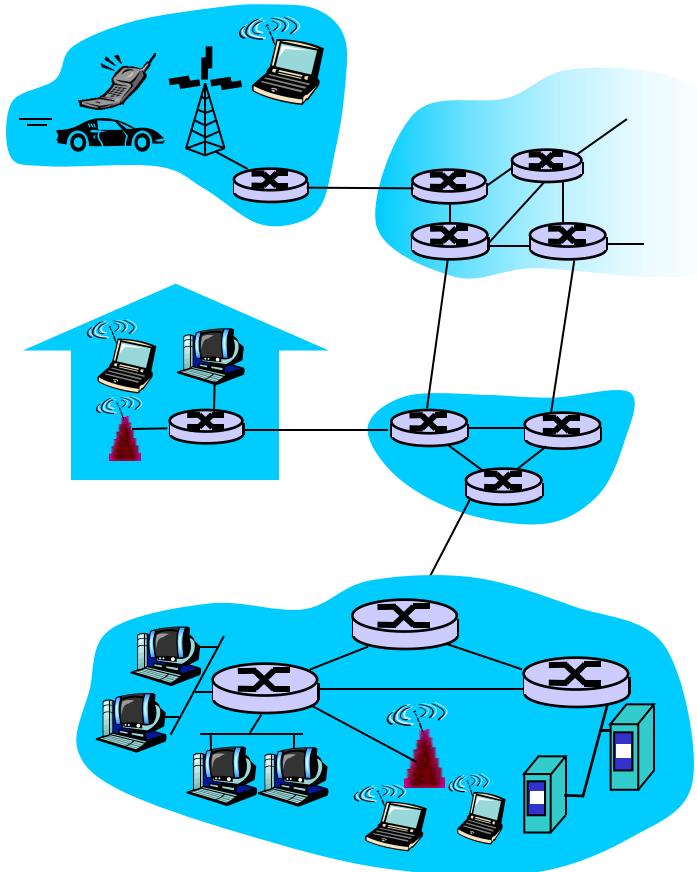
因特网的具体构成（续）

□ 因特网定义一：

- ❖ 由一群遵循**TCP/IP协议**的**ISP**，按照**松散的层次结构**组织而成的**网络的网络**

□ 因特网的几个特点：

- ❖ 因特网是“**网络的网络**”
- ❖ 因特网不存在严格的**层次结构**
- ❖ 因特网没有统一的管理机构



1.1.2 因特网的功能

□ 因特网定义二：

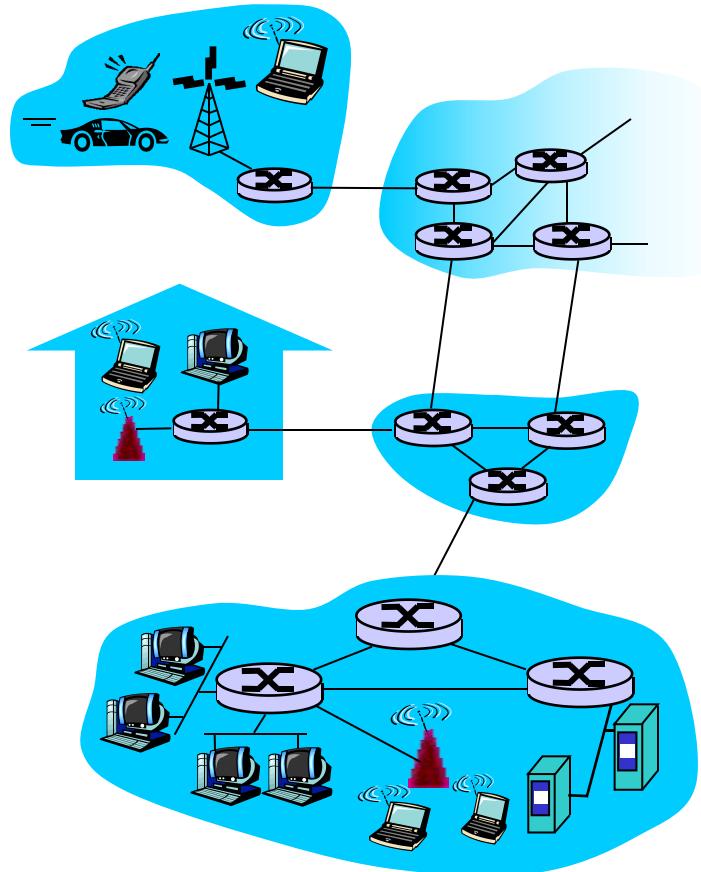
- ❖ 因特网是为分布式应用提供通信服务的基础设施

□ 传统通信系统的服务接口：

- ❖ 电话系统：拨号，振铃
- ❖ 邮政系统：写有通信地址的信封，邮筒，信箱

□ 因特网提供给应用程序的服务接口：

- ❖ 一组用于在因特网上发送和接收数据的应用编程接口**API**



小结

□ 因特网定义一：

- ❖ 由一群遵循**TCP/IP**协议的**ISP**，按照松散的层次结构组织而成的网络的网络

□ 对于通信功能的实现有指导作用：

- ❖ **ISP**内部实现
- ❖ **ISP**之间互联

□ 因特网定义二：

- ❖ 为分布式应用提供通信服务的基础设施

□ 对于服务接口的定义有指导作用：

- ❖ 有序、可靠的数据交付服务
- ❖ 不可靠的数据交付服务

本课程使用这两种定义，介绍因特网服务接口及端到端通信的实现

Chapter 1: roadmap

1.1 What *is* the Internet?

1.2 Network edge

□ end systems, access networks, links

1.3 Network core

□ circuit switching, packet switching, network structure

1.4 Delay, loss and throughput in packet-switched networks

1.5 Protocol layers, service models

1.6 Networks under attack: security

1.7 History

A closer look at network structure:

- **end systems:**

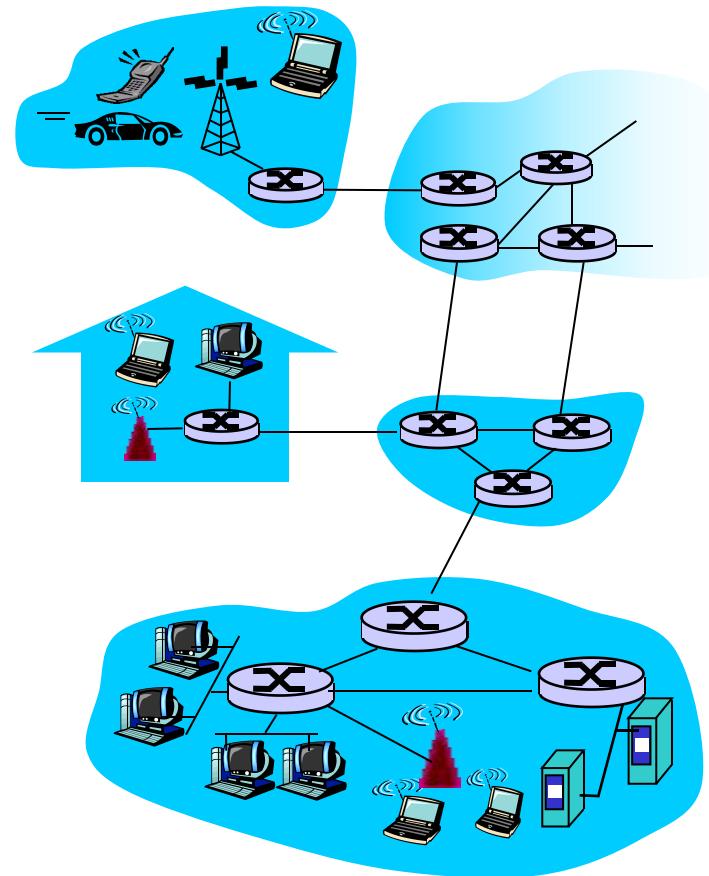
终端

- **access networks:**

将终端连接到其边缘路由器的**物理链路**

- **network core:**

路由器和通信链路组成的网
网络



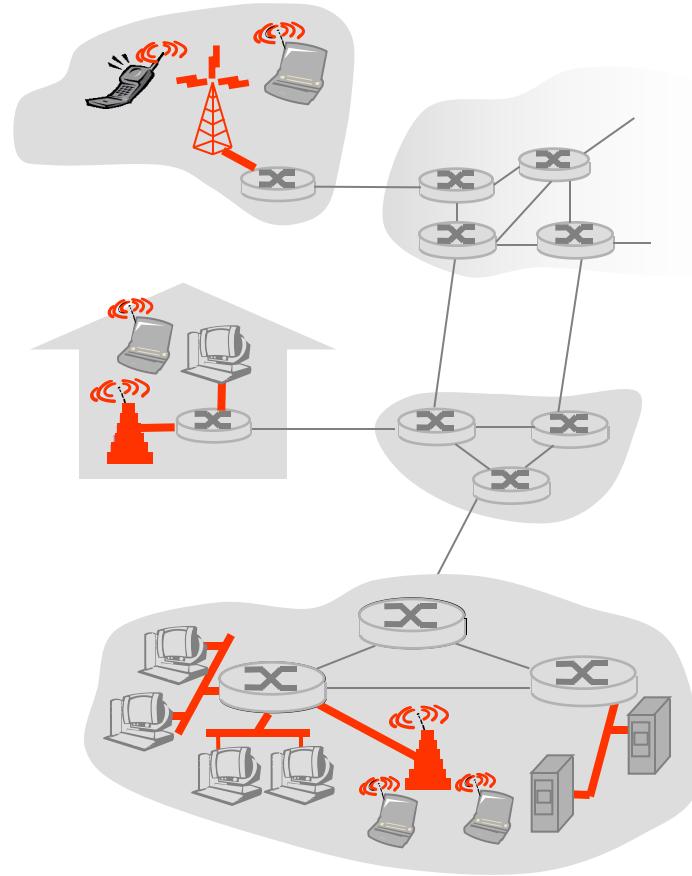
1.2.1 接入网

Q: How to connect end systems to edge router?

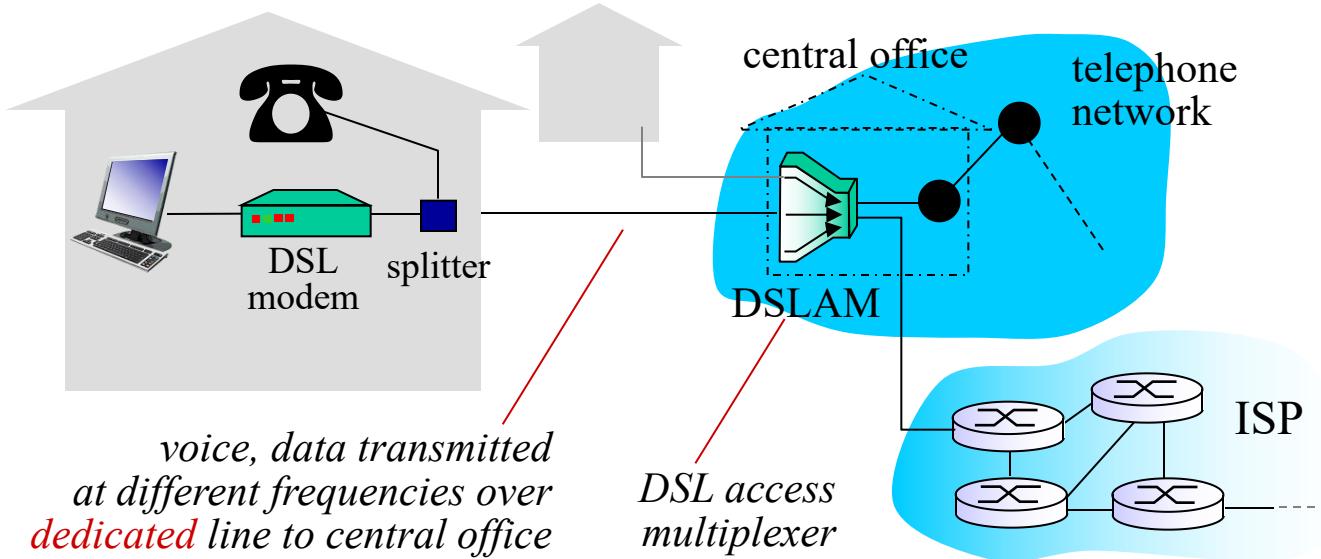
- 住宅接入
- 企业接入（学校，公司）
- 移动接入

Keep in mind:

- 接入网的带宽是多少？
- 共享还是专用？

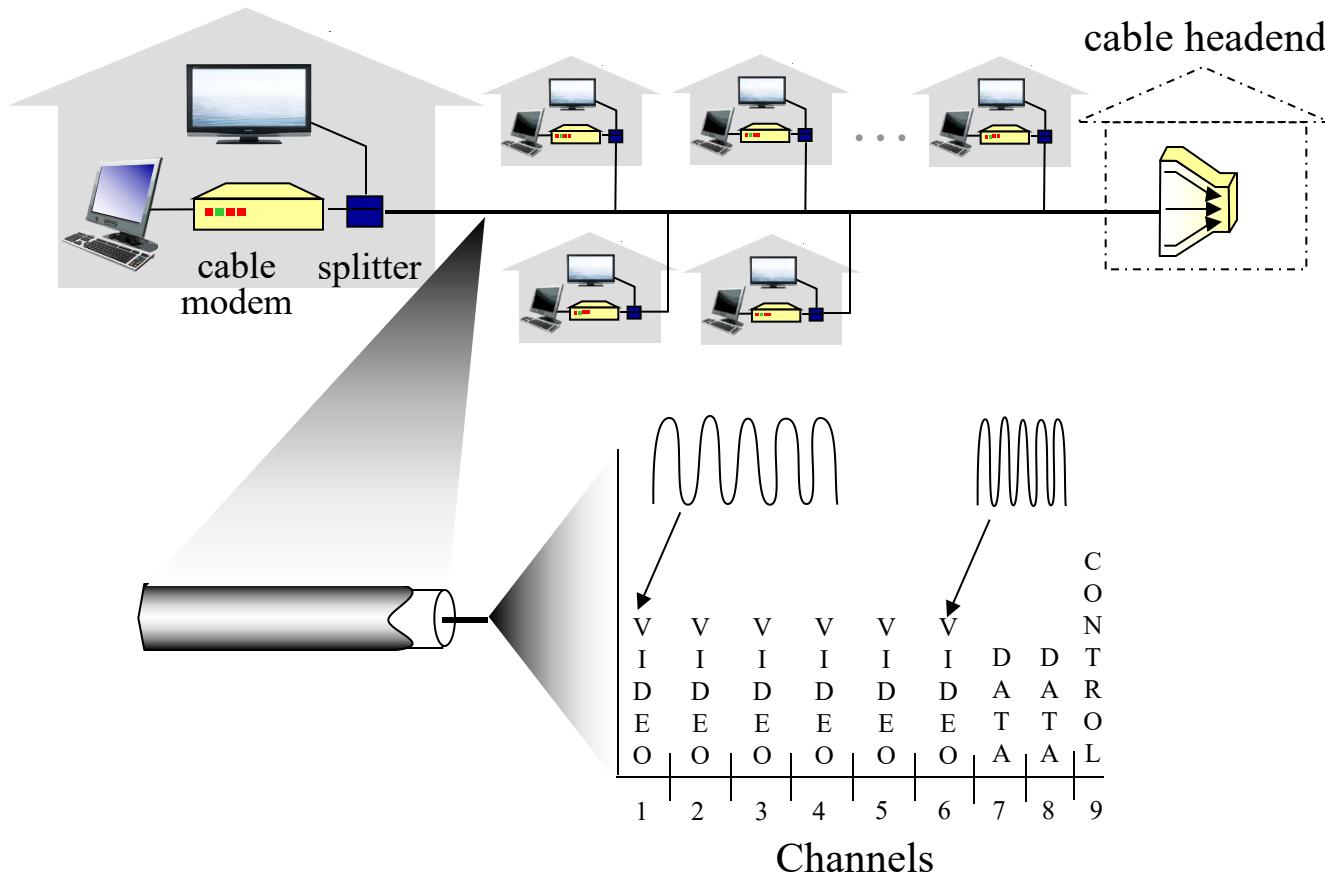


住宅接入：数字用户线 (DSL)



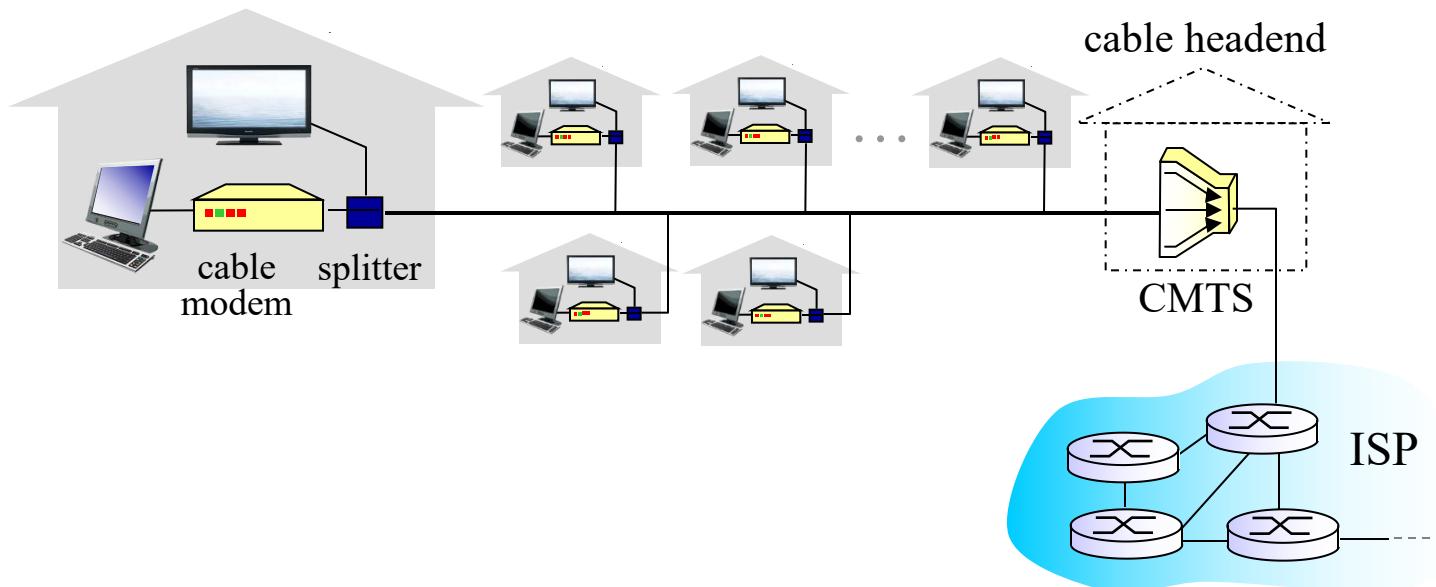
- ❖ 由电话公司提供，使用已有的数字电话线（每户一条线）：
 - **DSL modem**: 转换模拟信号和数字信号
 - **Splitter**: 合并/分离话音和数据（用户侧）
 - **DSLAM**: 汇聚/分离多条DSL线路（ISP侧）
- ❖ 上行速率 < 2.5 Mbps (典型地 < 1 Mbps)
- ❖ 下行速率 < 24 Mbps (典型地 < 10 Mbps)

