Computer Networks

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课程安排

- 课程名称：计算机网络
- 任课教师：
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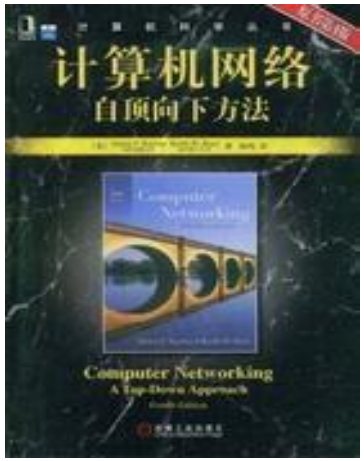
  - 研究方向为无线网络、移动互联网、社交网络分析及大数据挖掘
  - 个人主页：http://cs.nju.edu.cn/lwz/
- 授课方式：课堂讲授+实验
  - 实验课为每双周周四，3-4节，地点：乙124
- 课程主页：http://cs.nju.edu.cn/lwz/
- 助教QQ群：956204655（实验验收、作业提交、答疑）
- 课程考核
  - 平时成绩：15%
  - 实验：25%
  - 期末考试：60%

参考书籍

- James F. Kurose, Keith W. Ross. 计算机网络—自顶向下方法 (6th). 机械工业出版社，2014.



- William Stallings. 数据与计算机通信 (8th). 电子工业出版社

Chapter 1. Introduction of Networking

Chapter 1. Introduction of Networking

- Basic Concepts
- Internet History

- Protocol Layers and Service Model
- Network Security
- Typical Network Applications

Basic Concepts

问题1：什么是因特网？

what is the Internet?

- [WiKi]
  - The Internet is the global system of interconnected mainframe, personal, and wireless computer networks that use the Internet protocol suite (TCP/IP) to link billions of devices worldwide.
  - It is a network of networks that consists of millions of private, public, academic, business, and government networks of local to global scope, linked by a broad array of electronic, wireless, and optical networking technologies.
- The terms Internet and World Wide Web are often used interchangeably in everyday speech; it is common to speak of "going on the Internet" when invoking a web browser to view web pages. However, the World Wide Web or the Web is only one of a large number of Internet services. The Web is a collection of interconnected documents (web pages) and other web resources, linked by hyperlinks and URLs.

问题2：您期望从本课程中学习到什么？

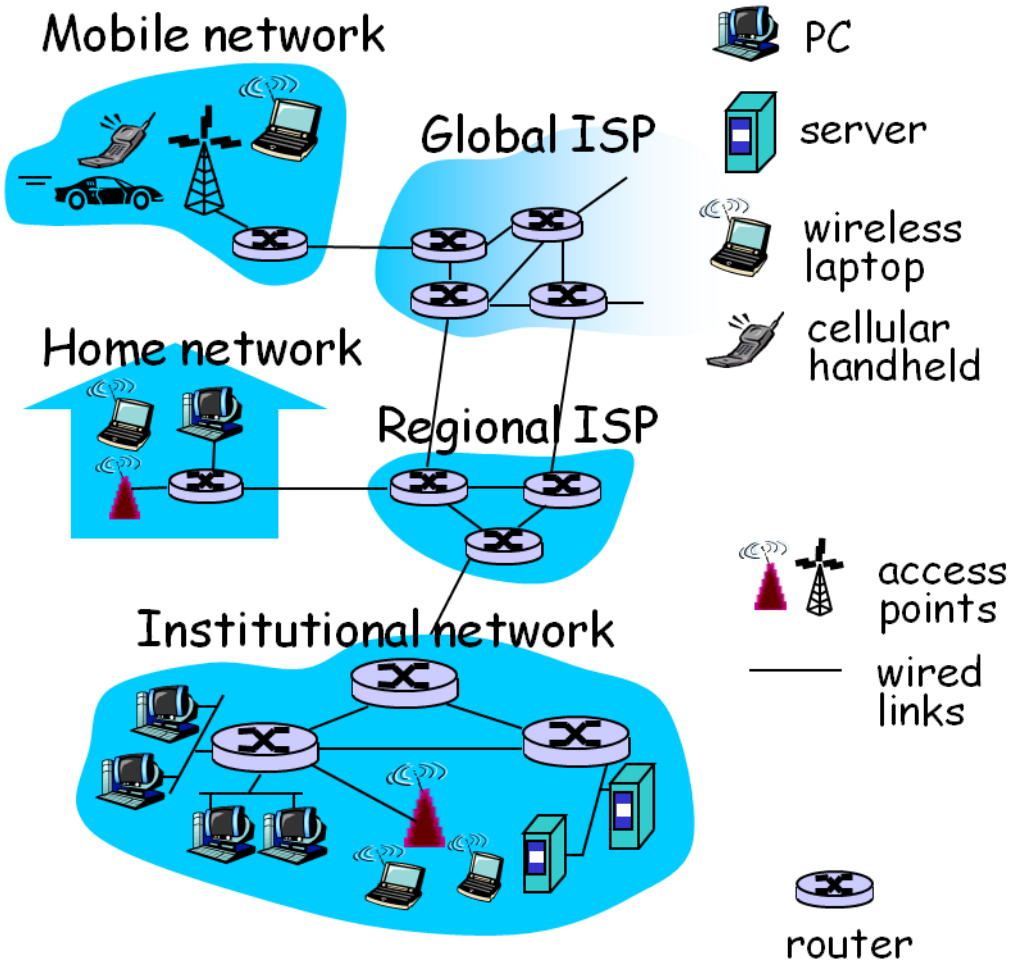
课程大纲

- Chapter 1. Introduction of Networking
- Chapter 2. Direct Link Networks
- Chapter 3. Packet Switching Networks
- Chapter 4. Internetworking
- Chapter 5. End-to-End Protocols
- Chapter 6. Congestion Control and QoS
- Chapter 7. Network Security
- Chapter 8. Internet Applications

问题3：因特网由什么组成？

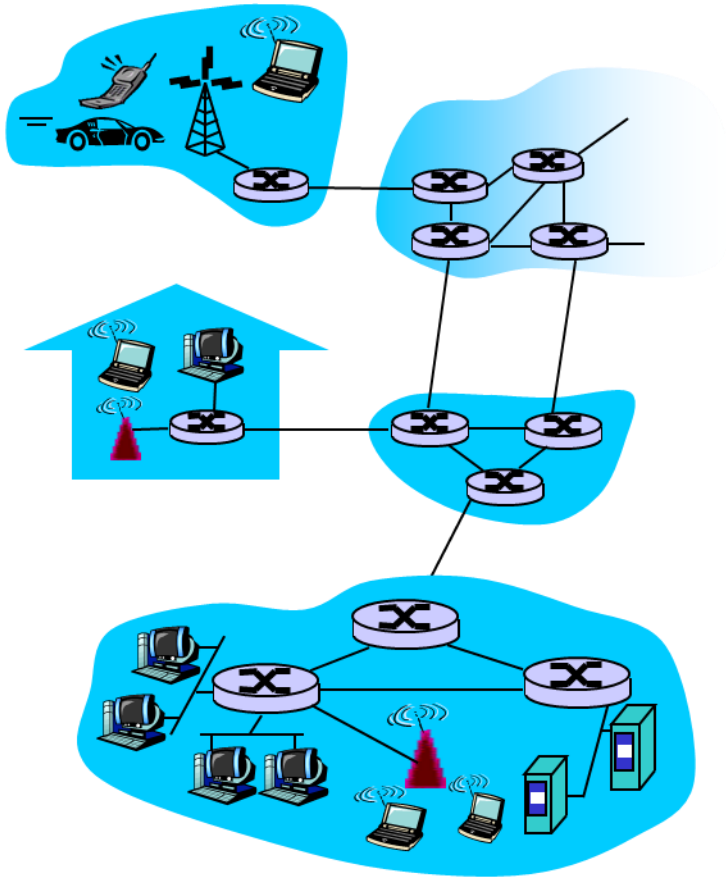
Internet – Component View

- Millions of connected computing devices
  - Hosts = End systems
  - Running network applications
- Communication links
  - Fiber, Copper, Radio, Satellite
  - Building physical networks
- Routers
  - Forward packets (chunks of data) between physical networks



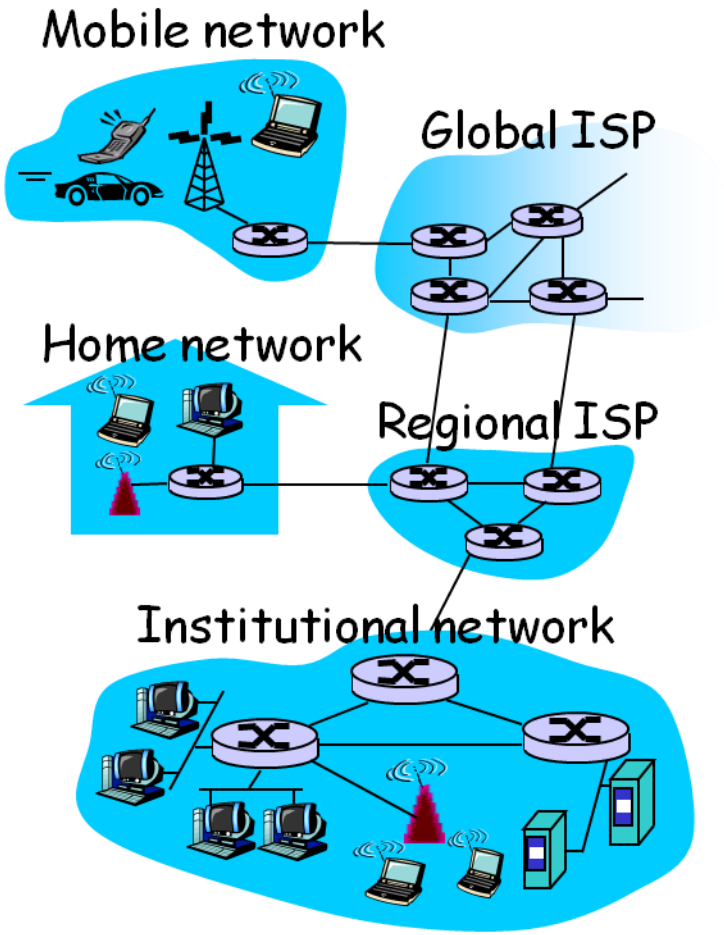
Internet – Service View

- Communication infrastructure
  - Enables distributed applications
  - Web, VoIP, email, online games, e-commerce, file sharing
- Communication services provided to Apps:
  - Reliable data delivery from source to destination
  - "best effort" (unreliable) data delivery
  - Guaranteed delay and throughput