住宅接入：电缆网



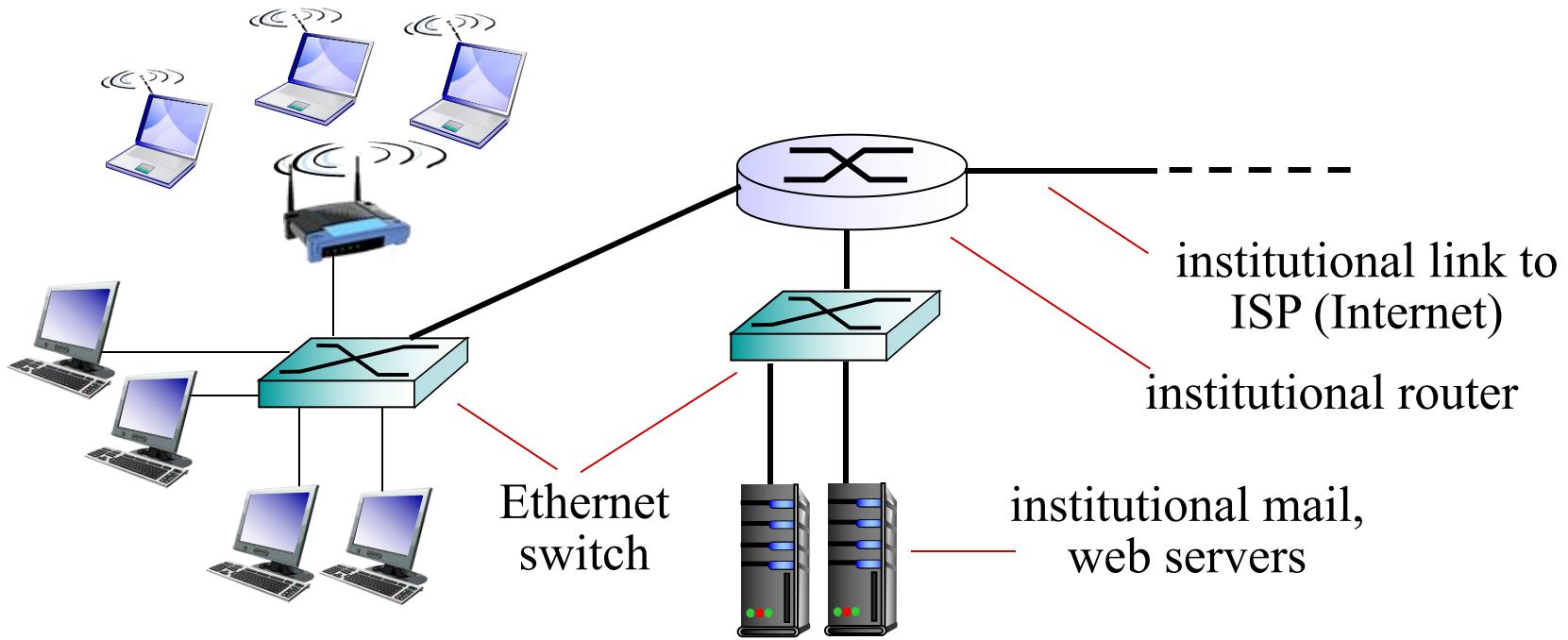
- 有线电视公司提供，使用已有的有线电视基础设施
- 数据和电视信号在同一条电缆中传输

住宅接入：电缆网



- ❖ 混合光纤同轴电缆HFC: **hybrid fiber coax**
 - 有线电视网由光纤网+电缆网组成 (**光纤网未画出**)
 - **cable modem、Splitter、电缆、光纤、CMTS**构成接入网
 - 下行速率最高 **30Mbps**, 上行速率最高 **2 Mbps**
 - ❖ 几百~几千户家庭共用一条电缆

企业接入网：以太网 (Ethernet)

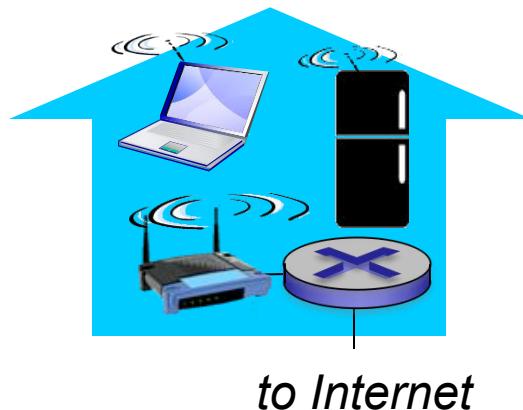


- 用于公司、学校及有较多终端的家庭：
 - ❖ 以太网交换机及链路构成接入网
 - ❖ 传输速率：10 Mbps, 100Mbps, 1Gbps, 10Gbps

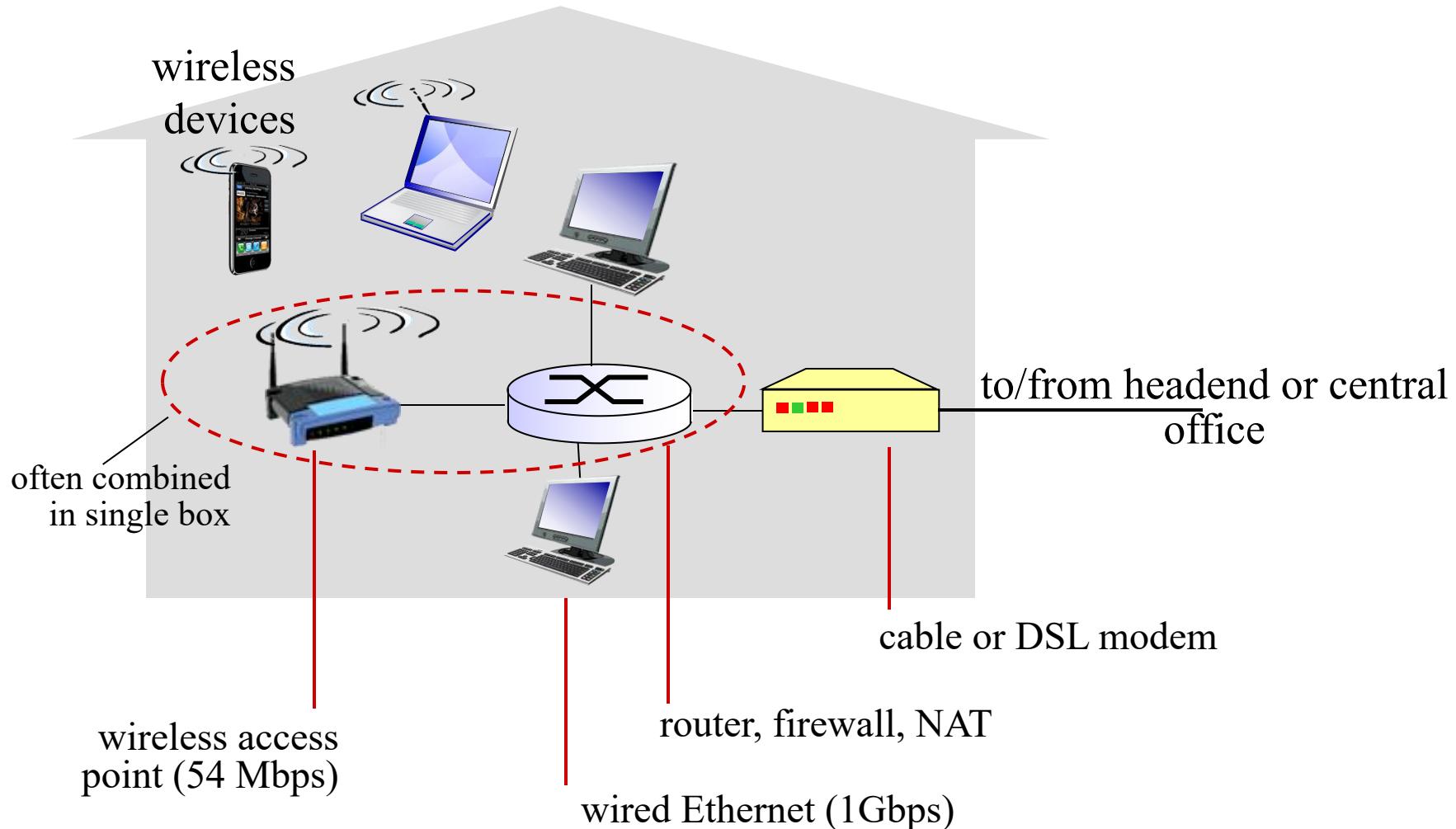
无线接入网：无线局域网（Wifi）

□ 公司或个人提供基站（接入点），将移动终端连接到有线网络：

- ❖ 终端与基站相距几十米内
- ❖ 基站通常位于有线网络上
- ❖ 无线传输速率：**11 Mbps**、**54Mbps**、**450Mbps**
- ❖ 无线局域网是共享的



一个典型的家庭网络



无线接入网：广域无线接入

- 由移动通信公司提供，使用现有的蜂窝电话网络
- 基站可为数万米半径内的用户提供无线接入服务
- 传输速率（共享信道）：
 - ❖ **3G**: 最大（静止） **2Mbps**
 - ❖ **4G**: 下行**100Mbps**, 上行**20Mbps**



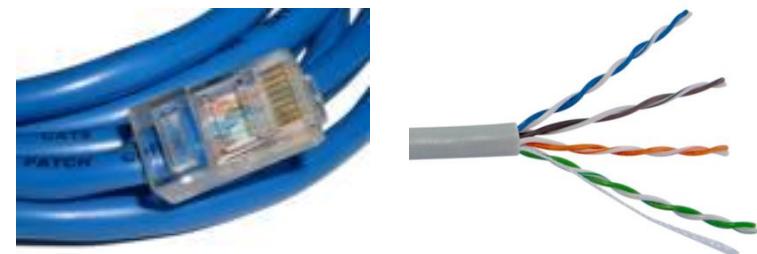
to Internet

1.2.2 物理媒体（传输媒体，传输介质）

- 设备之间通过物理媒体相连，物理媒体两端各需要一对收/发设备
- 在一条路径上，每对设备之间的物理媒体可以不同
- 导引型媒体：
 - ❖ 信号沿固体媒体传播，如铜线，光纤
- 非导引型媒体：
 - ❖ 信号在空间自由传播，如电磁波

双绞线：

- 两条绝缘的铜导线：
 - ❖ 3类线：10 Mbps
 - ❖ 5类线：
100Mbps~1Gbps
 - ❖ 6类线：10Gbps
- 电话线，网线



物理媒体（续）

同轴电缆：

- 两根同心的绝缘铜导体
- 有线电视电缆

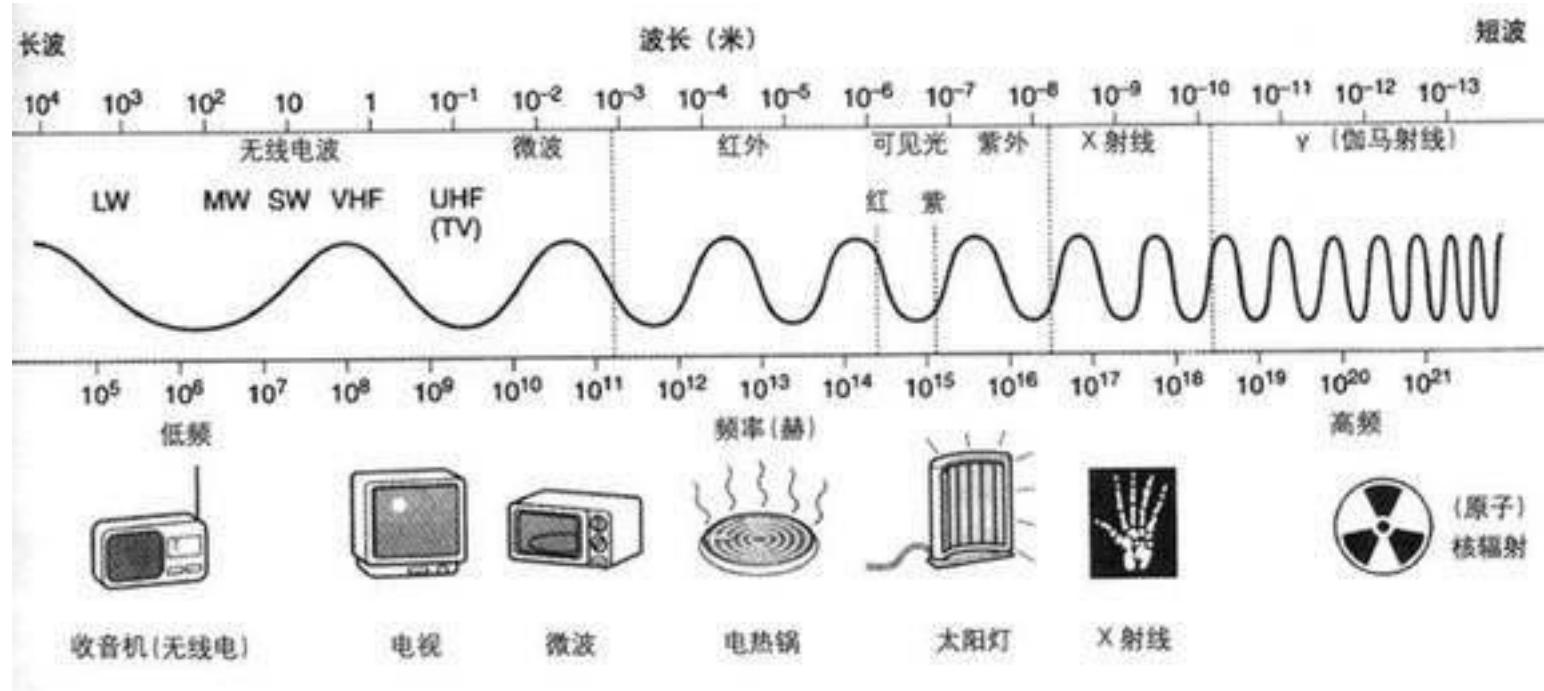


光纤：

- 能引导光脉冲的玻璃纤维
- 传输速率：
 - ❖ 几十 ~ 几百 **Gbps**
- 低误码率，长距离传输，抗电磁干扰



物理媒体：电磁波



- 蓝牙: 2.4GHz, 10米左右
- Wifi: 2.4GHz, 几十米
- 红外: 室内短距离
- 陆地微波: 2GHz, 长距离
- 卫星: 2GHz, 长距离、大范围
- 可见光: 1-2km, 50Gbps

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1.4 Delay, loss and throughput in packet-switched networks

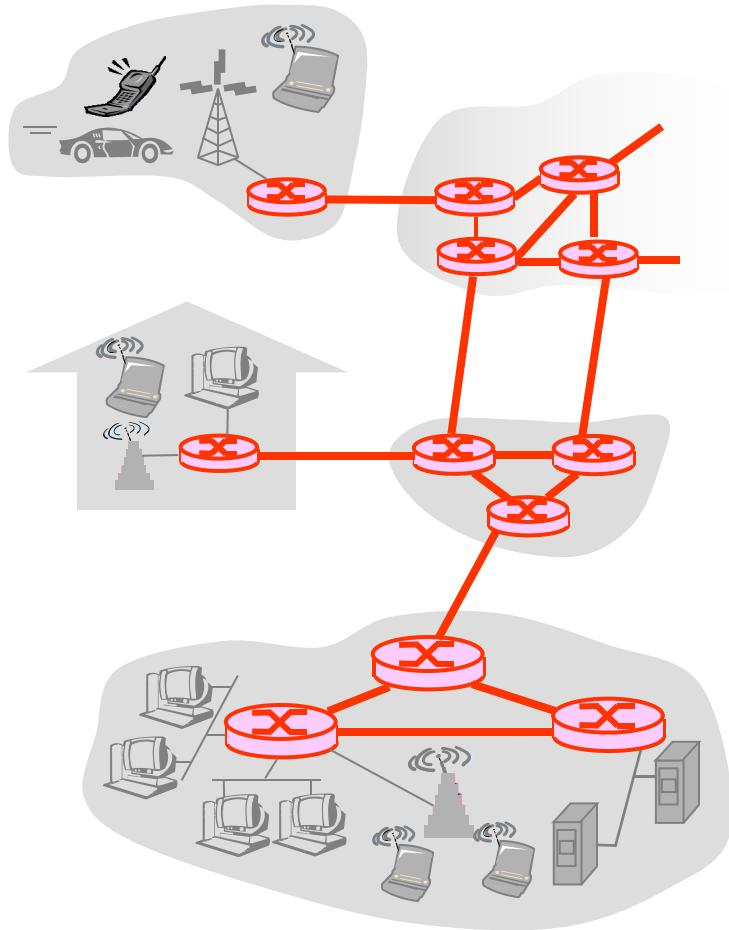
1.5 Protocol layers, service models

1.6 Networks under attack: security

1.7 History

1.3 网络核心

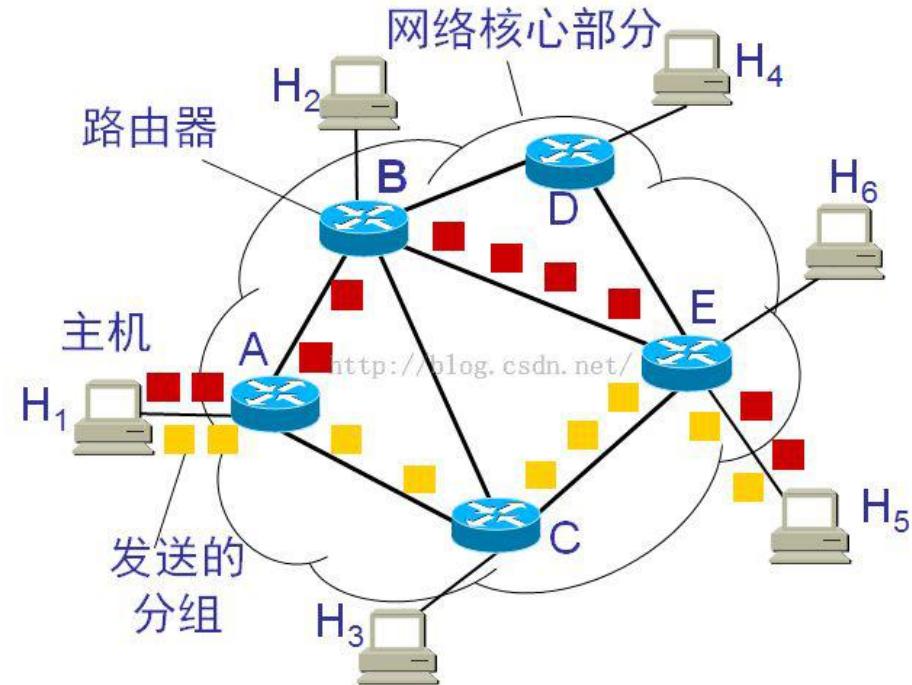
- **网络核心：**由路由器和链路形成的网状网络
- **任务：**将数据包从发送侧的边缘路由器，传送到接收侧的边缘路由器
- **基本问题：**数据包如何在网络核心中高效地传递？
 - ❖ 分组传输延迟小
 - ❖ 网络吞吐量高
- 通信网络中**移动数据的两种基本方法：**
 - ❖ 电路交换（独占信道）：电话网使用
 - ❖ 分组交换（复用信道）：计算机网络使用



1.3.1 分组交换 (packet switching)

□ 分组交换的过程：

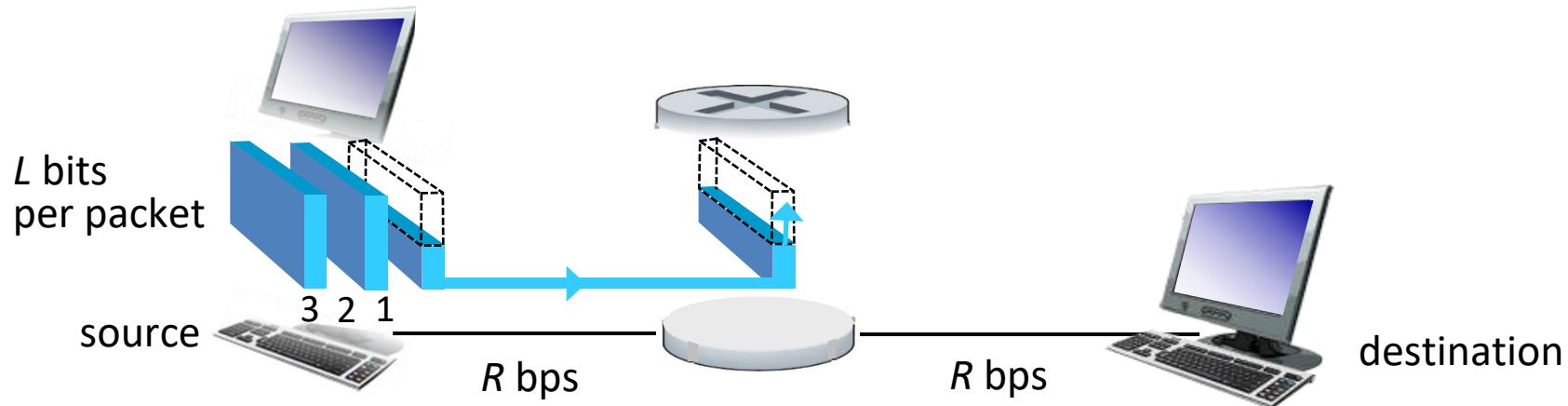
- ❖ 主机将要传输的数据分段，并组装成一系列分组
- ❖ 交换：在传输路径上，交换设备从一条链路上接收分组，将其发送到另一条链路上
- ❖ 存储转发：交换设备在接收到完整的分组后，才可以开始转发



□ 思考：

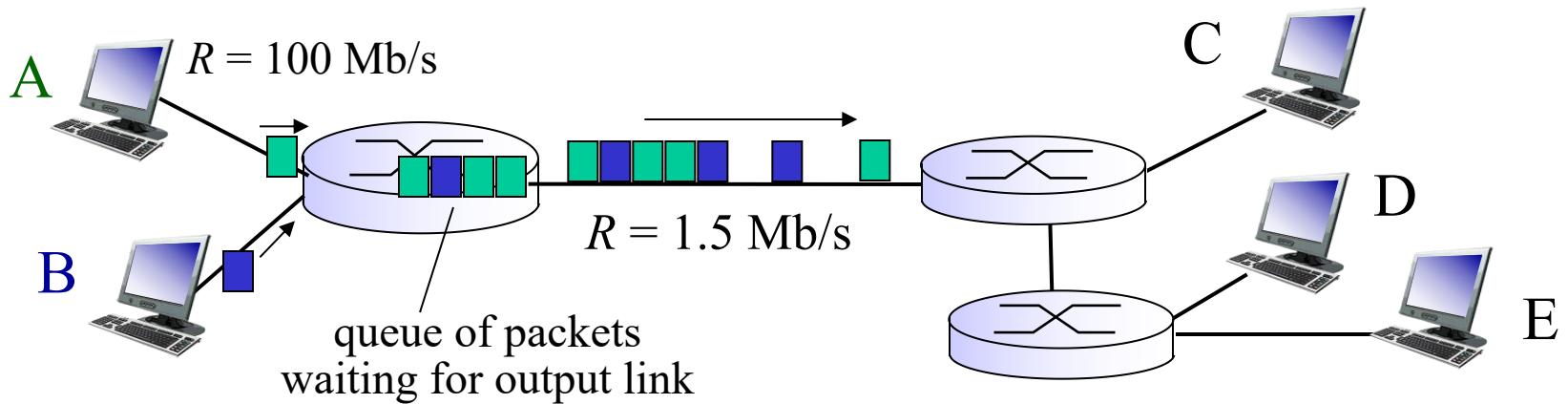
- ❖ 为什么不是边收边发？

存储转发引入序列化延迟



- 将一个分组全部推送到一条链路上，耗时 L/R 秒
- 将一个分组从源发送到目的，总耗时 = $2 L/R$ （不考虑信号传播时间）
- 3个分组从源终端发送到目的终端，总耗时=?
 - ❖ $4 L/R$
- 问题：P个分组经过N条链路的总耗时是多少?
 - ❖ $(P+N-1) L/R$
- **当P远大于N时，存储转发不会引入过多的延迟!**

存储转发引入排队延迟和丢包

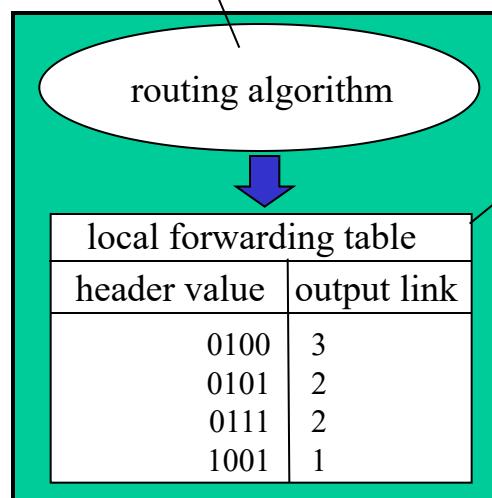


- 排队延迟：分组在输出链路的缓存中排队，引入延迟
- 丢包：若输出链路的缓存满，溢出的分组被丢弃
- 当大量分组集中到达时，排队延迟和丢包较严重

网络核心的两个重要功能

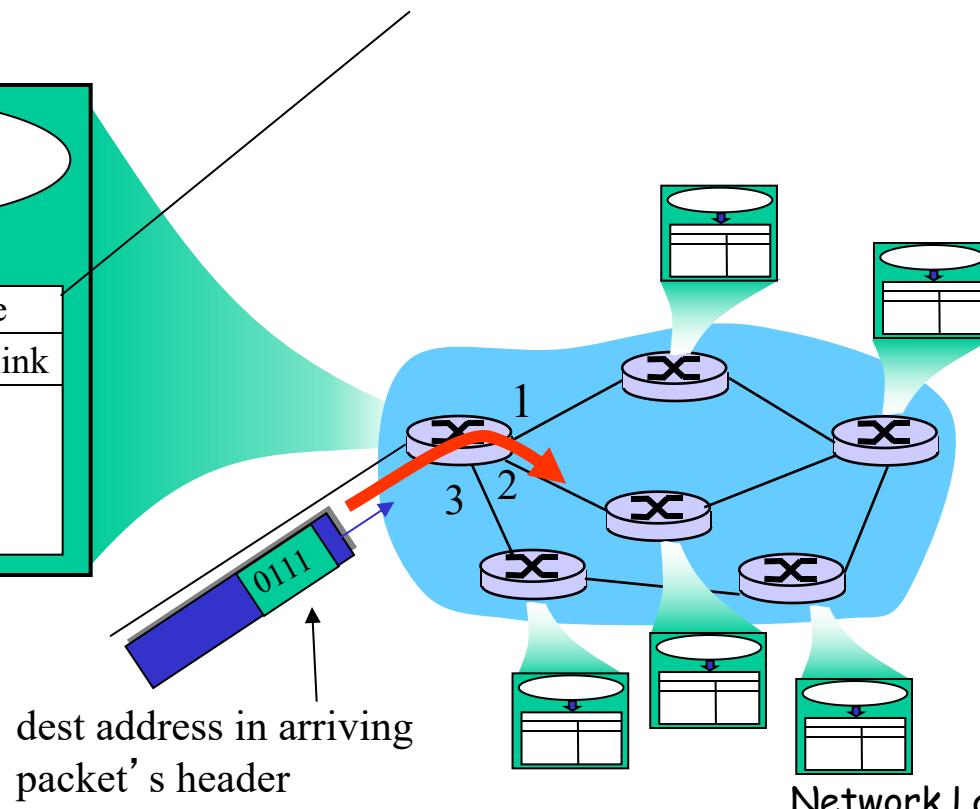
选路 (routing) :

交换设备确定不同目的地的转发端口，生成转发表



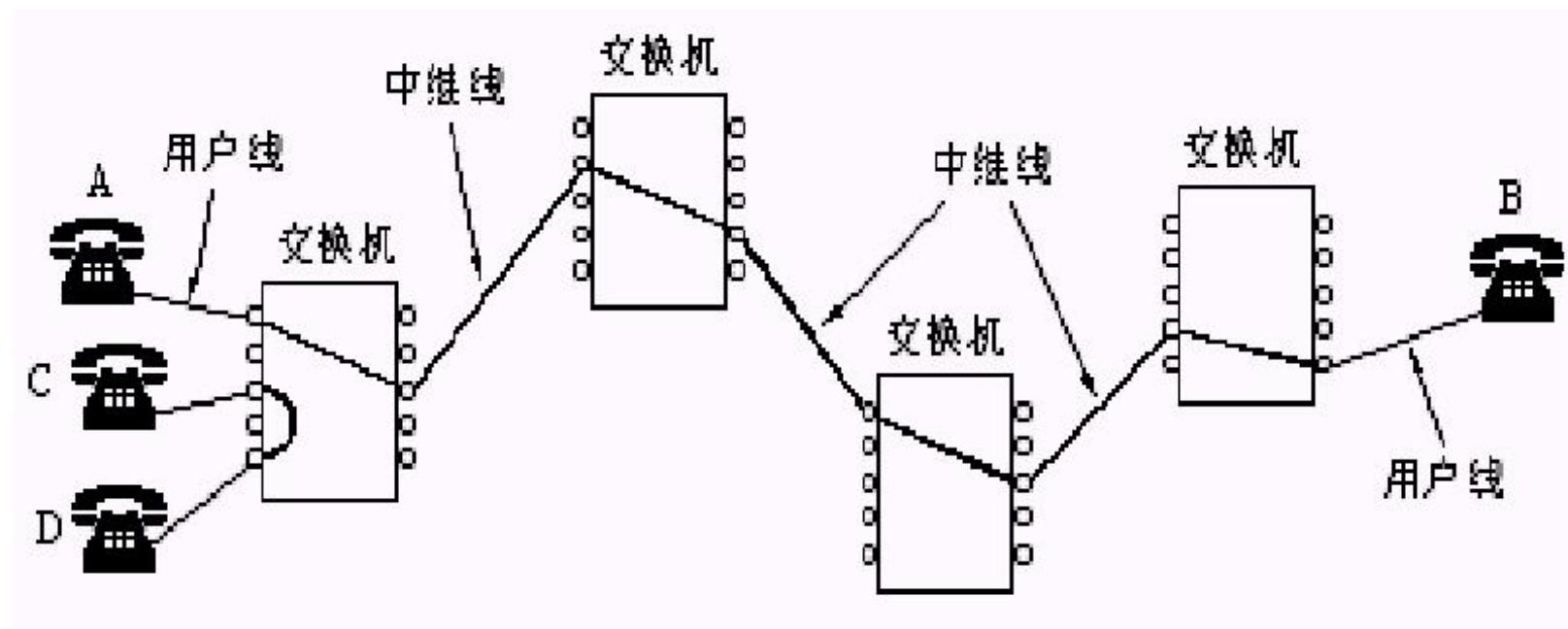
转发 (forwarding) :

交换设备按照转发表，将分组移动到相应的输出链路



1.3.2 电路交换(circuit switching)

- 电话网采用电路交换：
 - ❖ 通话前完成两部电话机之间的电路接续，通话结束后释放整条电路
- 本质是**预留资源和独占资源**



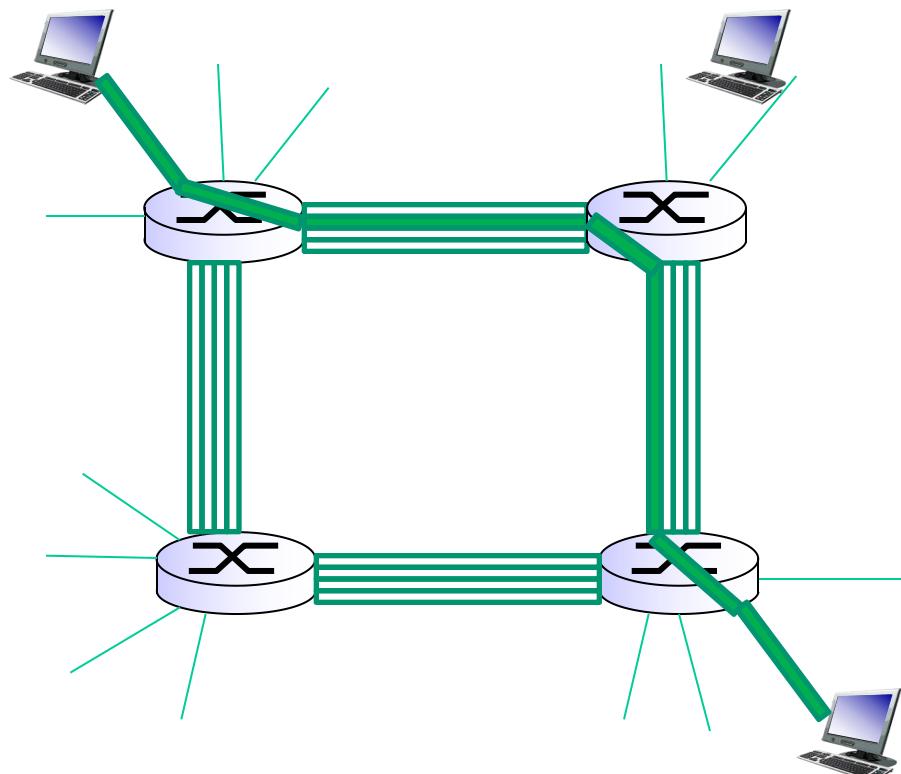
概念区分：链路和电路

□ 链路 (link) :

- ❖ 物理媒体，也称信道 (channel)
- ❖ 可以通过某种方式划分为若干条独立的子信道

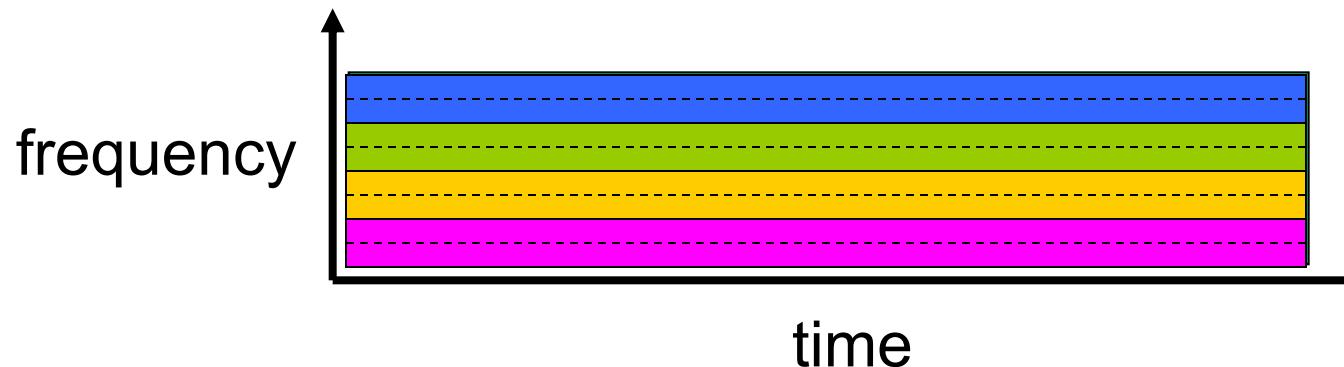
□ 电路 (circuit) :

- ❖ 物理媒体中的一条子信道

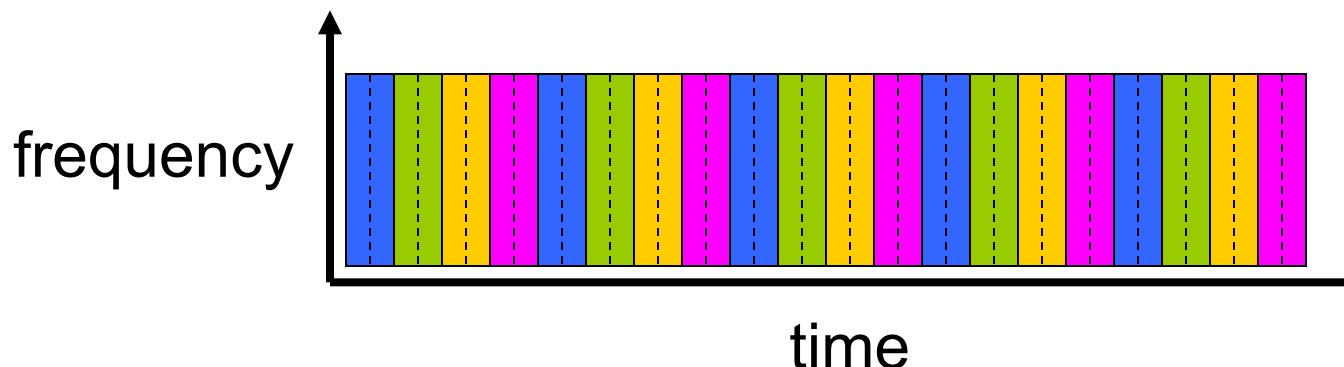


多路复用 (multiplex)

频分复用 FDM



时分复用 TDM



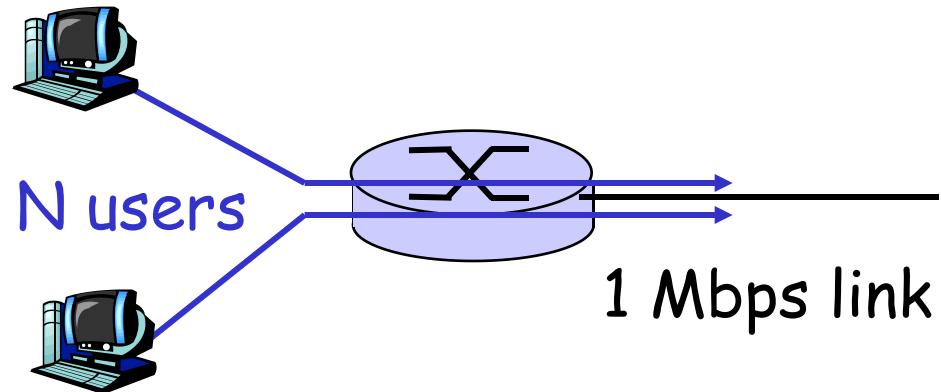
采用电路交换的文件传输时间

- How long does it take to send a file of 640,000 bits from host A to host B over a circuit-switched network?
 - ❖ All links are 1.536 Mbps
 - ❖ Each link uses TDM with 24 slots/sec
 - ❖ 500 msec to establish end-to-end circuit
- Let's work it out!
 - ❖ 数据传输速率: $1.536 \text{ Mbps} / 24 = 64 \text{ kbps}$
 - ❖ 传输数据的时间: $640 \text{ kbits} / 64 \text{ kbps} = 10 \text{ s}$
 - ❖ 总时间: $500 \text{ ms} + 10 \text{ s} = 10.5 \text{ s}$