Internet – Protocols

- Network Protocols
  - Control sending, receiving of messages
  - e.g. HTTP, Skype; TCP, IP; PPP, Ethernet
- Internet standards
  - IETF: Internet Engineering Task Force
  - RFC: Request for comments
- Internet: "network of networks"
  - Public Internet versus private Intranet
  - Loosely hierarchical



What's a protocol?

human protocols:

- "what's the time?"
- "I have a question"

… specific msgs sent

… specific actions taken when msgs received, or other events

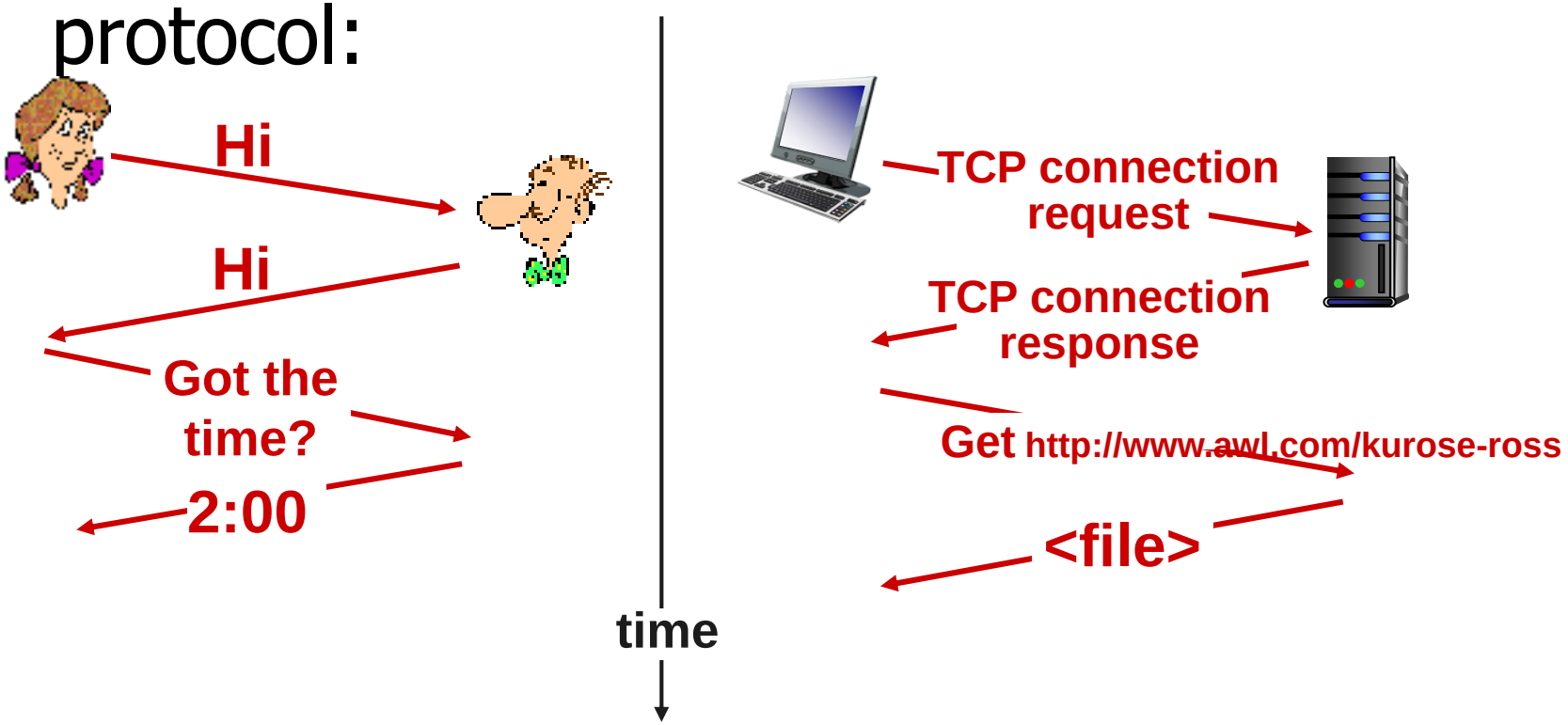
network protocols:

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

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

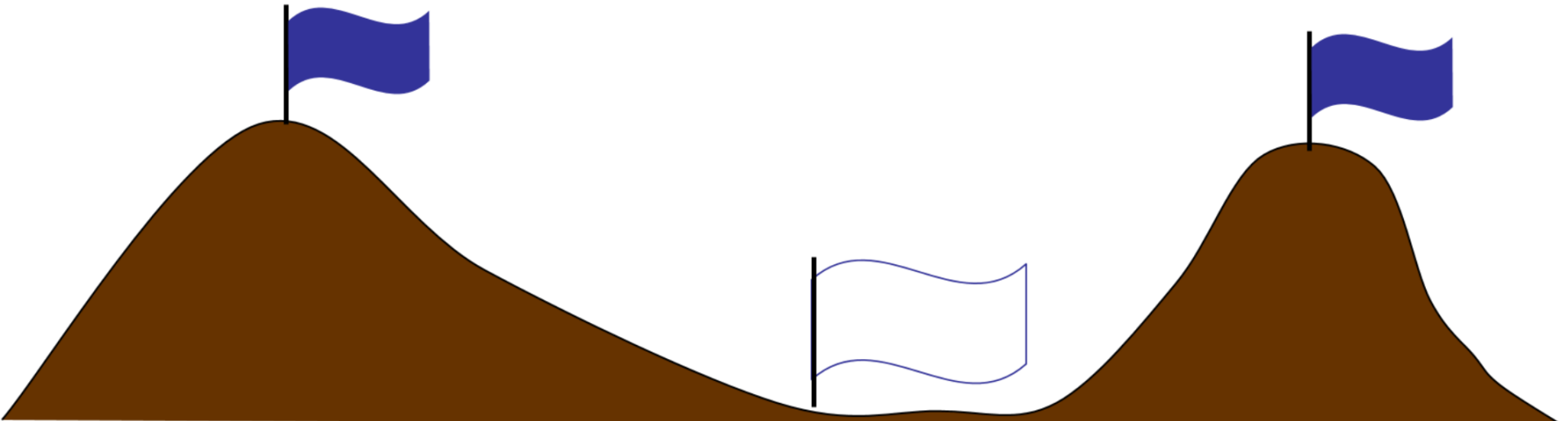
What's a protocol?

a human protocol and a computer network protocol:



例子：蓝军-白军作战

- 占据东、西两个山顶的蓝军1和蓝军2与驻扎在山谷的白军作战。其力量对比是：单独的蓝军1或蓝军2打不过白军，但蓝军1和蓝军2协同作战则可战胜白军。现蓝军1拟于次日正午向白军发起攻击。有什么方法能保证蓝军取得胜利？



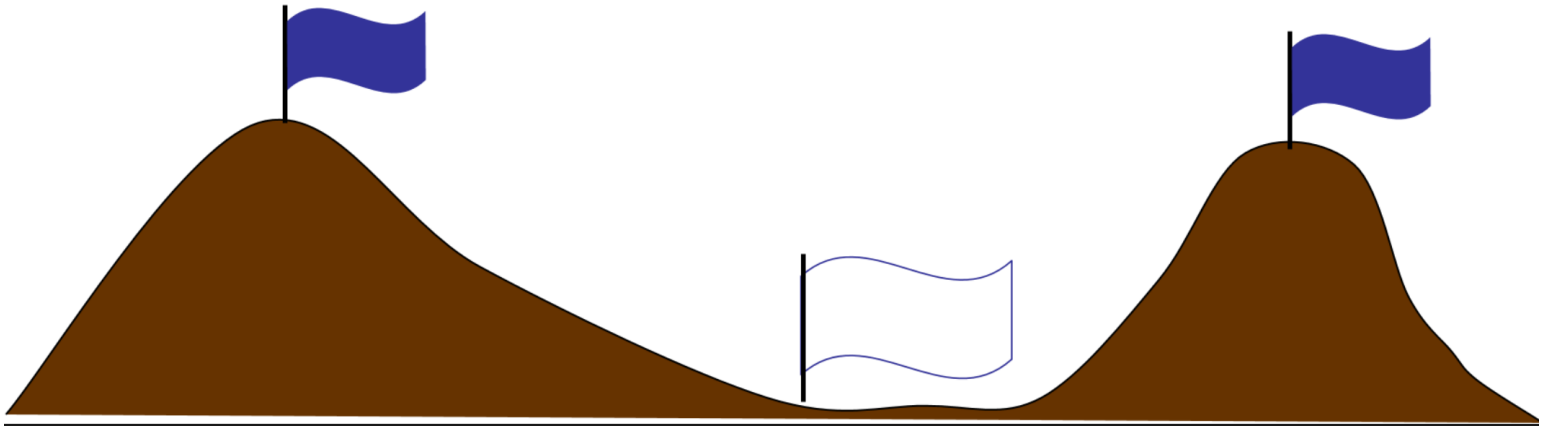
明日正午进攻，如何？

同意

收到“同意”

收到：收到“同意”

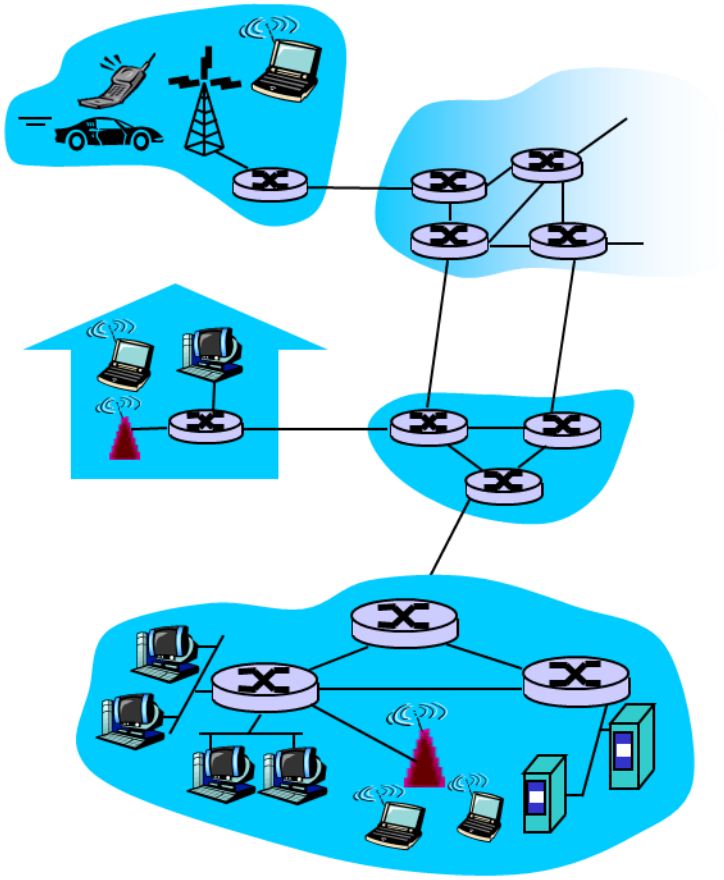
这样的协议无法实现！
没有方法能保证蓝军100%取得胜利



问题3：从工作方式来看，接入因特网的组件有哪些？各自功能是什么？

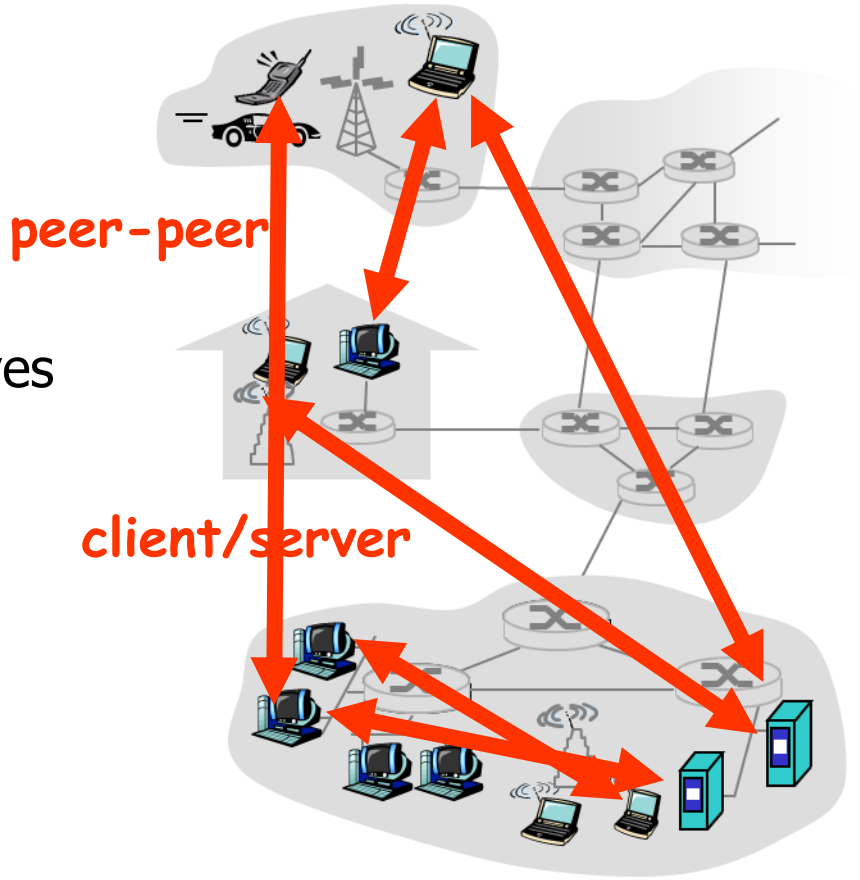
Access Internet

- Network edge
  - Applications and hosts
- Access networks
  - Physical media
  - Wired and wireless communication links
- Network core
  - Interconnected routers
  - Network of networks



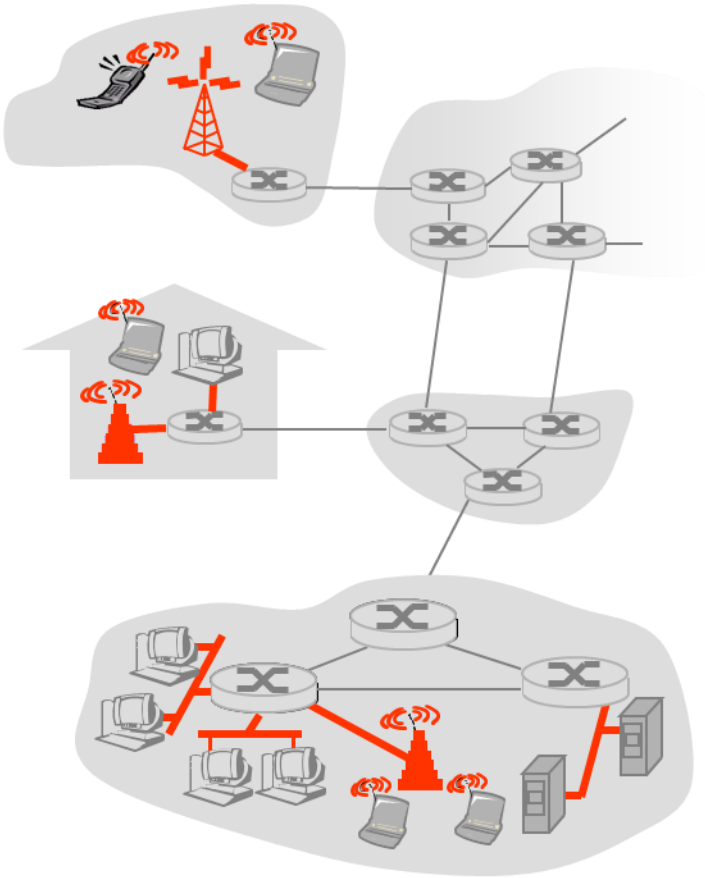
Network Edge

- End systems (hosts)
  - Run application programs
  - e.g. Web, Email
- Client/server model
  - Client host requests, receives service from always-on server
  - e.g. Web browser/server; Email client/server
- Peer-to-peer model
  - Minimal (or no) use of dedicated servers
  - e.g. Skype, BitTorrent



Access Networks

- How to connect end systems to edge router?
  - Residential (Home) access networks
  - Institutional access networks (school, company)
  - Mobile access networks
- Performance
  - Bandwidth (bits per second) of access network
  - Shared or dedicated

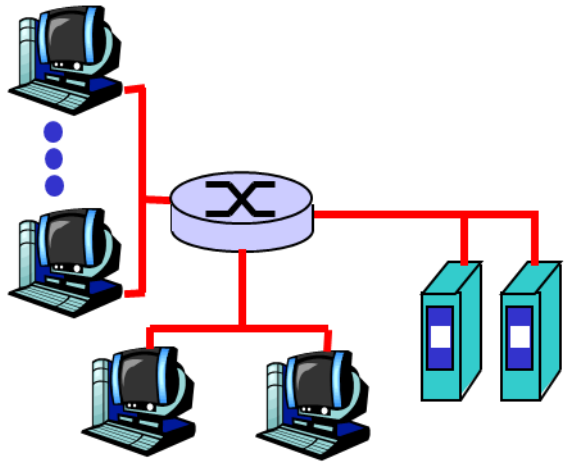


Residential Access

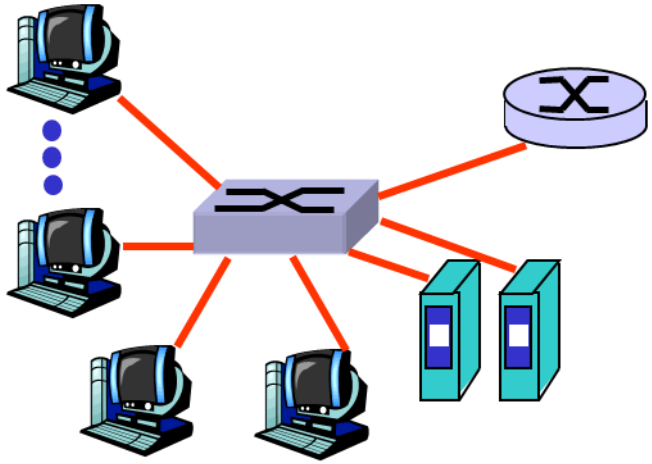
- Dialup via modem
  - Up to 56Kbps direct access to router
- DSL: digital subscriber line
  - Deployment: telephone company
  - Up to 1 Mbps upstream, and 8 Mbps downstream
  - Dedicated physical line to telephone central office
- HFC: hybrid fiber coax
  - Asymmetric: up to 30Mbps downstream, 2 Mbps upstream
  - Homes share access to ISP router
  - Deployment: cable TV companies