为什么采用分组交换？

同样的链路容量，分组交换允许支持更多的用户！

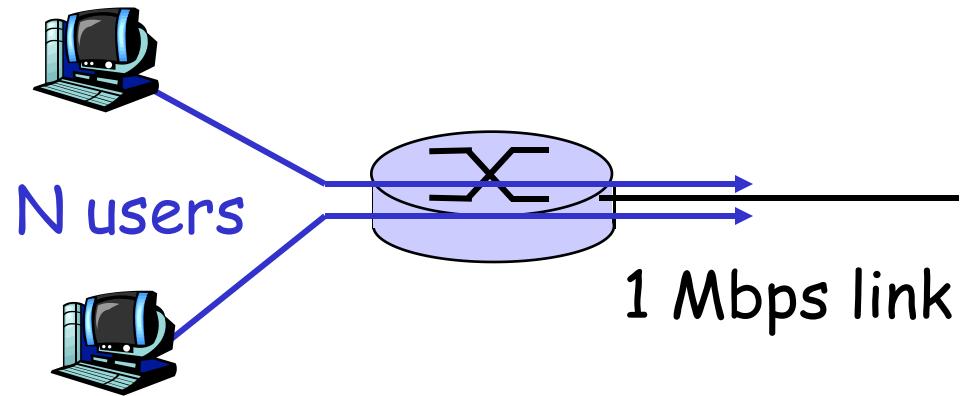
- 1 Mb/s link
- each user:
 - ❖ 100 kb/s when "active"
 - ❖ active 10% of time
- 电路交换（固定分配）
 - ❖ 10 users
- 分组交换（按需分配）
 - ❖ with 35 users,
probability > 10 active
at same time is less
than .0004



为什么采用分组交换？

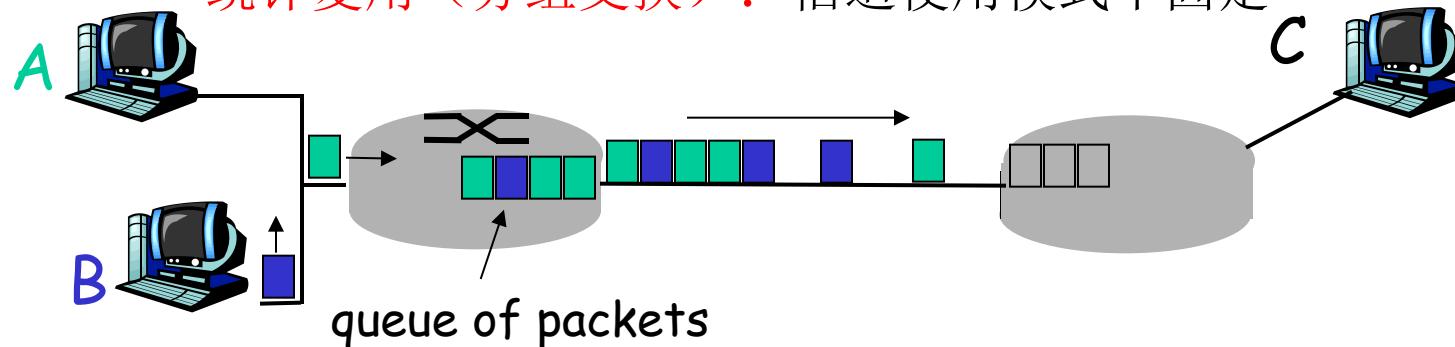
轻负载时，分组交换可以更快地服务用户！

- 1 Mb/s link
- Only one active user:
 - ❖ 1000 1kb-packet's
- 电路交换（固定分配）
 - ❖ Need 10s
- 分组交换（按需分配）
 - ❖ Need 1s

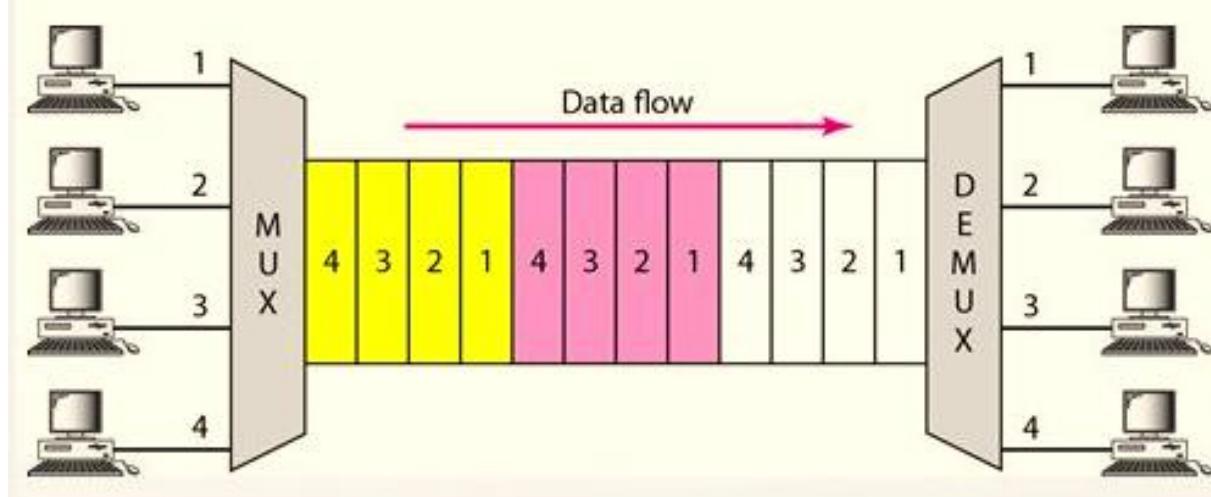


统计复用 vs 同步时分复用

统计复用（分组交换）：信道使用模式不固定



同步时分复用（电路交换）：信道使用模式固定



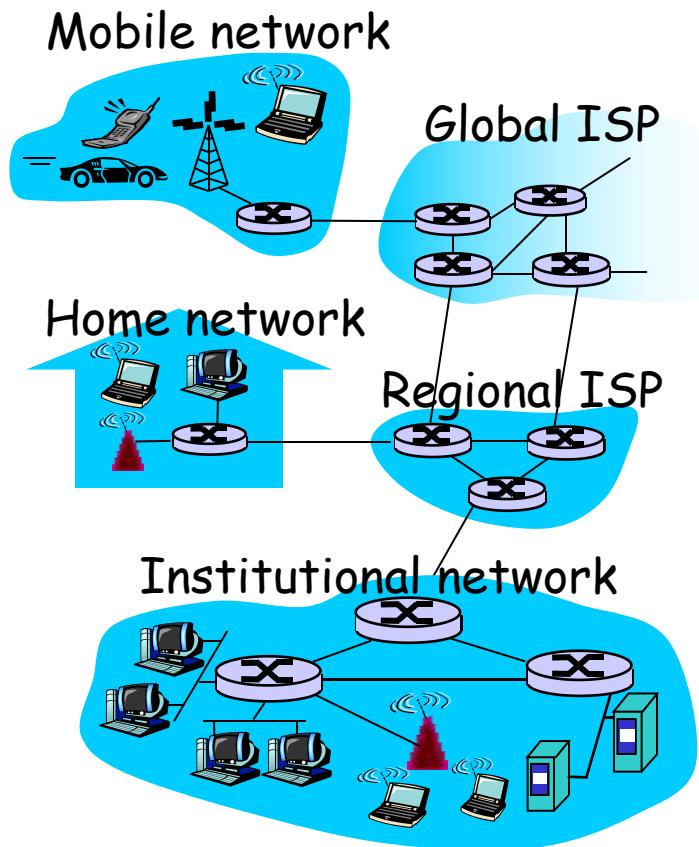
Packet switching versus circuit switching

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 (chapter 9)