Company Access: Local Area Networks

- Company/University local area network (LAN) connects end systems to edge router

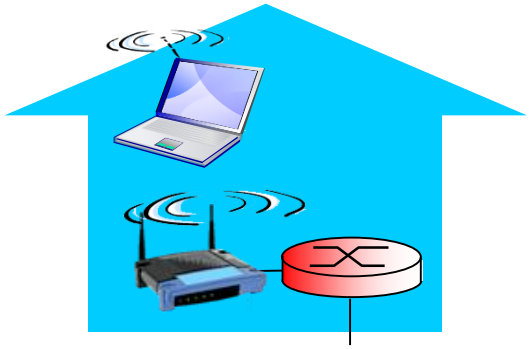


- Ethernet:
  - 10 Mbs, 100Mbps, 1Gbps, 10Gbps Ethernet
  - Modern configuration: end systems connect into backbone of Ethernet switches



Wireless Access Networks

- Shared wireless media connects end system to router
  - via base station, or "access point"
- Wireless LANs:
  - 802.11b/g (WiFi): 11 or 54 Mbps
- Wider-area wireless access
  - Provided by telecommunication operator，10's Km
  - between 1 and 10 Mbps
  - 3G, 4G: LTE, WiMax



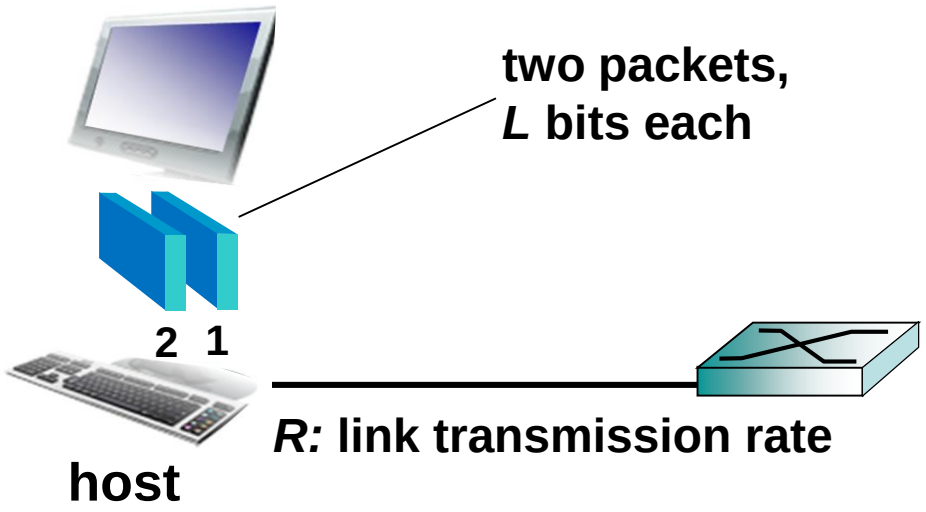
to Internet

to Internet

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*



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

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

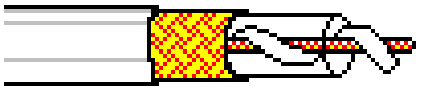
twisted pair (TP)

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

Physical media: coax, fiber

coaxial cable:

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



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**

Physical media: radio

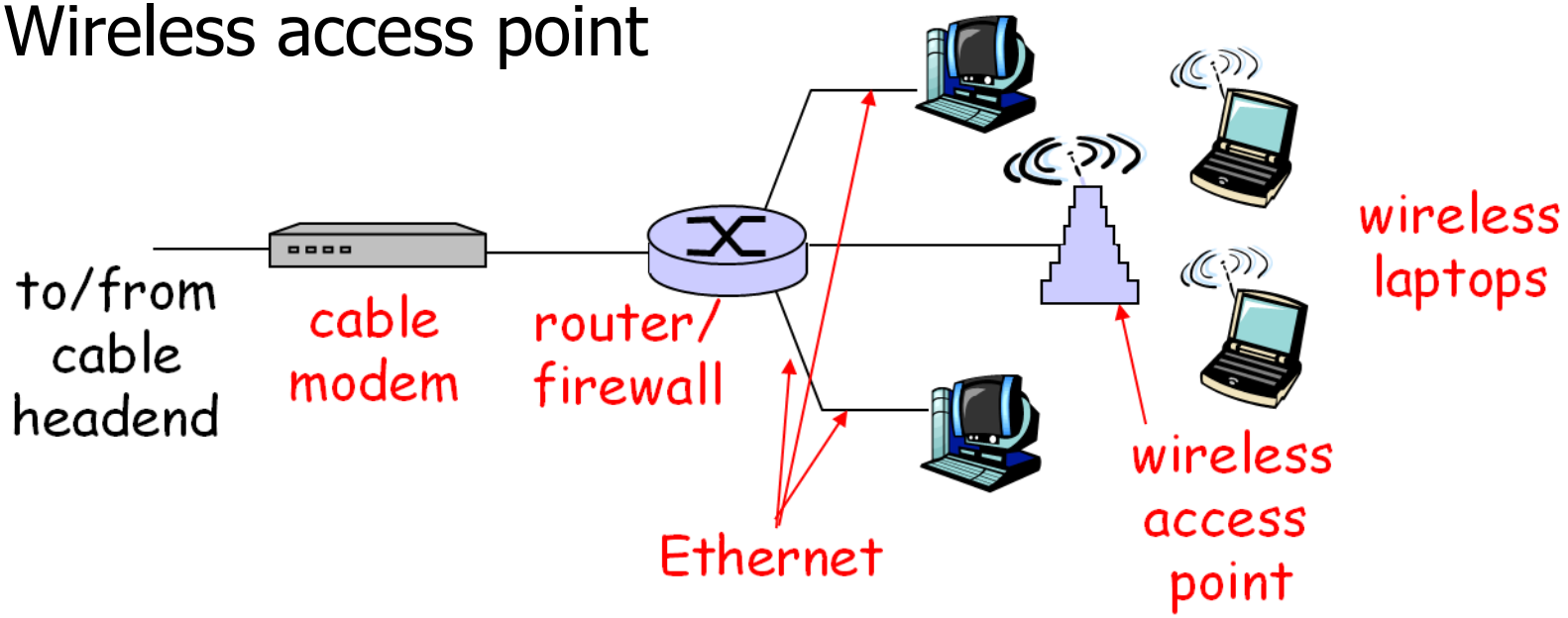
- signal carried in electromagnetic spectrum
- no physical "wire"
- bidirectional
- propagation environment effects:
  - reflection
  - obstruction by objects
  - interference

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: ~ 1 Mbps**
- **satellite**
  - **Kbps to 45Mbps channel (or multiple smaller channels)**
  - **270 msec end-end delay**
  - **geosynchronous versus low altitude**

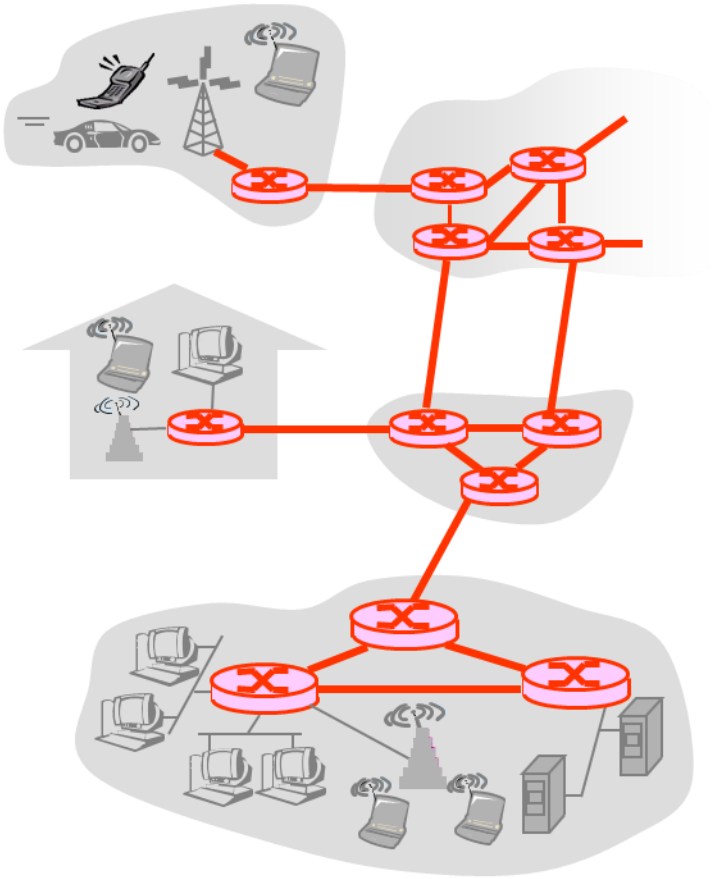
Example: A Modern Family

- A home network components:
  - DSL or cable modem
  - Router/Firewall/NAT
  - Ethernet switch
  - Wireless access point