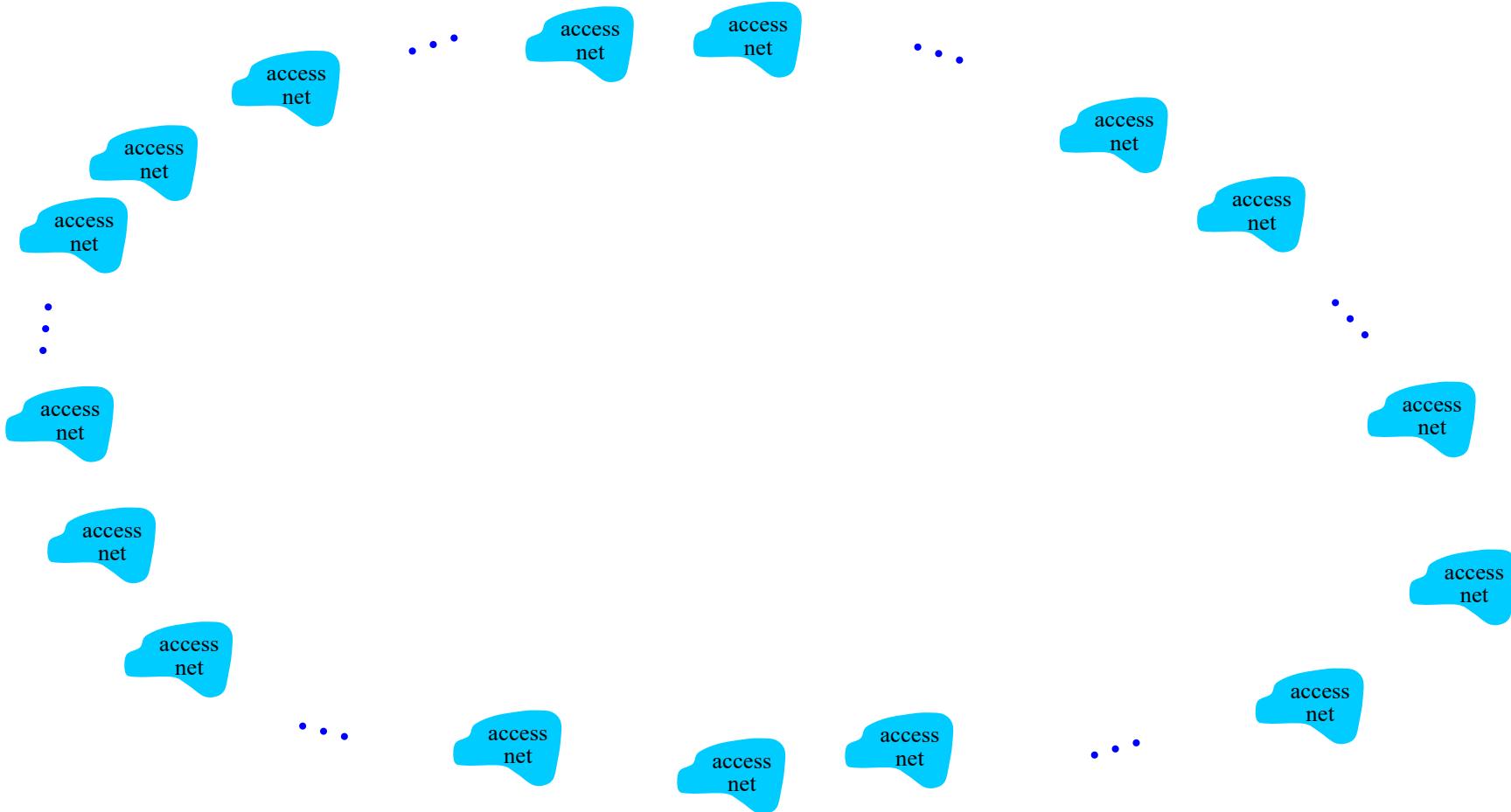
1.3.3 网络的网络

- 因特网上的所有终端都要连接到一起
- 问题：如何连接？



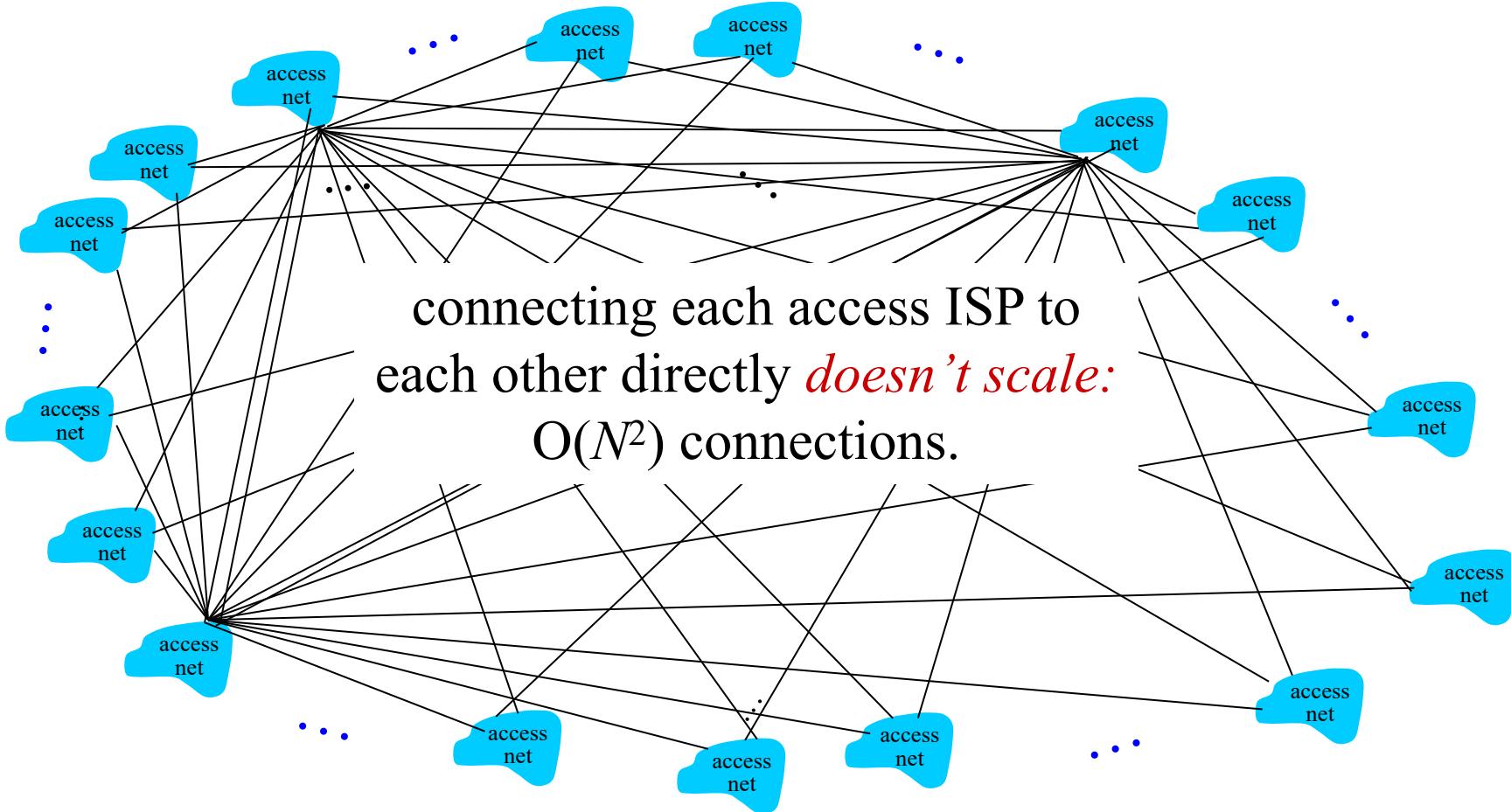
网络的网络

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



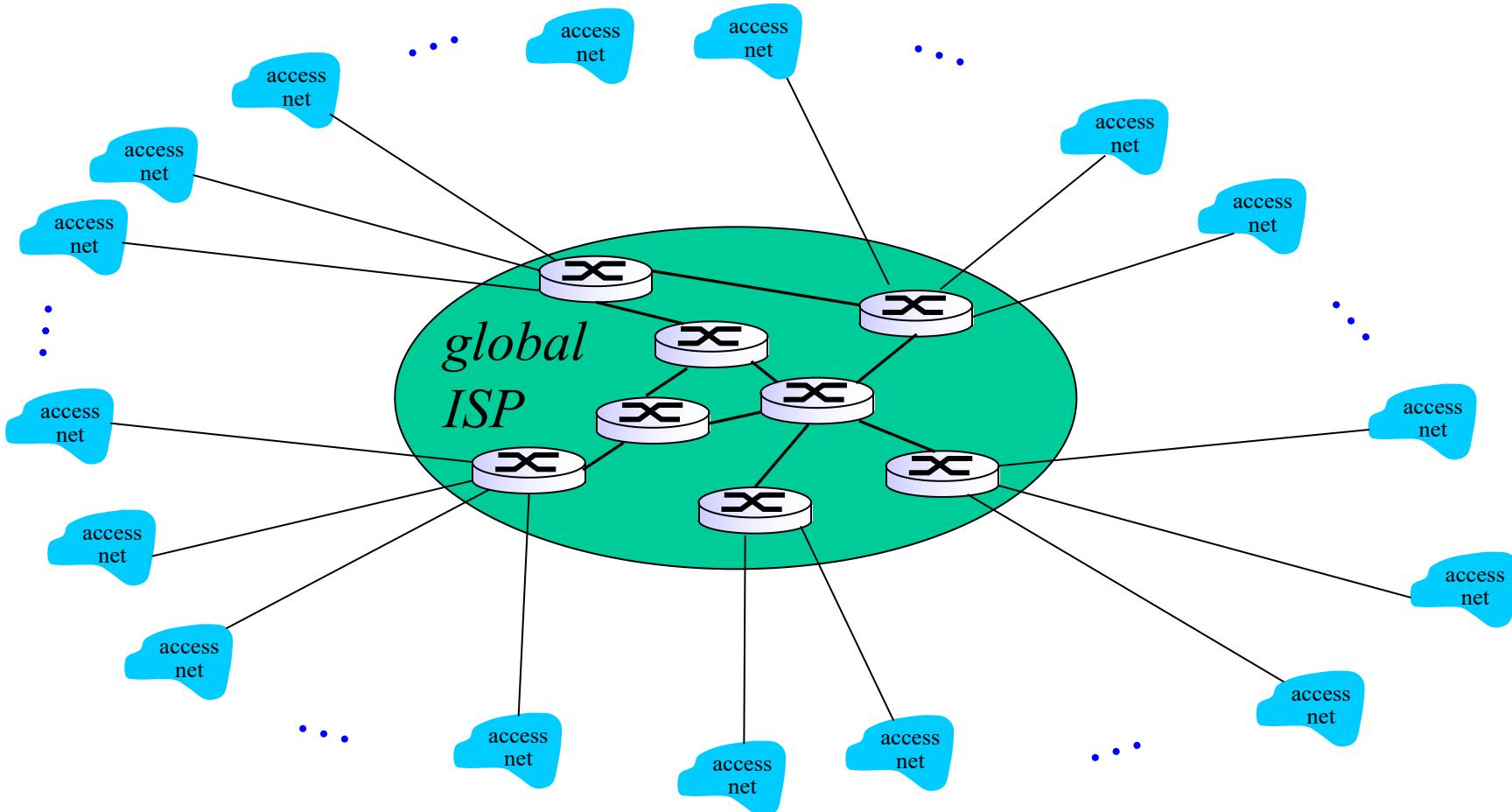
网络的网络：朴素的方法

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



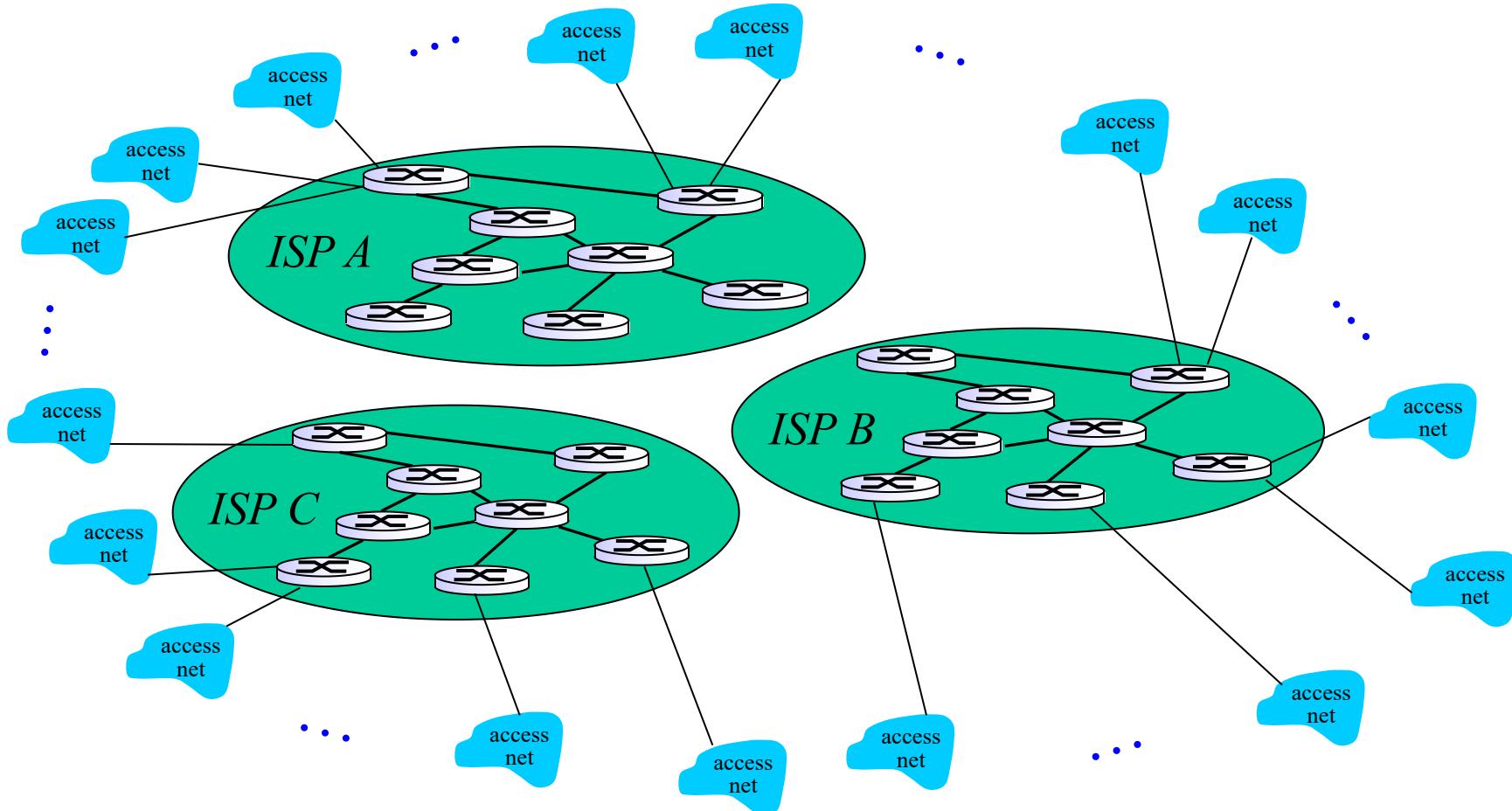
网络的网络：连接到一个全球ISP

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



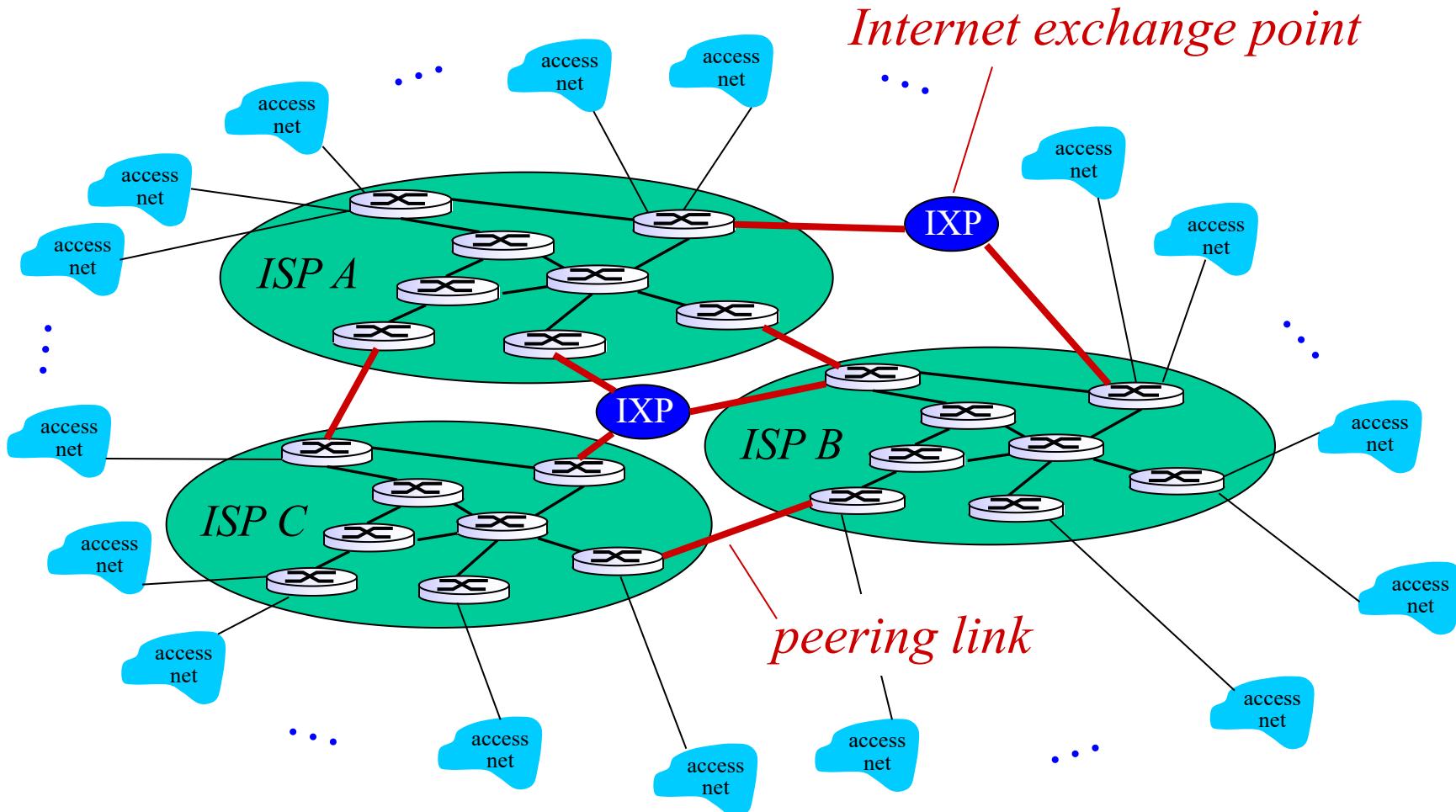
网络的网络：建立多个全球ISP

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

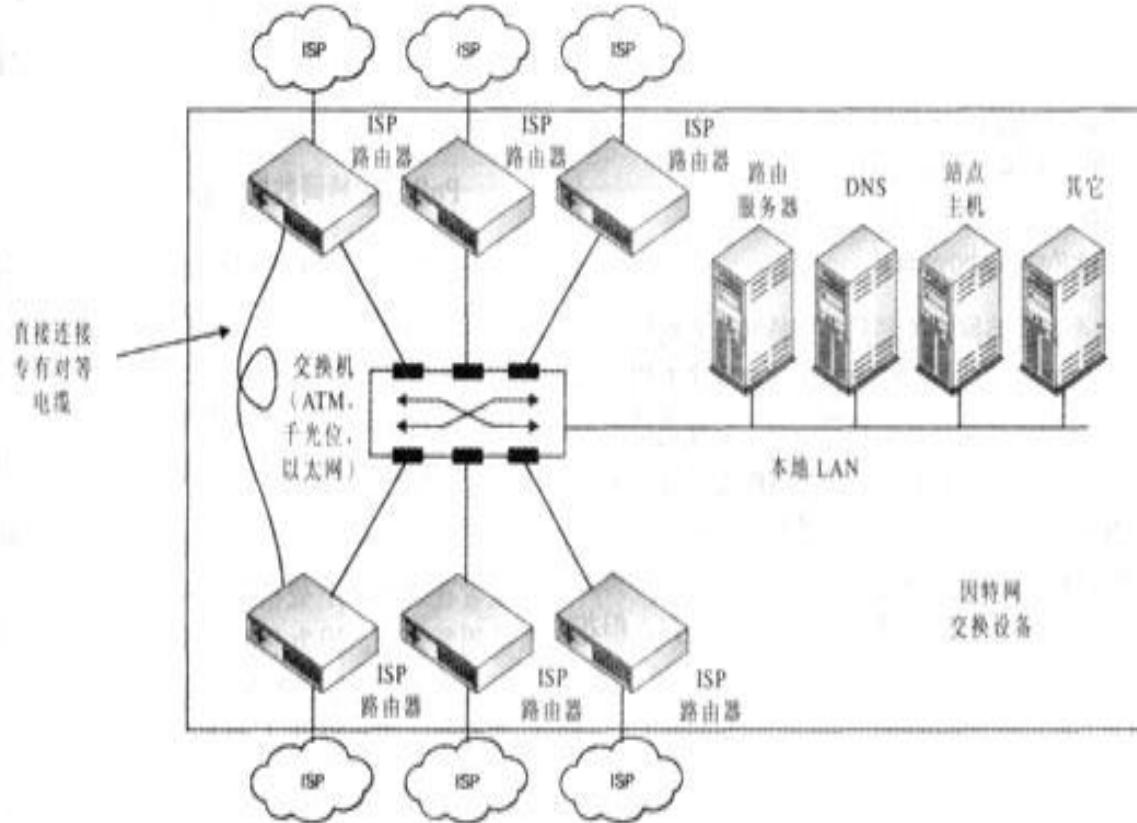


网络的网络：多个全球ISP

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

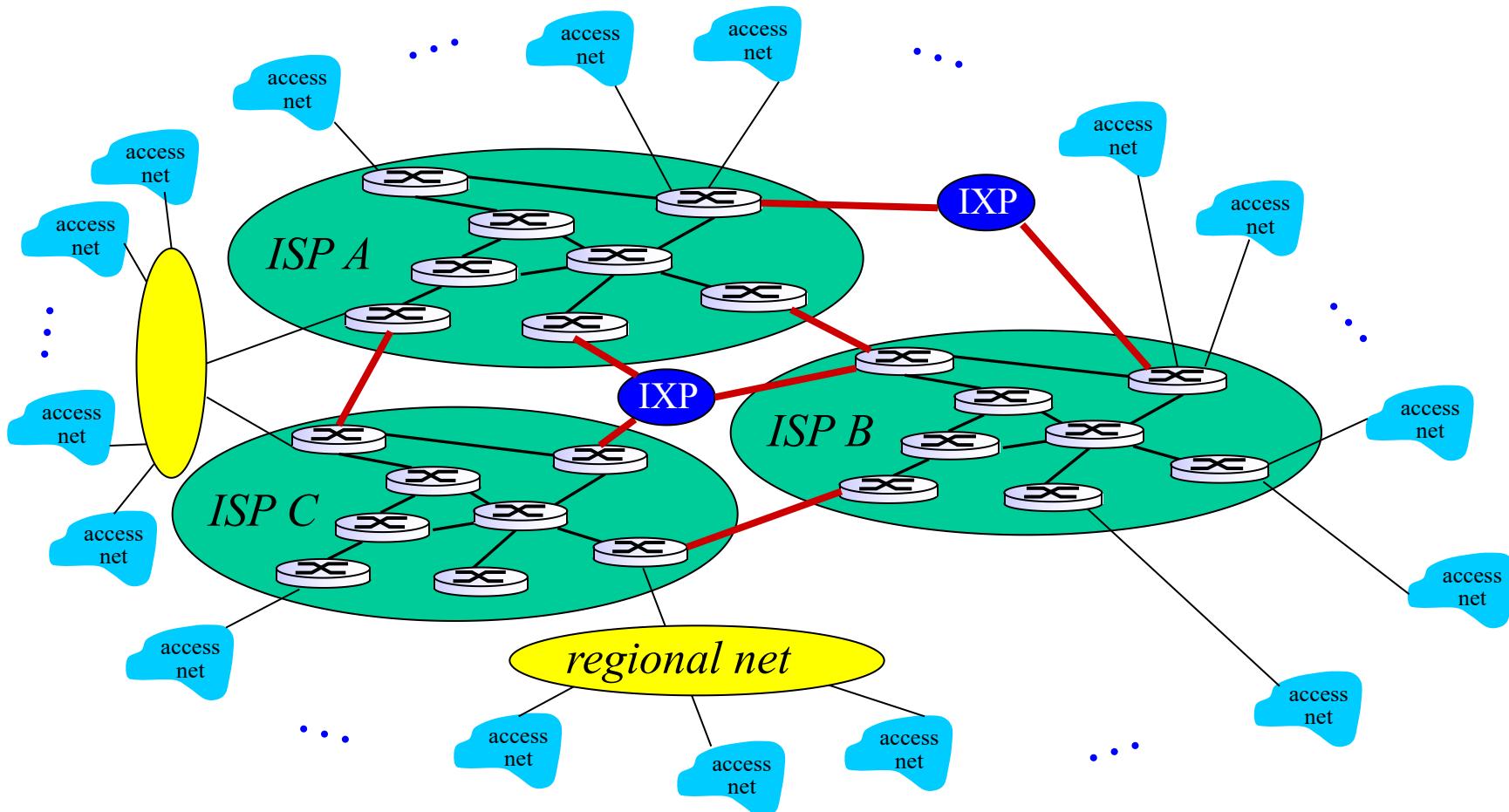


因特网交换点 (IXP)



网络的网络：多层次结构

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

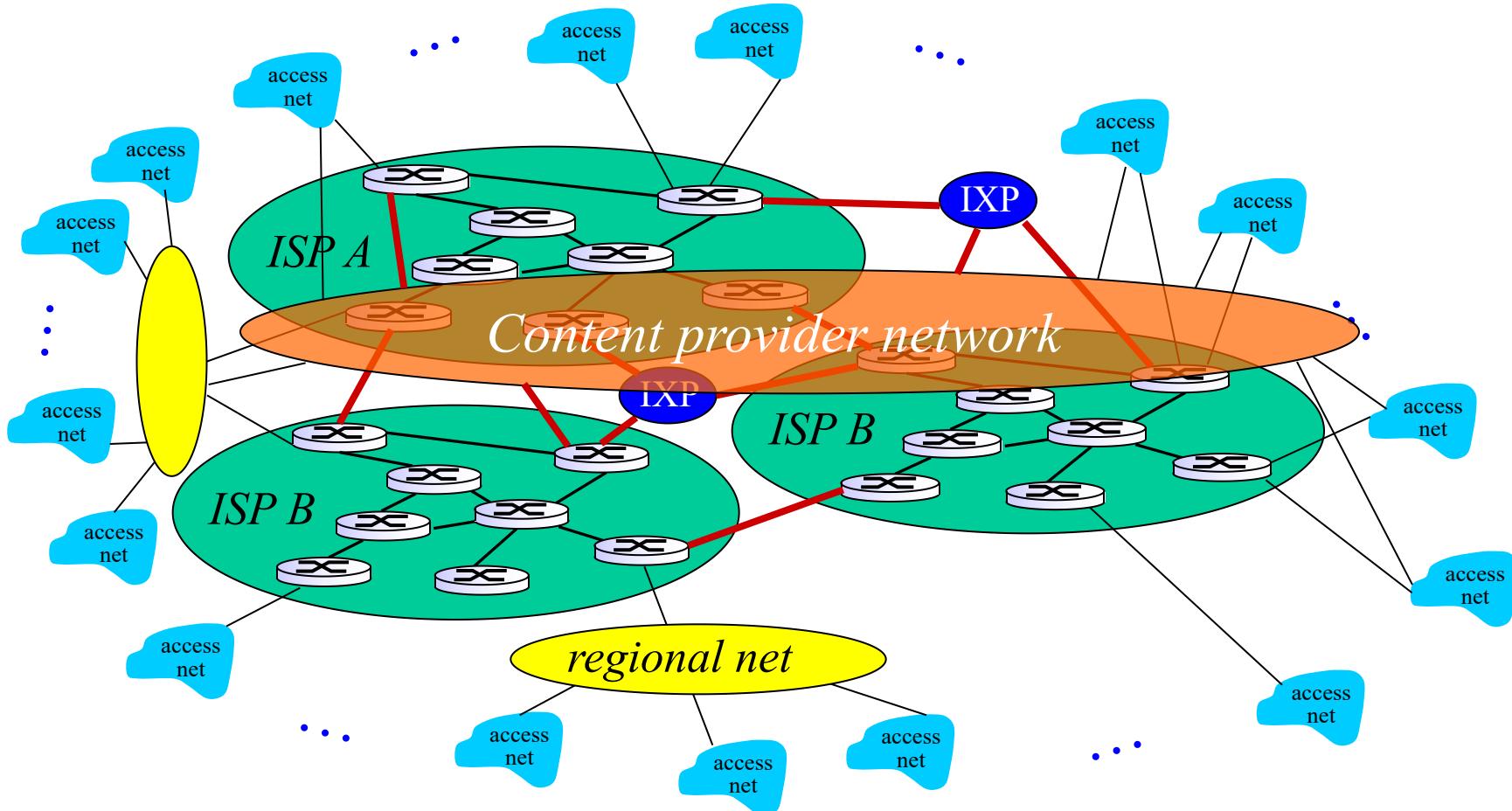


因特网生态系统

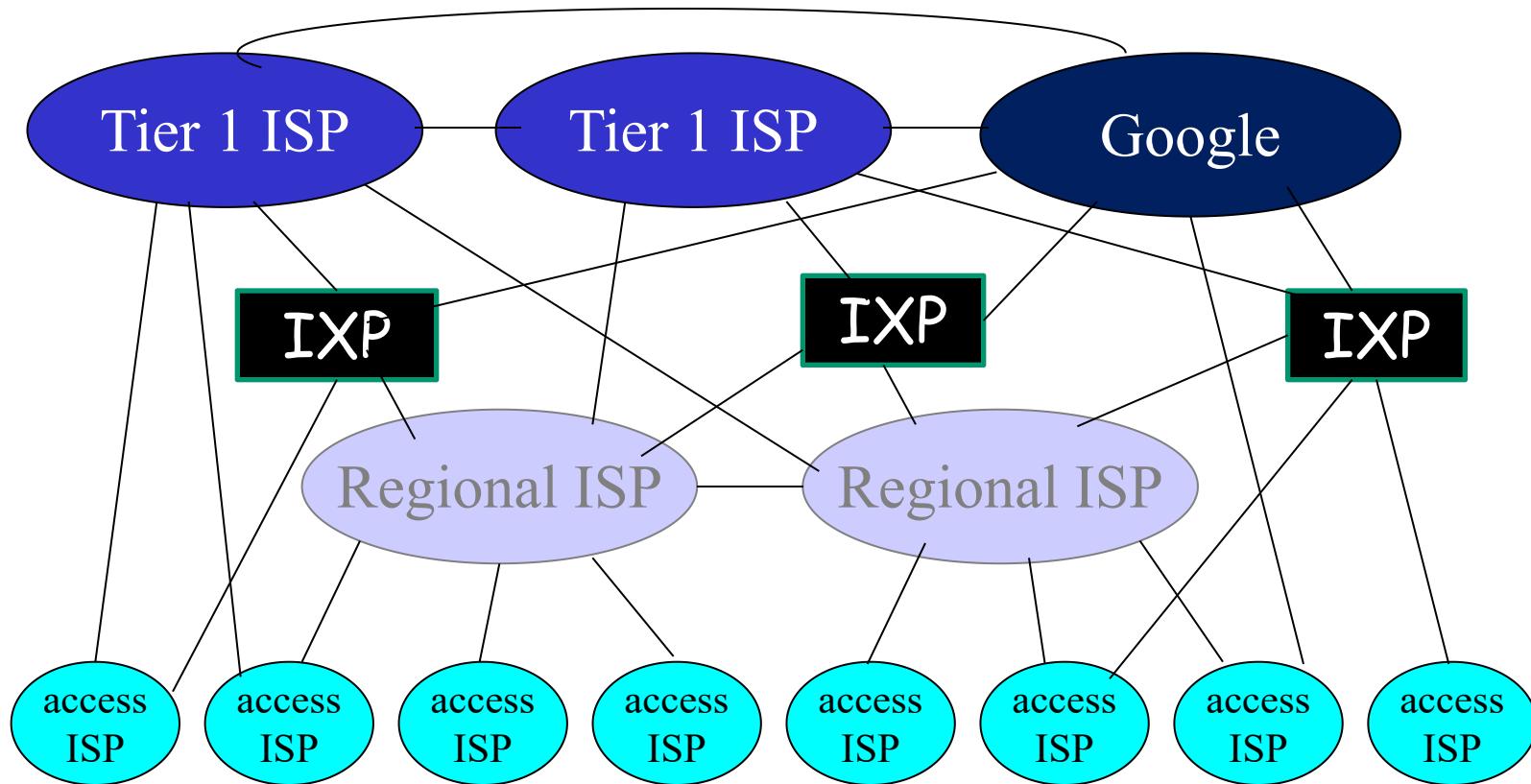
- ❖ 接入ISP
- ❖ 地区ISP
- ❖ 第一层ISP
- ❖ 对等链路
- ❖ 因特网交换点IXP：多个ISP共同对等的地方
- ❖ 存在点PoP（Point of Presence）：低层ISP接入高层ISP的地方
- ❖ 多宿（multi-home）：一个低层ISP可以接入多个高层ISP

网络的网络：内容提供商网络

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



网络的网络：今天的因特网结构



- at center: small # of well-connected large networks
 - ❖ “tier-1” commercial ISPs : national & international coverage
 - ❖ content provider network : private network that connects its data centers to Internet, often bypassing tier-1, regional ISPs

小结

□ 端系统

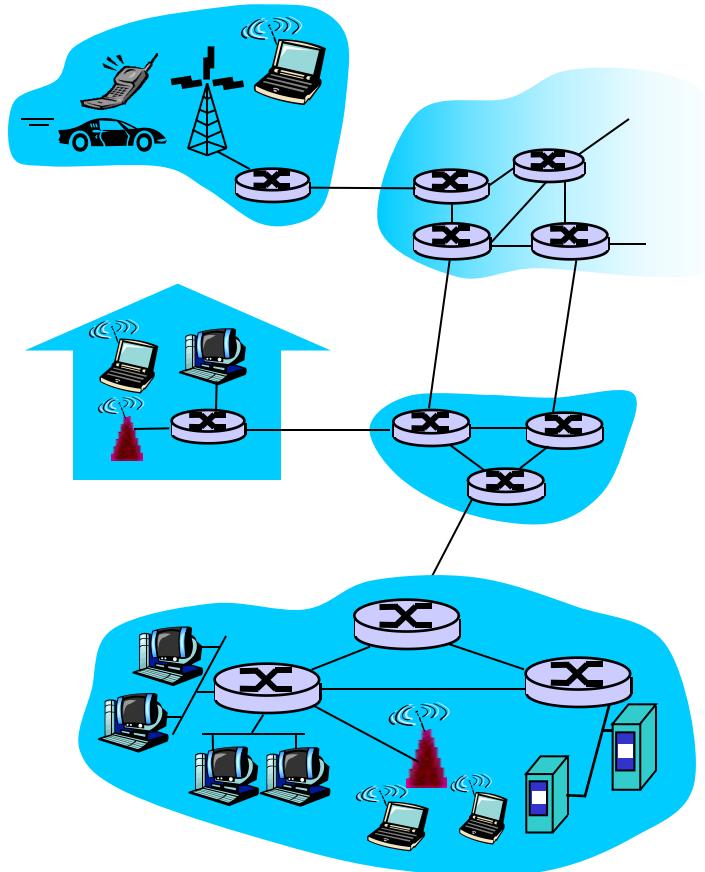
- ❖ 调用因特网服务接口，实现分布式应用
- ❖ 因特网中的通信过程对其不可见

□ 接入网

- ❖ 因特网到用户的“最后一公里”，将各类终端接入因特网
- ❖ 关注物理媒体、信号传输技术

□ 网络核心

- ❖ 任务是高效、准确地投递分组到目的地
- ❖ 关注选路、转发、拥塞控制等



Chapter 1: roadmap

1.1 What *is* the Internet?

1.2 Network edge

- end systems, access networks, links

1.3 Network core

- circuit switching, packet switching, network structure

1.4 Delay, loss and throughput in packet-switched networks

1.5 Protocol layers, service models

1.6 Networks under attack: security

1.7 History

1.4 衡量网络性能的主要指标

□ 延迟

- ❖ 分组从源终端到达目的终端的时间

□ 丢包率

- ❖ 未成功交付到目的终端的分组比例

□ 吞吐量

- ❖ 单位时间内网络成功交付的数据量

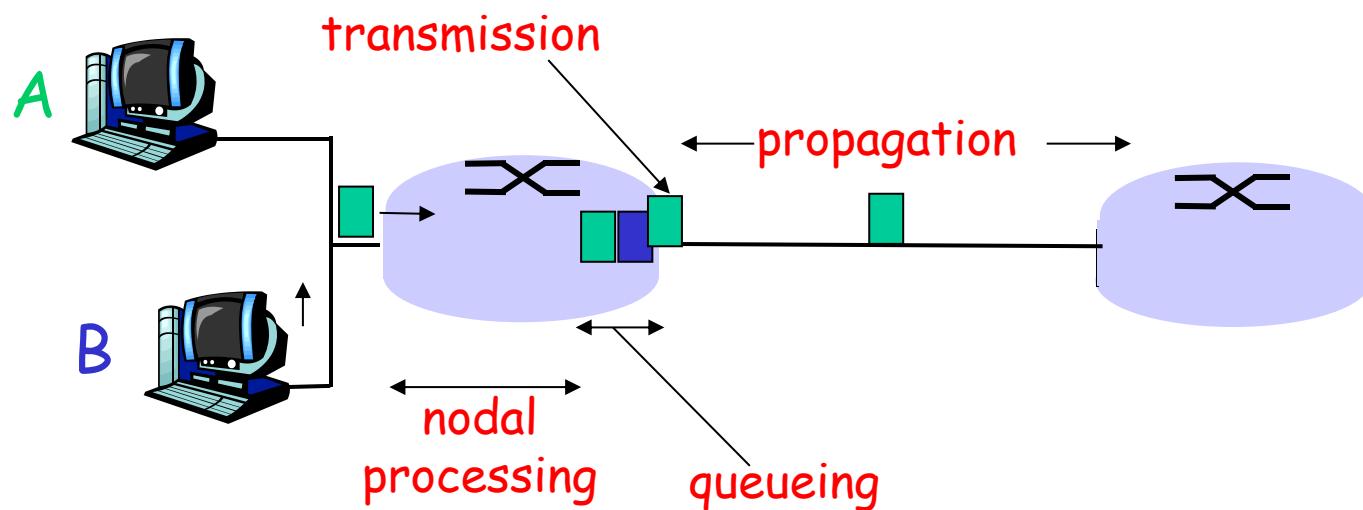
分组延迟的来源

□ 1. 节点处理:

- ❖ 检查错误
- ❖ 确定输出链路

□ 2. 排队

- ❖ 在输出缓存等待传输
- ❖ 时间长短取决于链路负载大小



分组延迟的来源

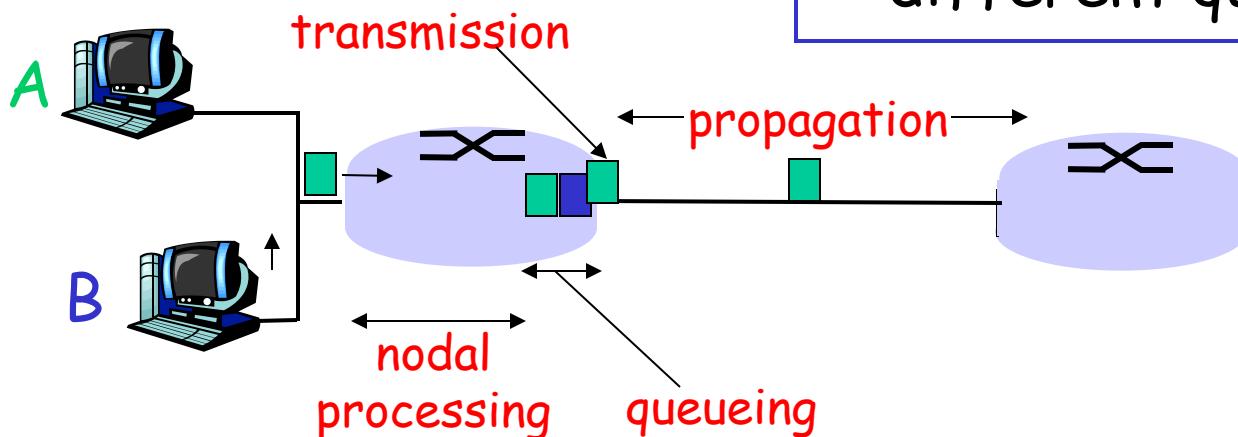
3. 传输延迟:

- $R = \text{link bandwidth (bps)}$
- $L = \text{packet length (bits)}$
- 将分组发送到链路上的时间 = L/R
(分组序列化时间)

4. 传播延迟:

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

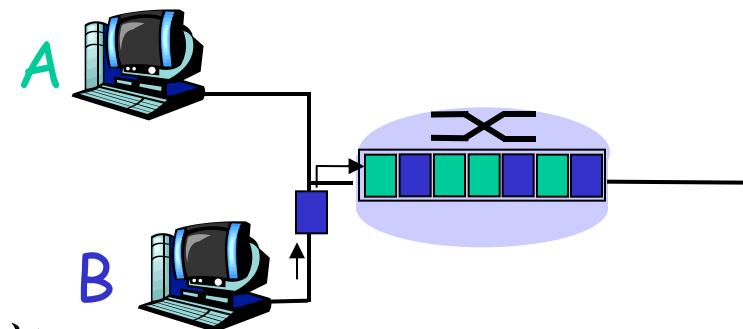
Note: s and R are very different quantities!



节点延迟

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

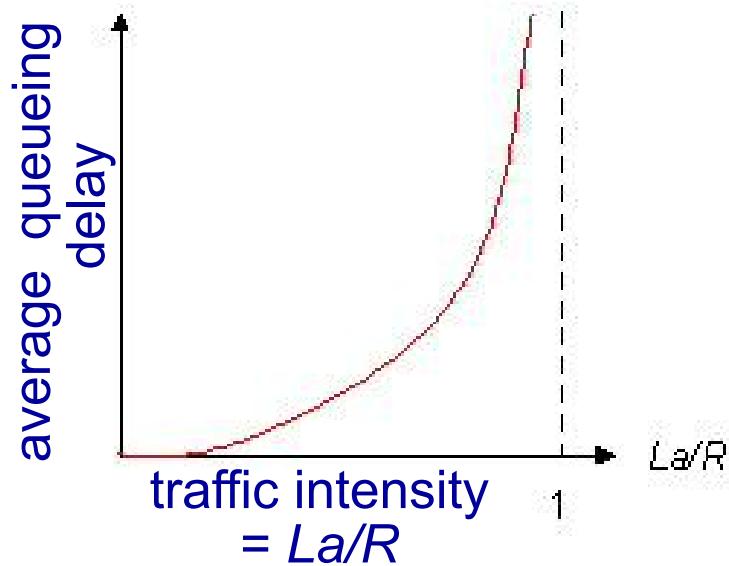
- d_{proc} = 处理延迟
 - ❖ 典型地为几个微秒或更低
- d_{queue} = 排队延迟
 - ❖ 差异很大，取决于链路负载
- d_{trans} = 传输延迟
 - ❖ 微秒~毫秒，主要取决于链路速率
- d_{prop} = 传播延迟
 - ❖ 几微秒~几百毫秒，主要取决于链路长度



排队延迟与流量强度

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

traffic intensity = La/R



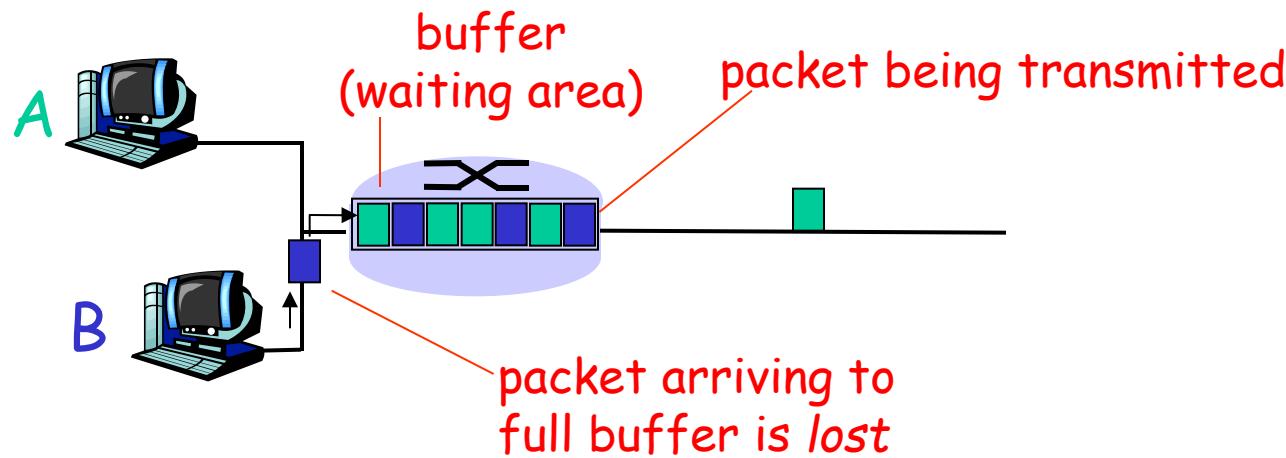
- $La/R \sim 0$: avg. queueing delay small
- $La/R \rightarrow 1$: avg. queueing delay large
- $La/R > 1$: more “work” arriving than can be serviced, average delay infinite!



* Check online interactive animation on queuing and loss

排队与丢包

- 输出队列的容量是有限的；队列满时，新来的分组被丢弃



- 队列长度是一个重要的参数：
 - ❖ 队列太短：丢包率增大
 - ❖ 队列太长：排队延迟增大（也会造成间接丢包！）

端到端延迟

□ 端到端延迟：

- ❖ 分组传输路径上所有节点的节点延迟之和

□ 对端到端延迟敏感的应用：

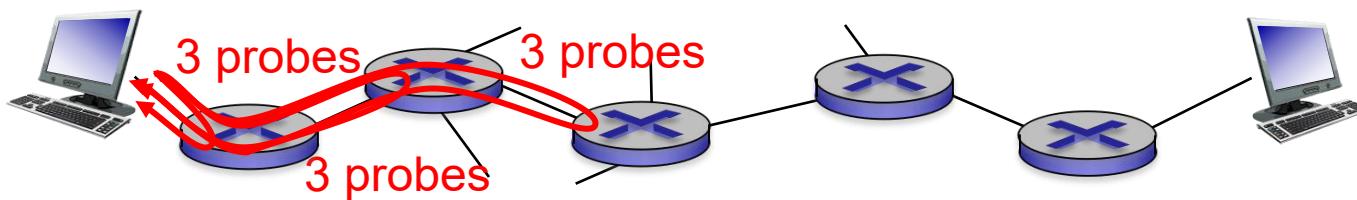
- ❖ 高度敏感：实时交互应用，如网络电话、视频会议
- ❖ 中度敏感：在线交互应用，如网页浏览

□ 探测端到端延迟：

- ❖ Ping, Traceroute

“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.