The Network Core

- Mesh of interconnected routers
- Fundamental question
  - How is data transferred through the net?
- Circuit switching
  - Dedicated circuit per call, e.g. telephone net
- 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



- 请归类：
  - 属于网络边缘的是：_____
  - 属于接入网络的是：_____
  - 属于网络核心的是：_____

A 笔记本电脑； B 手机； C 路由器；
D 双绞线； E 智能家具； F 无线路由器；
G 服务器； H 同轴电缆； I 光纤； J 交换机

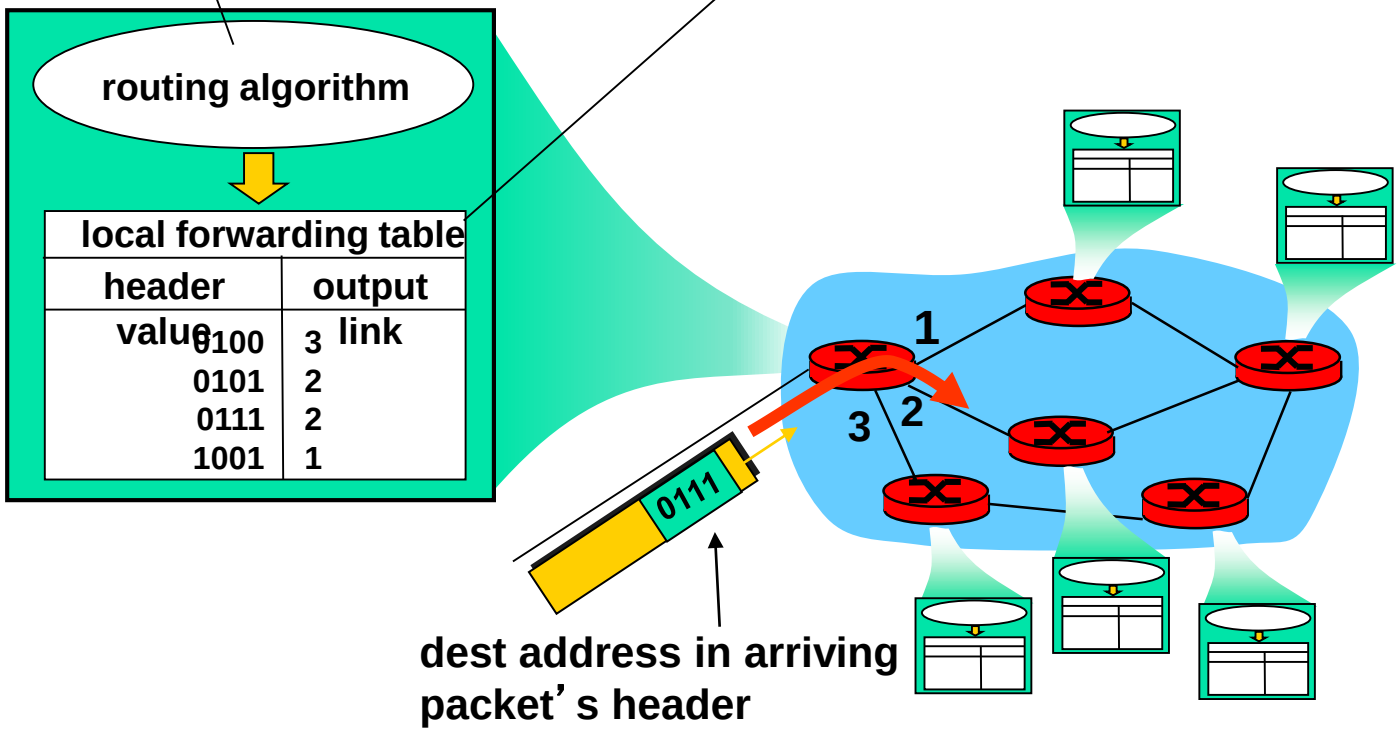
问题4：在网络核心中如何实现数据传输？

Two key network-layer functions

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

- ***routing algorithms***

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

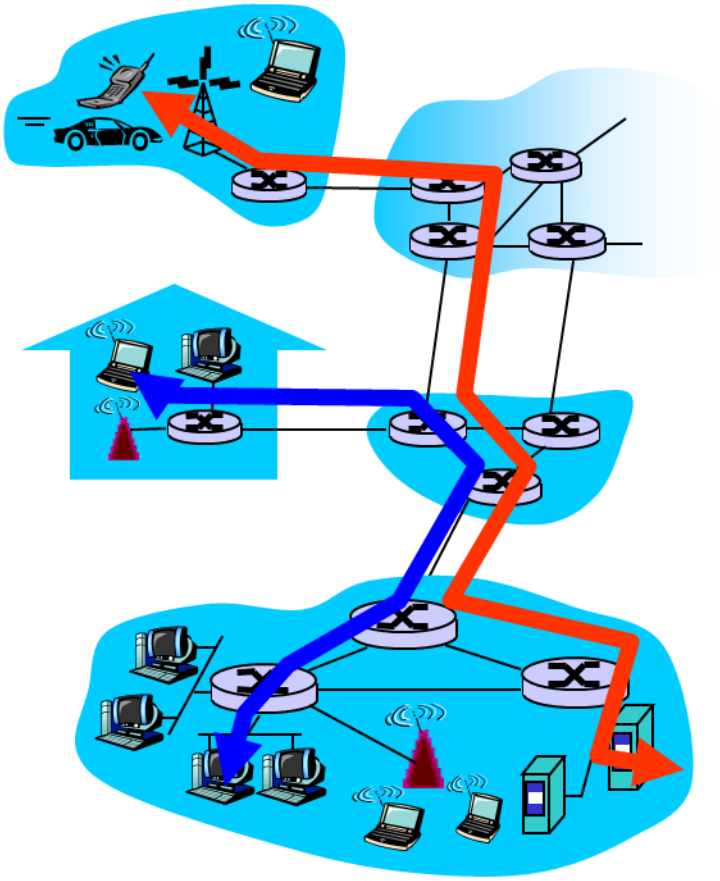


Circuit Switching

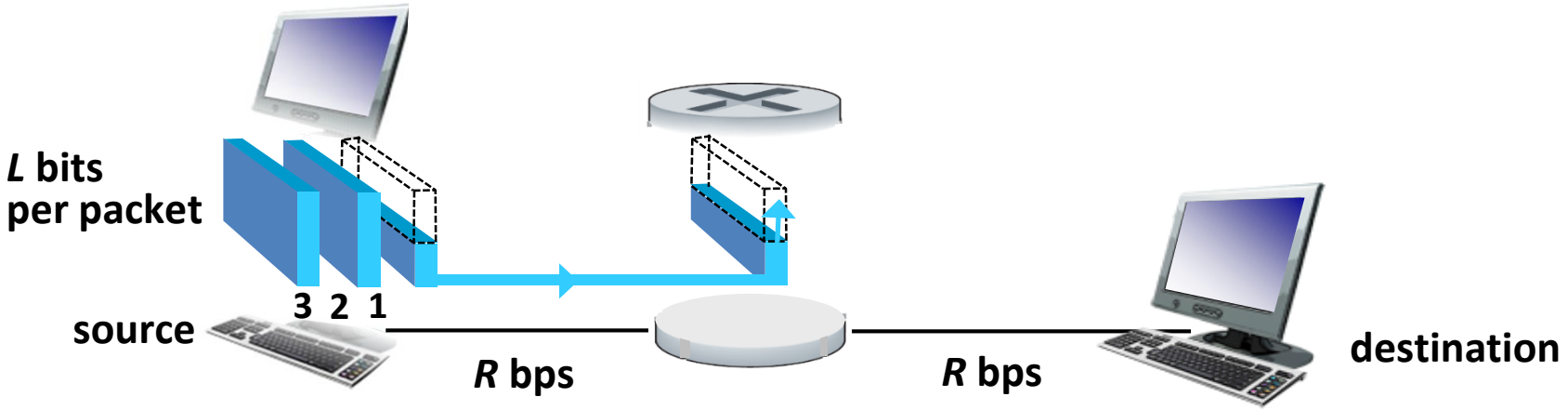
End-to-end resources reserved for "call"

- Link bandwidth, switch capacity
- Dedicated resources: no sharing

- Circuit-like (guaranteed) performance
- Call setup/teardown required



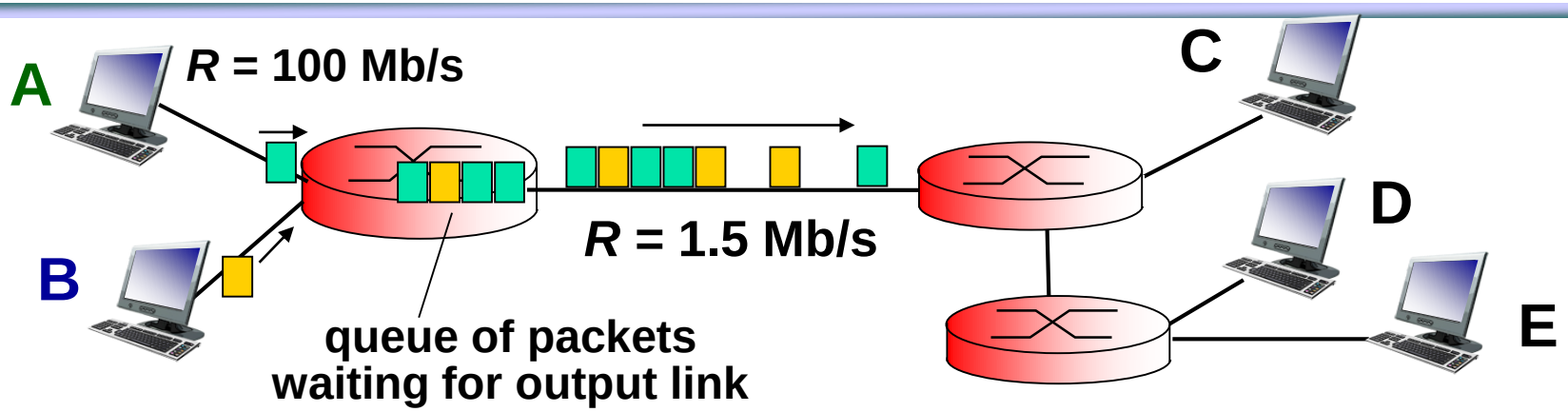
Packet Switching: store-and-forward



Each end-to-end data stream divided into packets

- Store and forward: packets move one hop at a time, stored (queued) at switches
- Each packet uses full link bandwidth
- Takes L/R seconds to transmit (push out) L-bit packet into link at R bps
  - one-hop numerical example:
    - L = 7.5 Mbits
    - R = 1.5 Mbps
    - one-hop transmission delay = 5 sec