“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

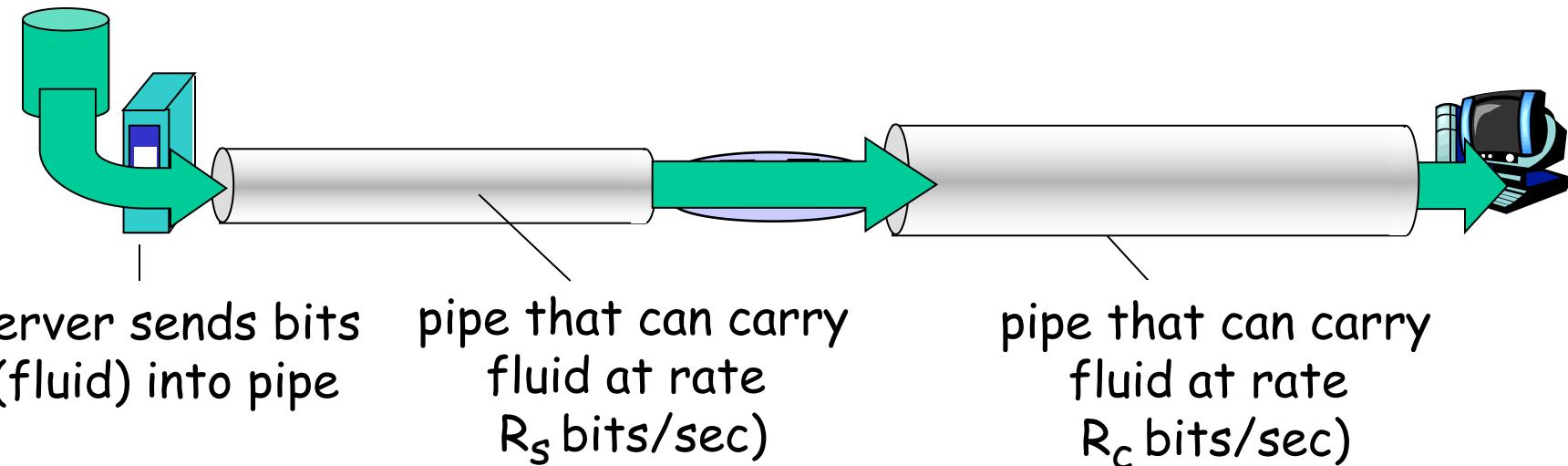
1	cs-gw (128.119.240.254)	1 ms	1 ms	2 ms
2	border1-rt-fa5-1-0.gw.umass.edu (128.119.3.145)	1 ms	1 ms	2 ms
3	cht-vbns.gw.umass.edu (128.119.3.130)	6 ms	5 ms	5 ms
4	jn1-at1-0-0-19.wor.vbns.net (204.147.132.129)	16 ms	11 ms	13 ms
5	jn1-so7-0-0-0.wae.vbns.net (204.147.136.136)	21 ms	18 ms	18 ms
6	abilene-vbns.abilene.ucaid.edu (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	***			
		* means no response (probe lost, router not replying)		
19	fantasia.eurecom.fr (193.55.113.142)	132 ms	128 ms	136 ms

trans-oceanic link

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

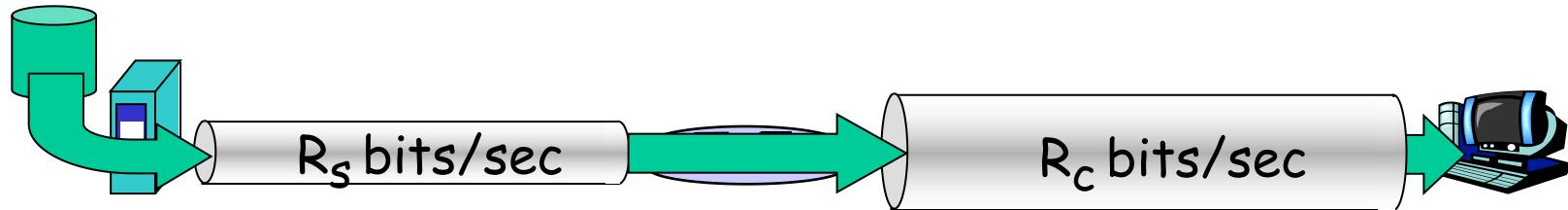
端到端吞吐量

- 单位时间内向接收端成功交付的数据量：
 - 瞬时吞吐量：给定时刻的传输速率
 - 平均吞吐量：较长时间内的传输速率

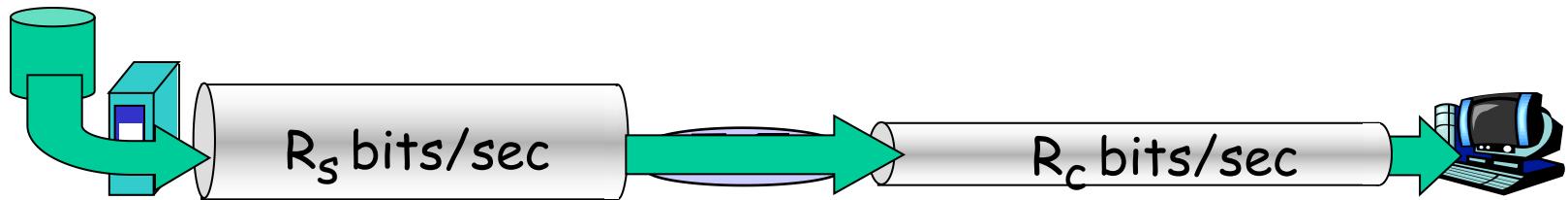


端到端吞吐量 (续)

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



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

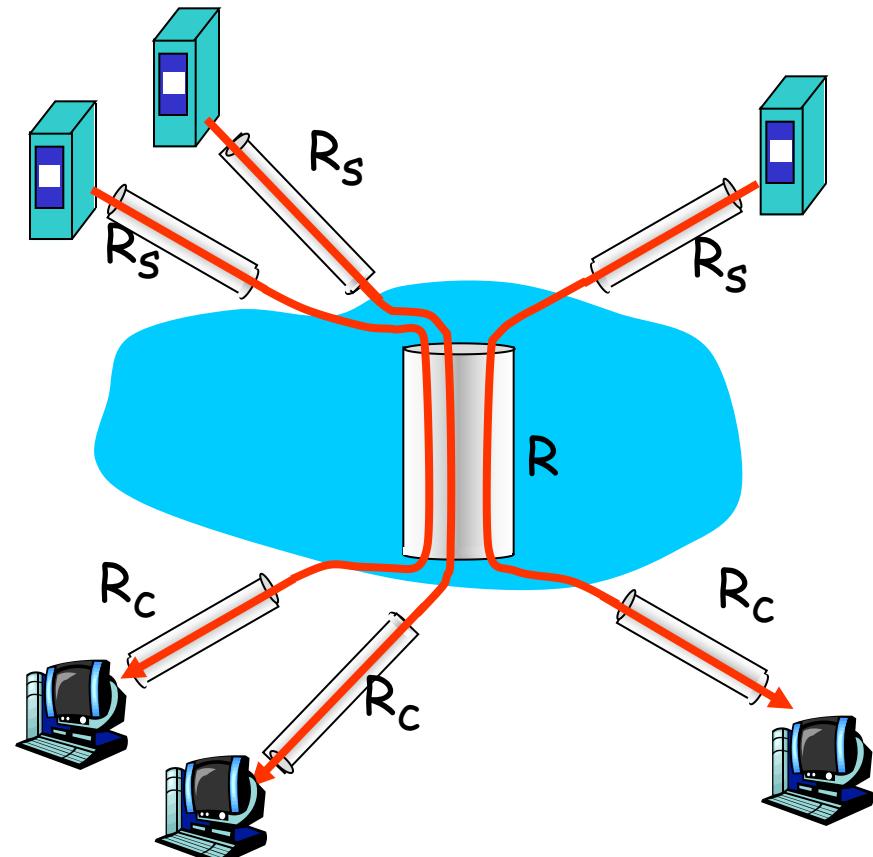


bottleneck link

瓶颈链路限制了端到端吞吐量。

Throughput: Internet scenario

- 端到端吞吐量:
 $\min(R_c, R_s, R/10)$
- 端到端吞吐量与瓶颈链路的速率、以及链路上的负载有关



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

小结

- 延迟、丢包率、吞吐量三个指标，均与负载有关
- 如何通过调节负载来获得这些指标的平衡，是因特网的重要研究内容之一

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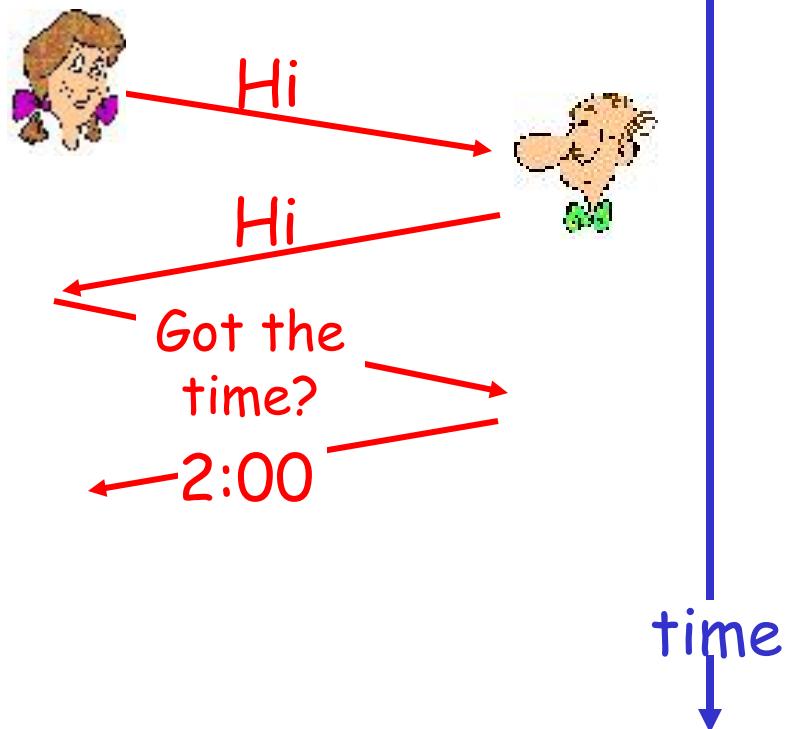
1.5 Protocol layers, service models

1.6 Networks under attack: security

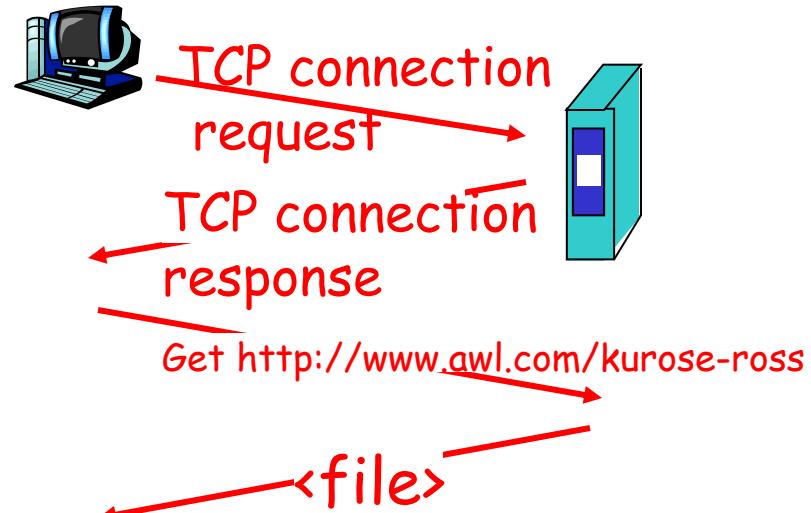
1.7 History

什么是协议?

一个人类协议



一个计算机网络协议



协议的要素

- Human/network protocols:
 - ❖ specific **mesages** sent
 - ❖ specific **actions** taken when messages received, or other events
- 网络协议定义了：
 - ❖ 通信实体之间交换的报文的格式和次序
 - ❖ 在发送/接收报文、或其它事件后采取的动作
- 掌握计算机网络知识的过程，就是理解网络协议的构成、原理和工作的过程

Networks are complex !

- many “pieces”:
 - ❖ hosts
 - ❖ routers
 - ❖ links of various media
 - ❖ applications
 - ❖ Protocols

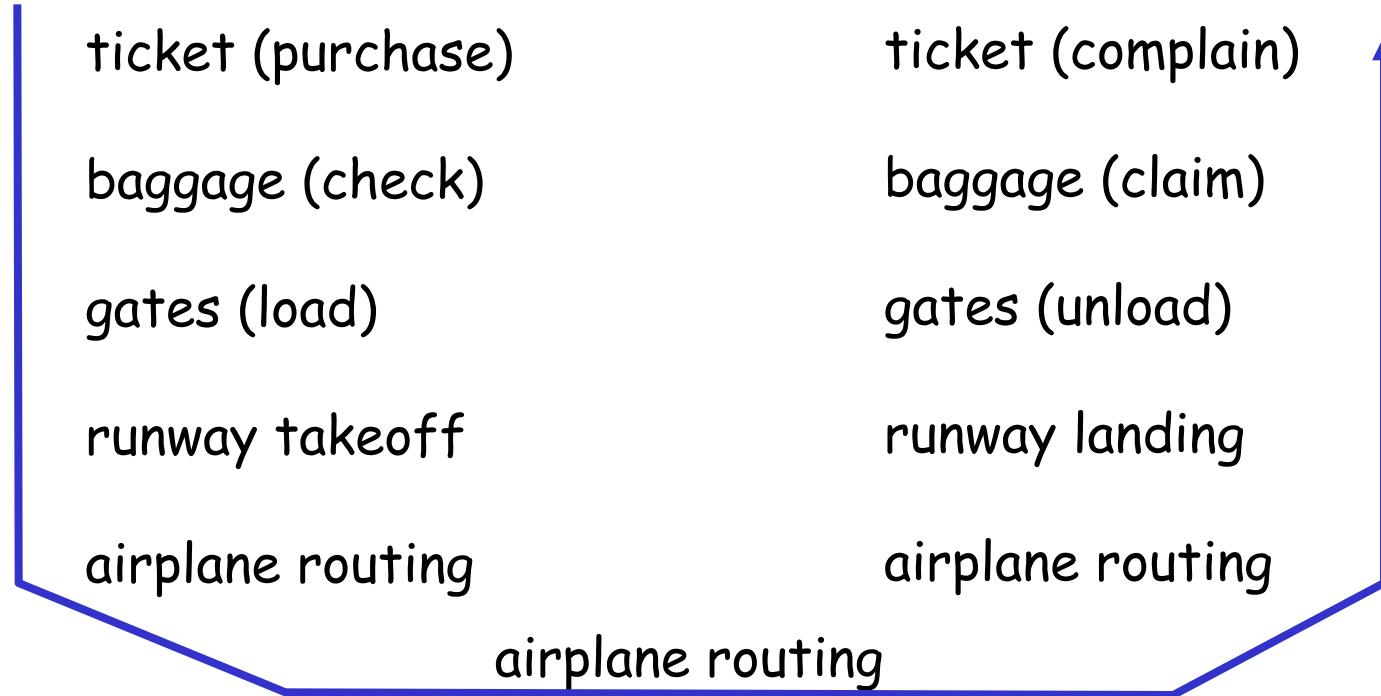
Question:

Is there any hope of
organizing structure of
network?

Or

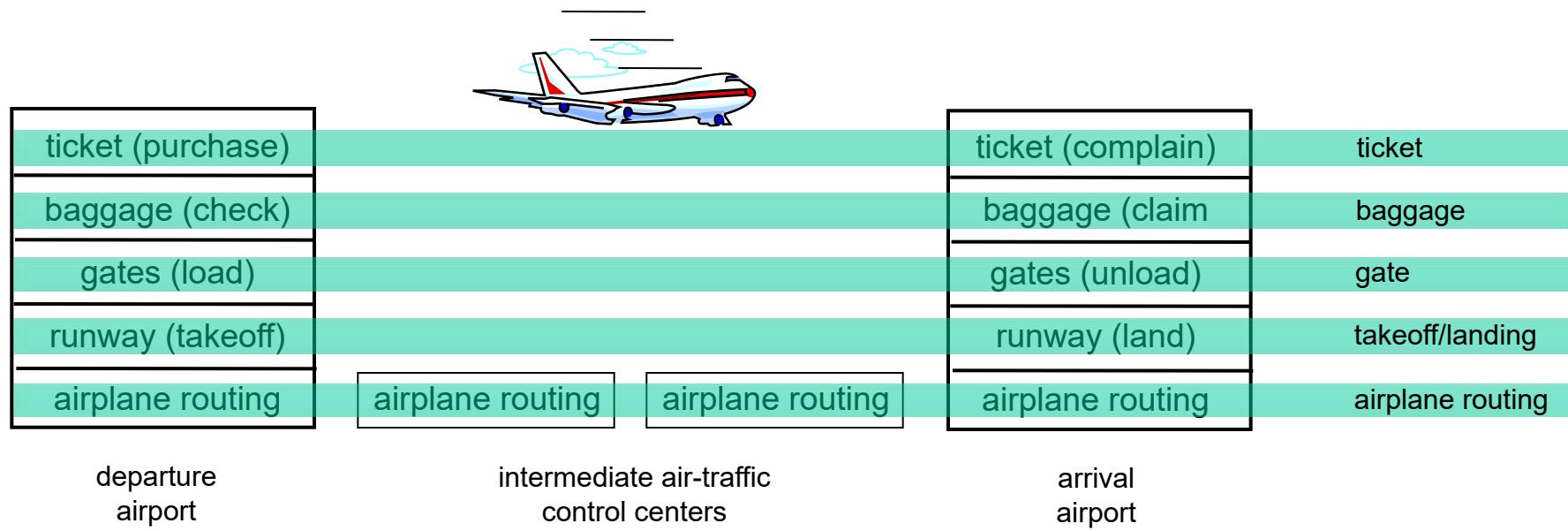
at least our discussion of
networks?

Organization of air travel



- ❑ a series of steps

Layering of airline functionality



- **系统分层:** 将系统按功能划分成一系列水平的层次，每一层实现一个功能（服务）
- **层次间关系:** 每一层的功能实现都要依赖其下各层提供的服务

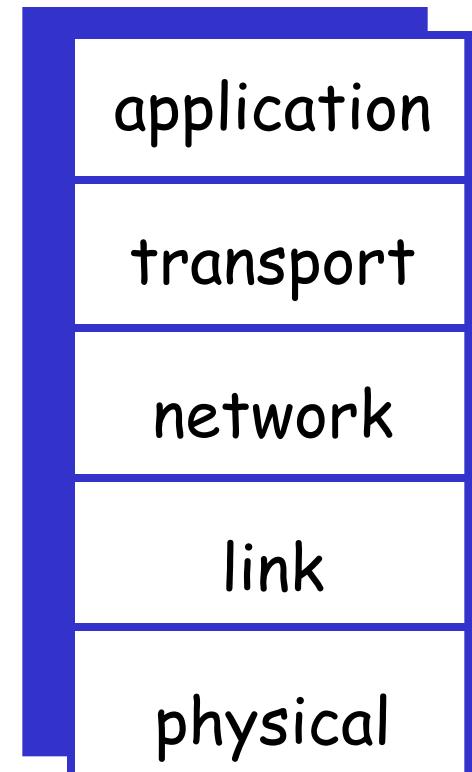
分层的好处

系统分层：易于处理复杂的系统

- 显式的层次结构易于确定系统的各个部分及其相互关系
- 模块化简化了系统的维护和升级
 - ❖ 改变某层服务的实现方式，对于其它层次是透明的

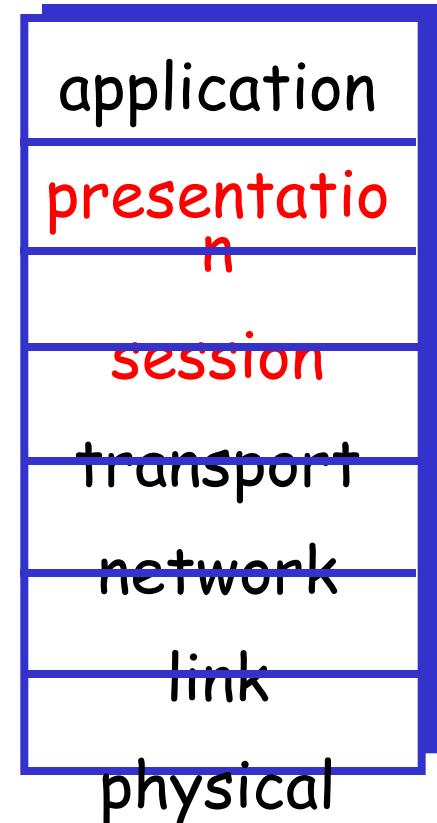
Internet协议栈

- **application**: 在应用程序之间传输应用特定的报文 (**message**)
 - ❖ E.g., FTP, SMTP, HTTP
- **transport**: 在应用程序与网络的接口间 (进程-进程) 传输报文段 (**segment**)
 - ❖ TCP, UDP
- **network**: 在源主机和目的主机 (终端-终端) 之间传输分组 (**packet**)
 - ❖ IP, routing protocols
- **link**: 在相邻设备之间传输帧 (**frame**)
 - ❖ E.g., PPP, Ethernet
- **physical**: 在物理媒体上上传输比特 (**bit**)



ISO/OSI reference model

- **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?

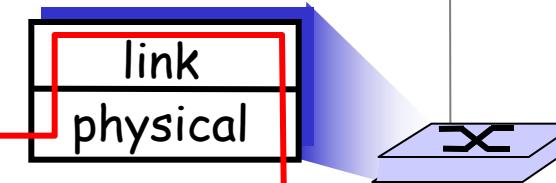
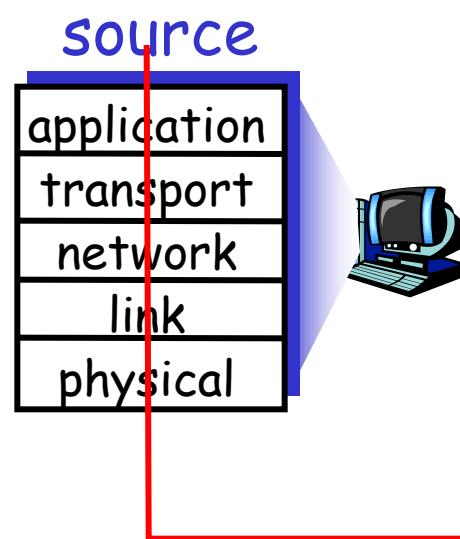


网络功能的分布式实现

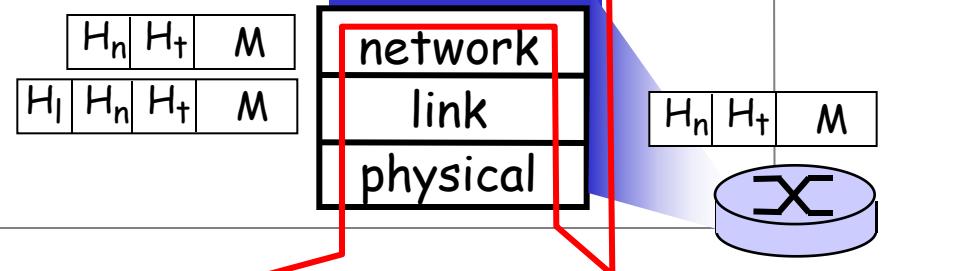
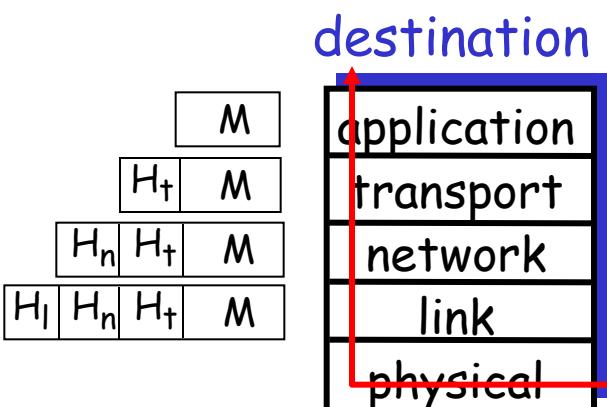
- 某一层上的网络功能，需要该层上的实体（分布在不同的节点）协同完成
- 协同计算要求功能实体之间能够交互信息，需要解决以下问题：
 - ❖ 信息交互的载体是什么：报文（*message, packet*）
 - ❖ 信息交互的约定：报文格式及语义规定
 - ❖ 报文的传输方式：封装和解封装

封装

message	M
segment	H _t M
datagram	H _n H _t M
frame	H _l H _n H _t M



switch



router

小结

- 网络按功能划分层次，每层实现一个功能
- 不同系统的同一层：
 - ❖ 对等实体执行该层的协议
- 相同系统的上下层：
 - ❖ 调用服务/提供服务
 - ❖ 封装/解封装分组
- 不同系统的不同层：
 - ❖ 不直接通信

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Network Security

□ Internet最初设计的时候，并没有考虑安全的问题

- ❖ *original vision: “a group of mutually trusting users attached to a transparent network”* ☺

□ 今天的Internet:

- ❖ 每天都有各种各样的安全事件发生
- ❖ 网络安全已成为近年来计算机网络领域的中心主题

因特网面临的安全威胁

□ 针对因特网基础设施的攻击：

- ❖ 恶意软件（病毒、蠕虫、间谍软件等）入侵计算机设备
- ❖ 对主机、网络等实施拒绝服务攻击（*Denial of Service*），使其中止服务

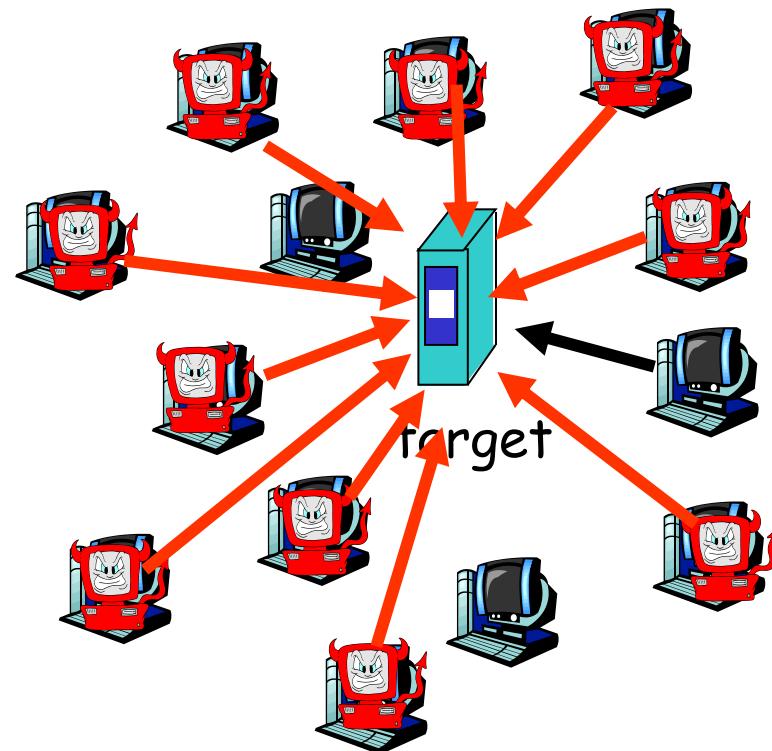
□ 针对因特网中信息的攻击：

- ❖ 窃听网络中传输的数据
- ❖ 在网络中注入虚假的信息欺骗用户

拒绝服务 (DoS) 攻击

- 攻击者通过耗尽主机或网络带宽资源，使得合法用户得不到所需的服务

1. 选择目标
2. 利用恶意软件攻陷网络中的主机（称肉鸡、僵尸机器）
3. 从僵尸主机向目标发送大量数据包

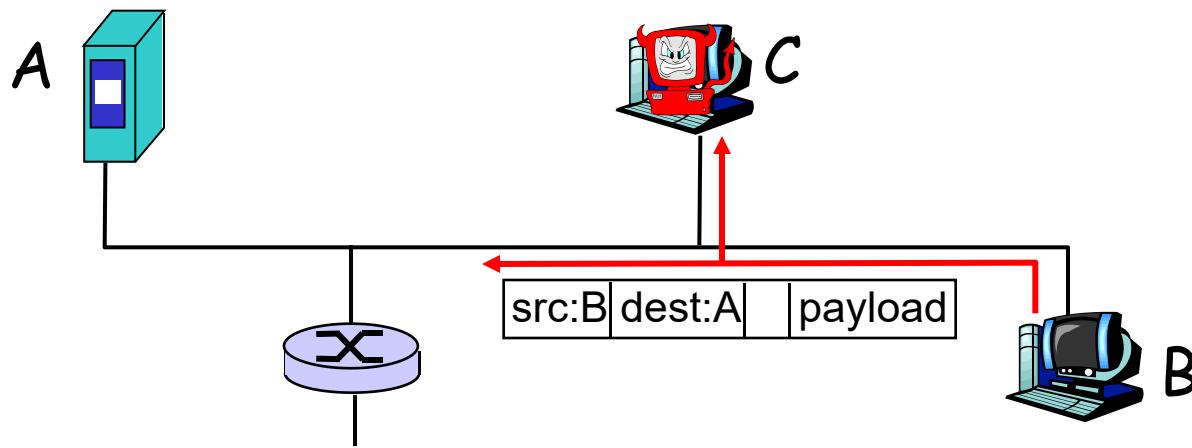


嗅探

□ 嗅探：

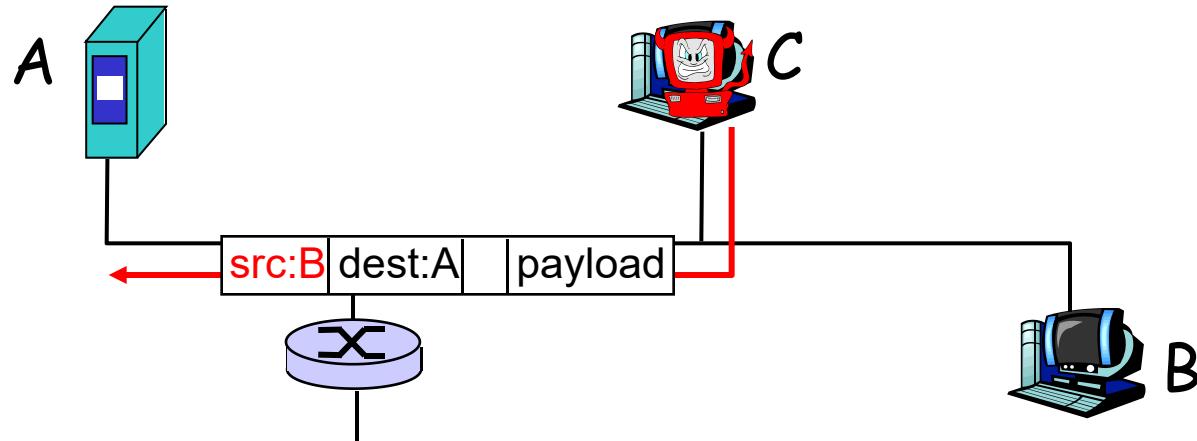
- ❖ 监听网络中传输的数据包，获取数据包中携带的信息，如密码

□ Wireshark就是一款免费的嗅探器



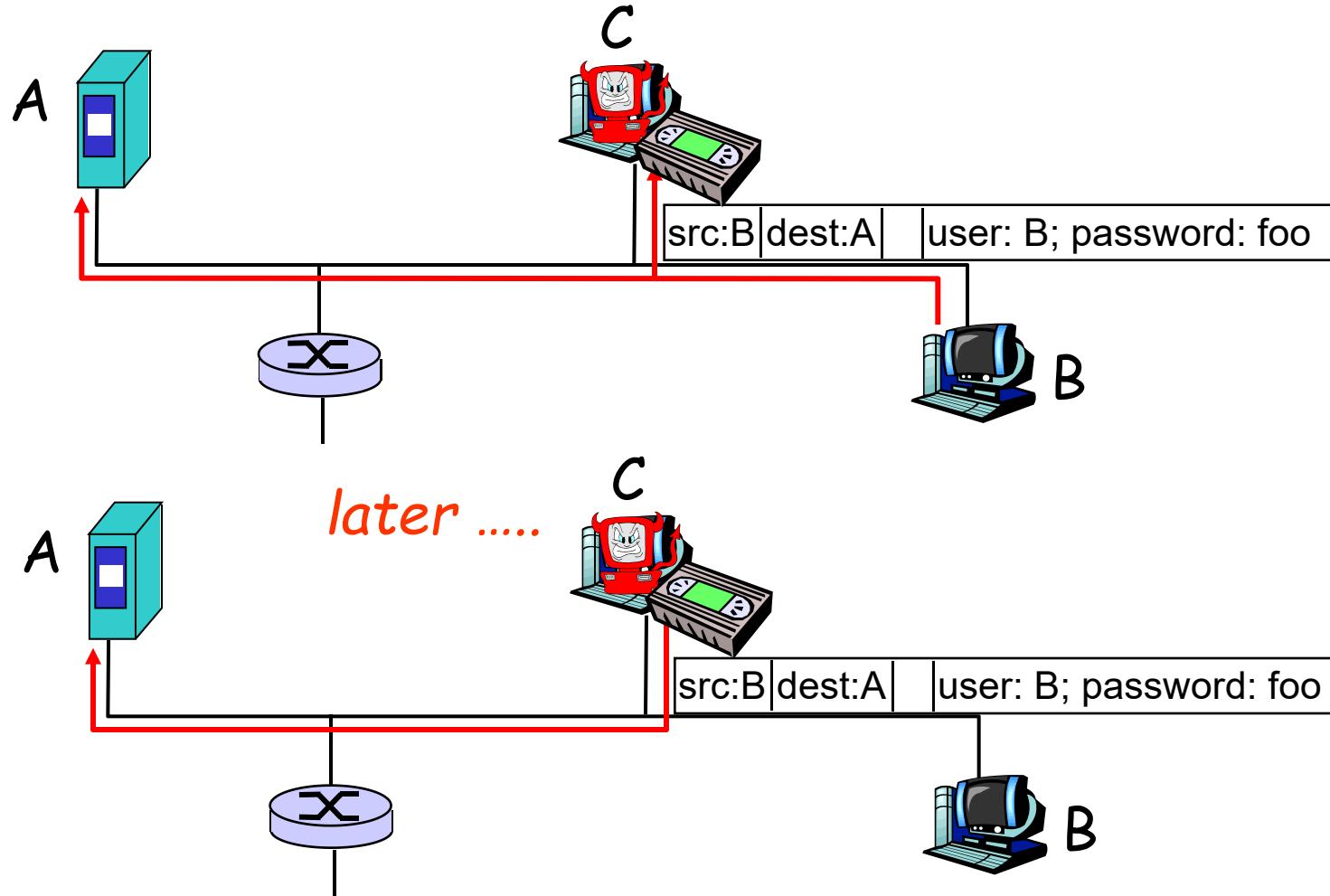
伪装

口 **IP欺骗**: 发送虚假地址的数据包



伪装

- 重放攻击：嗅探敏感信息（比如，某用户的口令），之后重新注入网络（以假冒该用户）



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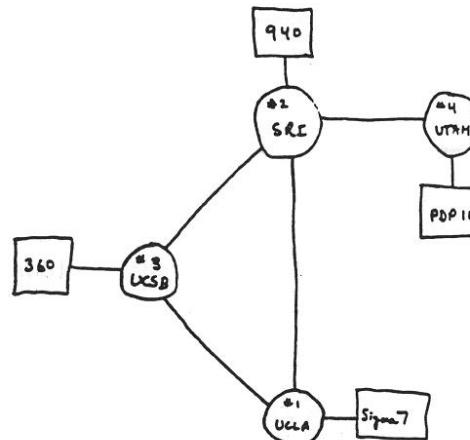
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Internet History

1961-1972: Early packet-switching principles

- 1961: Kleinrock - queueing theory shows effectiveness of packet-switching
- 1964: Baran - packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: first ARPAnet node operational
- 1972:
 - ❖ ARPAnet public demonstration
 - ❖ NCP (Network Control Protocol) first host-host protocol
 - ❖ first e-mail program
 - ❖ ARPAnet has 15 nodes



Internet History

1972-1980: Internetworking, new and proprietary nets

- 1970: ALOHAnet satellite network in Hawaii
- 1974: Cerf and Kahn - architecture for interconnecting networks
- 1976: Ethernet at Xerox PARC
- late 70's: proprietary architectures: DECnet, SNA, XNA
- late 70's: switching fixed length packets (ATM precursor)
- 1979: ARPAnet has 200 nodes

Cerf and Kahn's internetworking principles:

- ❖ minimalism, autonomy - no internal changes required to interconnect networks
- ❖ best effort service model
- ❖ stateless routers
- ❖ decentralized control

define today's Internet architecture

Internet History

1980-1990: new protocols, a proliferation of networks

- 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, BITnet, **NSFnet**, Minitel
- 100,000 hosts connected to confederation of networks

Internet History

1990, 2000's: commercialization, the Web, new apps

- Early 1990's: ARPAnet decommissioned
- 1991: NSF lifts restrictions on commercial use of NSFnet (decommissioned, 1995)
- early 1990s: Web
 - ❖ hypertext [Bush 1945, Nelson 1960's]
 - ❖ HTML, HTTP: Berners-Lee
 - ❖ 1994: Mosaic, later Netscape
 - ❖ late 1990's: commercialization of the Web

Late 1990's - 2000's:

- 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

2001~: Mobile Internet, Internet of Things

□ 2008年开启移动互联网时代:

- ❖ 国际电信联盟正式公布第三代移动通信标准（3G）
- ❖ 苹果公司发布iPhone3G、iOS 2.0，推出App Store

□ 移动互联网:

- ❖ 通过智能移动终端，从互联网获取业务和服务

□ 2009开启物联网时代:

- ❖ 物联网计划在欧洲、美国（智慧地球）、中国（感知中国）启动

□ 物联网:

- ❖ 在互联网的基础上，将用户端扩展和延伸到任何物体，允许对任何能够被独立寻址的普通物体进行智能化识别、定位、跟踪、监控和管理

Internet history

- ~5G devices attached to Internet (2016)
 - ❖ smartphones and tablets
- aggressive deployment of broadband access
- increasing ubiquity of high-speed wireless access
- emergence of online social networks:
 - ❖ Facebook: ~ one billion users
- service providers (Google, Microsoft) create their own networks
 - ❖ bypass Internet, providing “instantaneous” access to search, video content, email, etc.
- e-commerce, universities, enterprises running their services in “cloud” (e.g., Amazon EC2)

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!

本章小结

□ 计算机网络关注:

- ❖ 功能性问题: 可达性 (选路、转发), 正确性 (可靠性控制)
- ❖ 性能问题: 吞吐量, 延迟, 丢包率
- ❖ 安全性问题: 基础设施安全, 信息安全

□ 重点理解:

- ❖ 分组交换: 存储转发, 设计考虑 (利), 引入的问题 (弊)

说明: 在因特网中使用分组交换而不是电路交换, 是一个重大的决定。需要理解这个决定背后的考虑, 以及这些决定可能带来的问题, 如何解决这些问题则是协议的主要内容

- ❖ 网络分层架构: 服务, 功能, 接口, 协议, 封装

作业

□ 习题:

- ❖ 9, 10, 13, 21, 22,
25, 31, 33

□ 实验:

- ❖ 入门实验

□ 提交时间:

- ❖ 习题:
- ❖ 实验:

□ 思考与讨论:

理论上说，由于因特网采用分组交换，不能保证分组延迟，因此因特网对音视频应用的支持不好。这句话和你的亲身感受相符吗？回想一下，你在网络上看电影、看直播、打电话有什么样的体会。如果不符，举出例子；如果相符，也举出例子。对此你有什么疑问或思考吗？