Packet Switching: queueing delay, loss



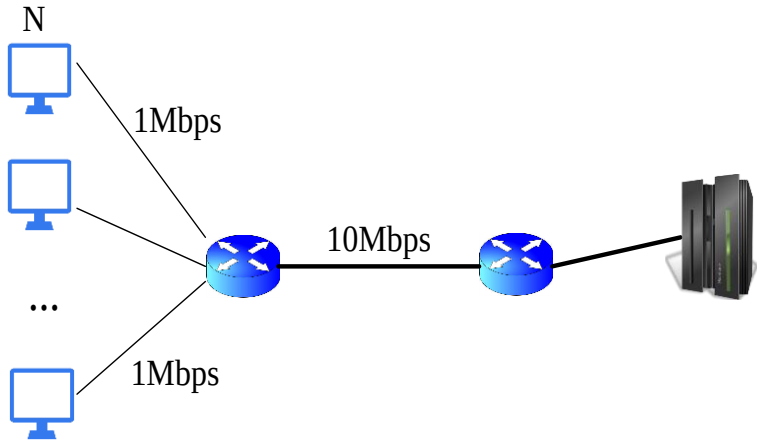
- Resource contention
  - aggregate (burst-up) resource demand can exceed amount available
- Congestion:
  - packets will queue, wait for link use
  - packets can be dropped (lost) if no memory to store them

Example: Statistical Multiplexing

- Statistical Multiplexing (统计多路复用): Link bandwidth shared on demand （按需共享）

Example:
- **N users share one link (10Mbps)**
- **Each user requires 1Mbps**
- **Each user: active 10%, idle 90%.**

How many users are supported?

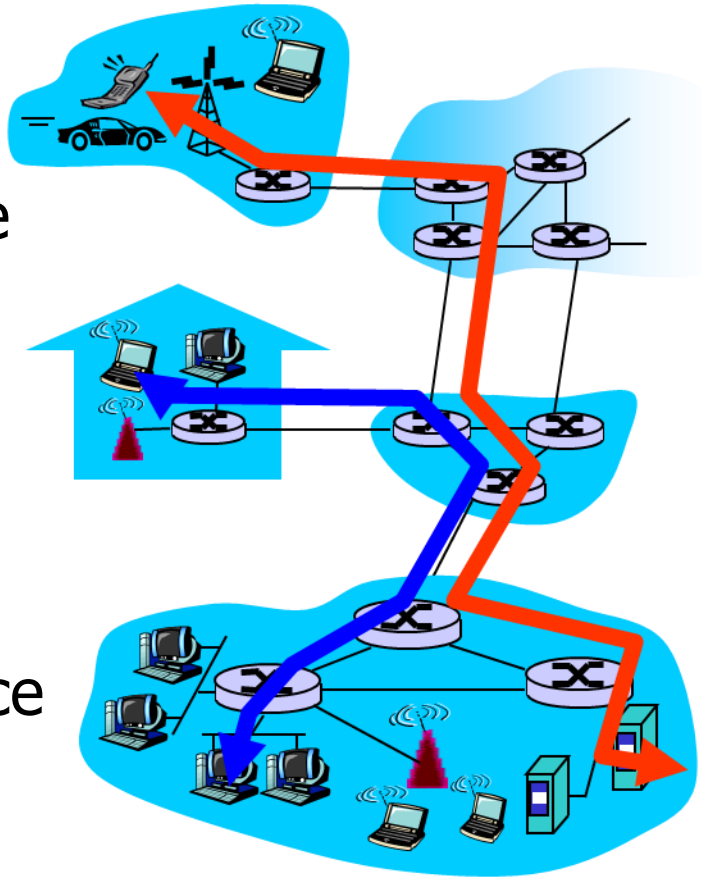


Circuit Switching:
N=10Mbps/1Mbps=10 users

Statistical Multiplexing:
Assume N=35,
Prob{active user>10}<=0.0004,
So for N=35, with probability 0.9996 a user have bandwidth larger than 1Mbps.

Virtual Circuit

- Circuit Switching + Packet Switching
  - Routes or main cross roads are fixed
  - Resources shared, congestion control needed
  - Resources can be preserved, leading to different performance
  - Connection setup/teardown needed



Comparison

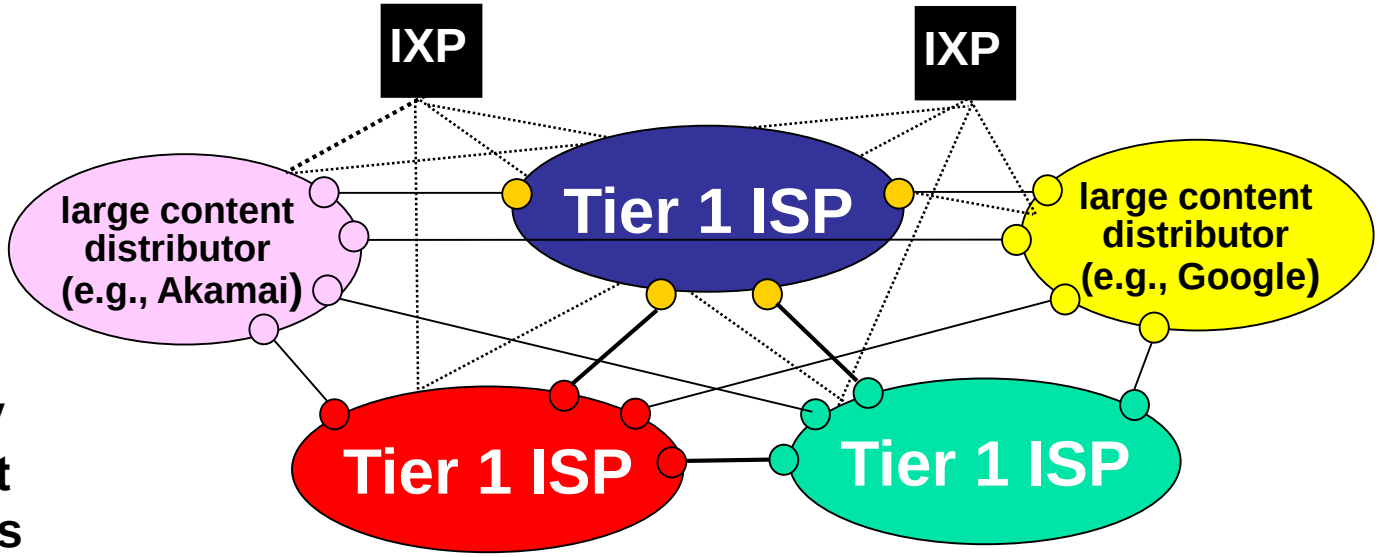
	电路交换	数据报分组交换	虚电路分组交换
传输通路	专用	非专用	非专用
连续性	连续传输	分组传输	分组传输
带宽	固定	动态使用	动态使用
路由	固定	动态	固定
时延	实时（只有呼叫建立时延）	分组传输时延	分组传输时延+呼叫建立时延
扩展性	差（接入用户有上限）	好（用户数量可动态扩充）	较好（用户数量动态，由拥塞控制来保证服务质量）

问题5：因特网是如何管理的？

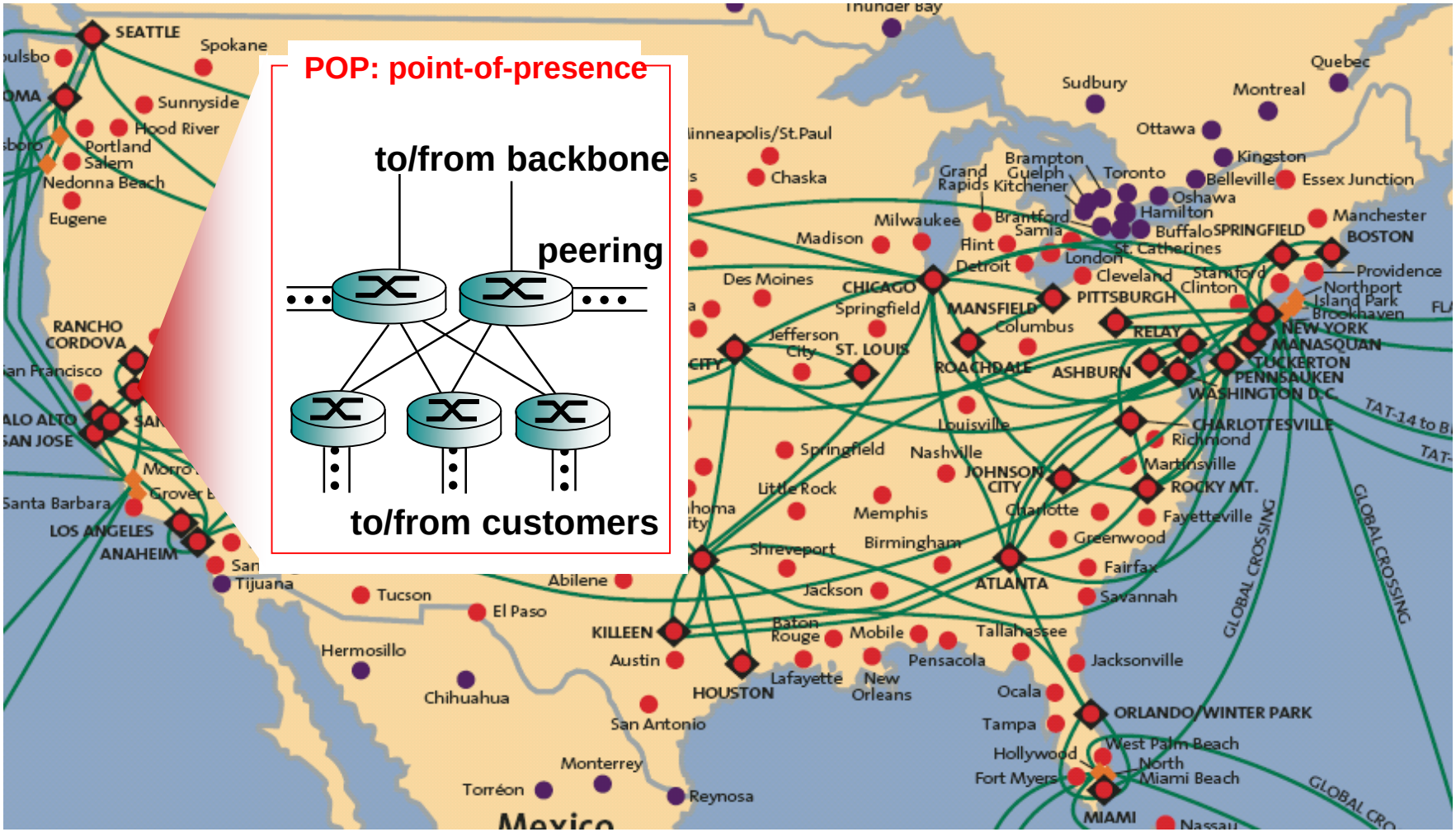
Internet structure: network of networks

- roughly hierarchical
- at center: small # of well-connected large networks
  - "tier-1" commercial ISPs (e.g., Verizon, Sprint, AT&T, Qwest, Level3), national & international coverage
  - large content distributors (Google, Akamai, Microsoft)
  - treat each other as equals (no charges)

tier-1 ISPs & content distributors, interconnect (peer) privately … or at Internet exchange points IXPs



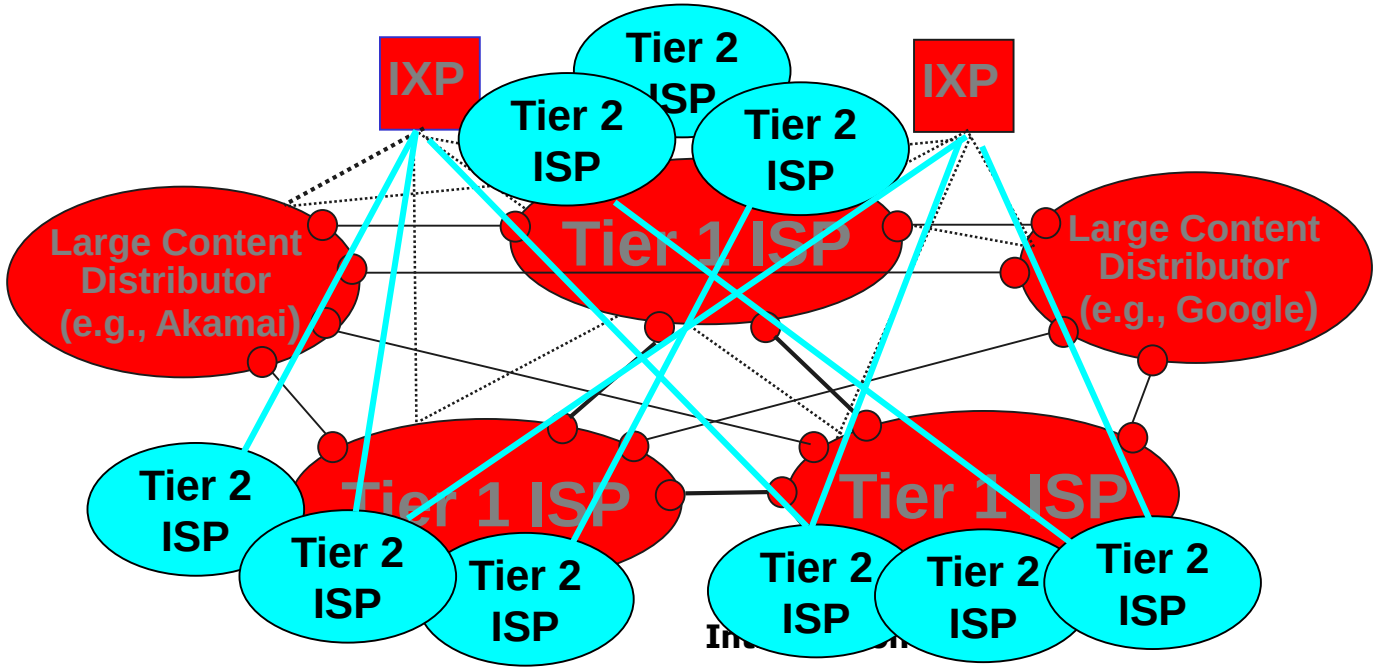
Tier-1 ISP: e.g., Sprint



Internet structure: network of networks

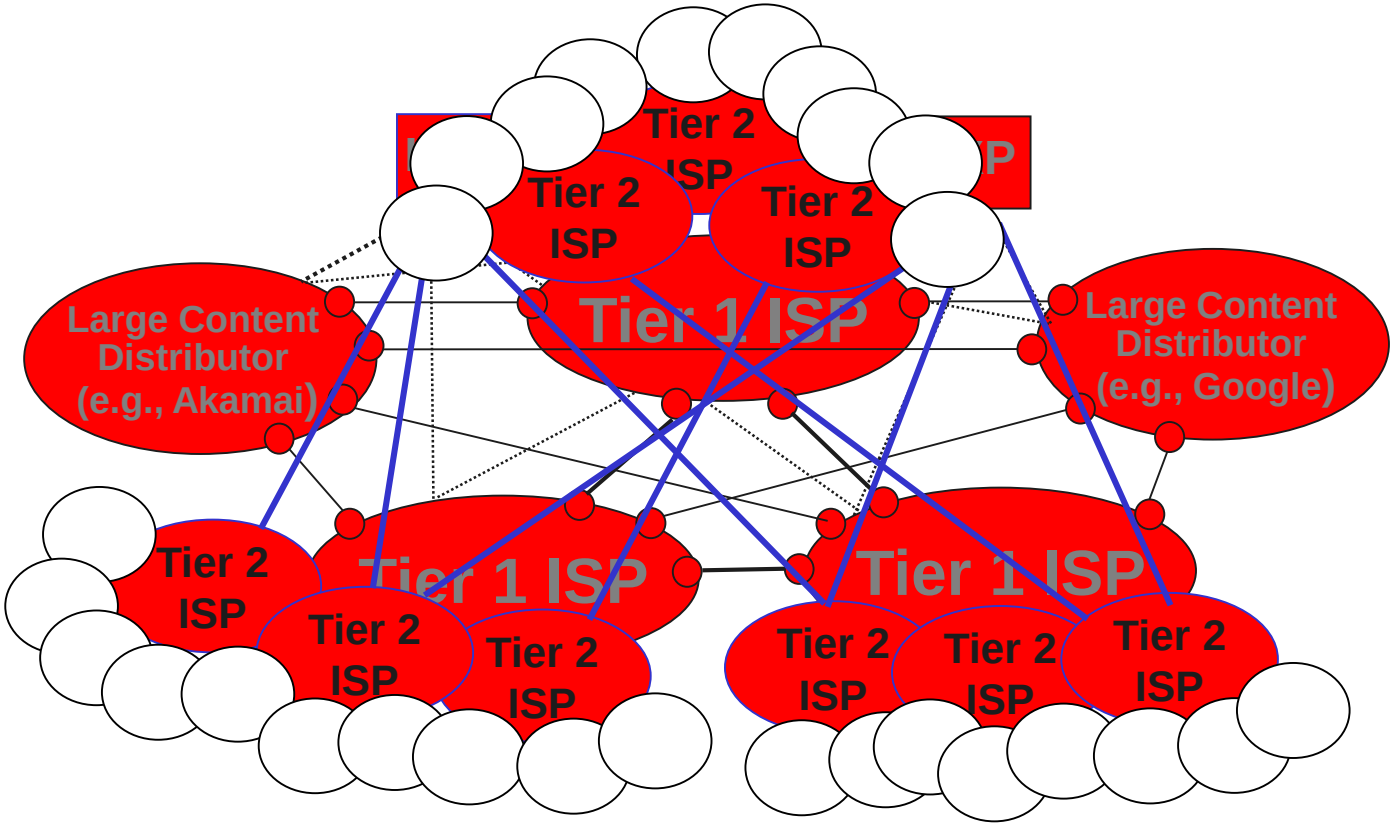
"tier-2" ISPs: smaller (often regional) ISPs

- **connect to one or more tier-1 *(provider)* ISPs**
  - **each tier-1 has many tier-2 *customer nets***
  - **tier 2 pays tier 1 provider**
- **tier-2 nets sometimes peer directly with each other (bypassing tier 1) , or at IXP**



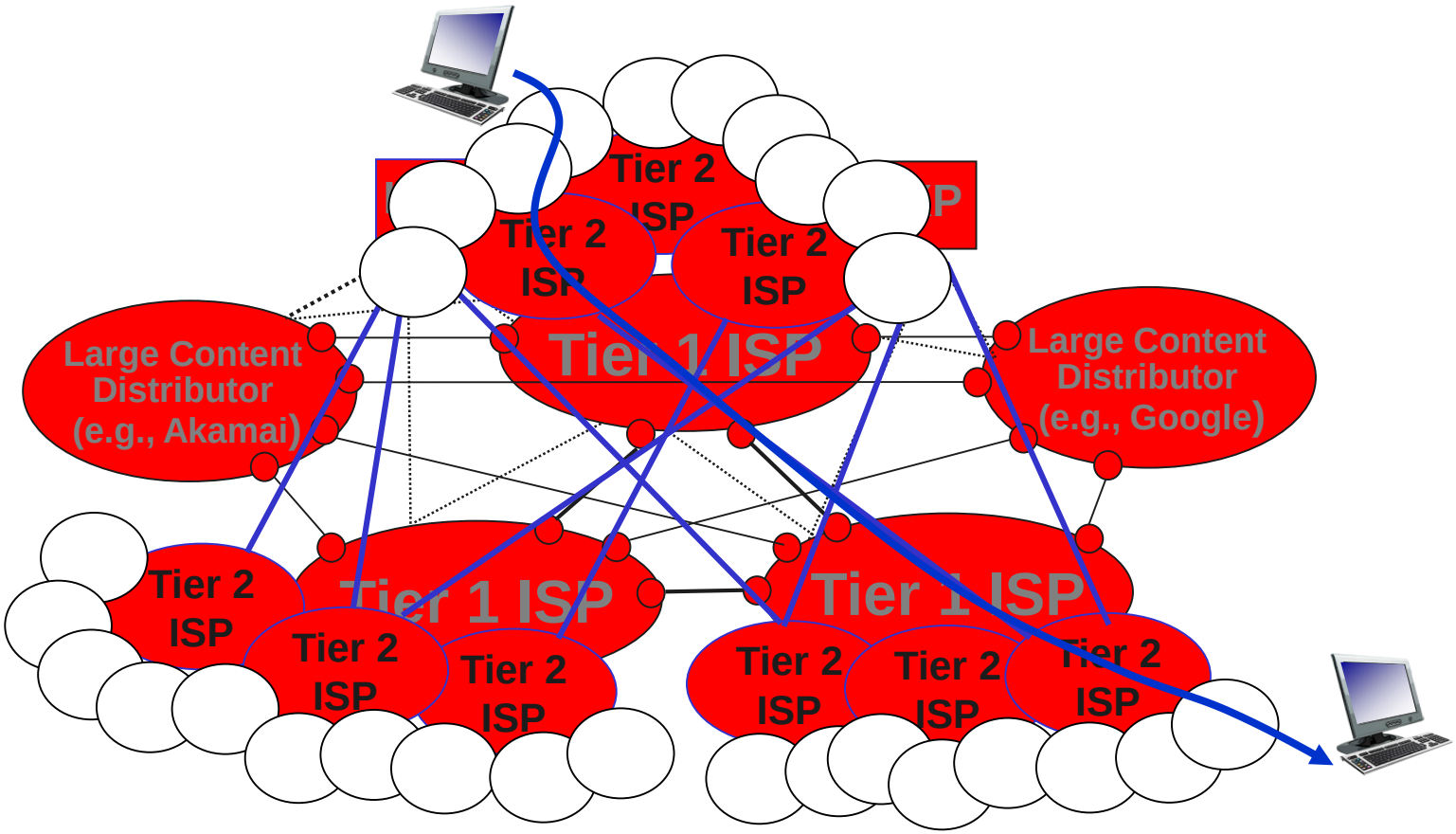
Internet structure: network of networks

- "tier-3" ISPs, local ISPs
- customer of tier 1 or tier 2 network
  - last hop ("access") network (closest to end systems)



Internet structure: network of networks

- a packet passes through *many* networks from source host to destination host



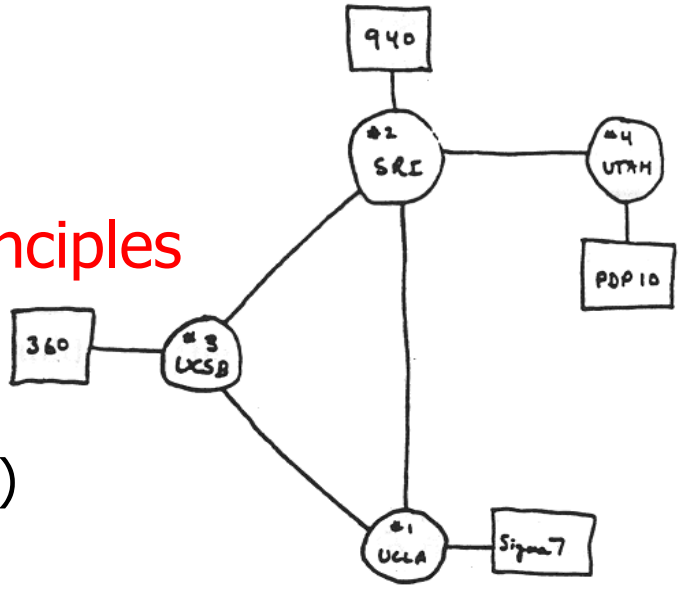
Internet History

Internet History (1)

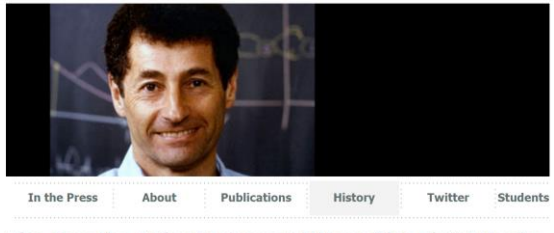
1961-1972: Early packet-switching principles

60年代：诞生-分组交换网络

- 1961: Kleinrock – queuing theory shows effectiveness of packet-switching (PhD@MIT)
- 1964: Baran – packet-switching in military nets
- 1967: ARPAnet conceived by Advanced Research Projects Agency
- 1969: first ARPAnet node operational (UCLA, Stanford, UCSB, UTAH), Kleinrock
- 1972:
  - ARPAnet demonstrated publicly
  - NCP (Network Control Protocol) first host-host protocol [RFC001]
  - First email program
  - ARPAnet has 15 nodes



THE ARPA NETWORK



The Day the Infant Internet Uttered its First Words

Below is a record of the first message ever sent over the ARPANET. It took place at 22:30 hours on October 29, 1969. This record is an excerpt from the "IMP Log" that was kept at UCLA. Professor Kleinrock was supervising his student/programmer Charley Kline (CSK) and they set up a message transmission to go from the UCLA SDS Sigma 7 Host computer to another programmer, Bill Duvall, at the SRI SDS 940 Host computer. The transmission itself was simply to "login" to SRI from UCLA. They succeeded in transmitting the "l" and the "o" and then the system crashed! Hence, the first message on the Internet was **"lo"**, as in "lo and behold! They were able to do the full login about an hour later.

Leonard Kleinrock

Born	June 13, 1934 (age 82) New York City
Residence	Los Angeles
Nationality	United States
Fields	Engineering Computer science
Institutions	UCLA

Internet History (2)

Vint Cerf, Robert E. Kahn and George W. Bush

1972-1980: Internetworking, new and proprietary nets

70年代：成型　　单一、封闭网络 -〉开放互联网络

- 1970: ALOHAnet satellite network in Hawaii, Norman Abramson （无线分组网络）
- 1973: Robert Metcalfe's PhD thesis (@Harvard) proposes Ethernet（以太网）, at Xerox PARC in 1976（局域网诞生）
- 1974: Cerf and Kahn – architecture for interconnecting networks（Internet构架）
- Late70's:
  - Proprietary architectures: DECnet, SNA, XNA
  - 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
- Design of TCP/IP suits

Internet History (3)

1980-1990: new protocols, a proliferation of networks

80年代：持续发展
- 新协议： **NCP-〉TCP/IP**
- **DNS**：实现域名解析
- 应用：**Email，Ftp**

- 1983: deployment of TCP/IP
- 1982: SMTP email 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 (4)

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

90年代：因特网爆炸
- 万维网出现：**www （http，HTML，Web Server，Browser）**
- 商用化，逐渐普及
- 新型应用：**Email，Web，IM （instant messaging），MP3**文件共享

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

Late 1990's ~ 2000's:

- More killer apps: instant messaging, peer2peer file sharing (e.g. Napster)
- Network security to forefront
- Est. 50 million host, 100 million+ users
- Backbone links running at Gbps

蒂姆·伯纳斯-李爵士
Sir Tim Berners-Lee

出生 1955年6月8日（61歲）[1]
英格兰伦敦
机构 万维网联盟
南安普敦大学
Plessey
麻省理工学院
知名于 发明万维网
麻省理工学院计算机科学及人工智能实验室创办主席

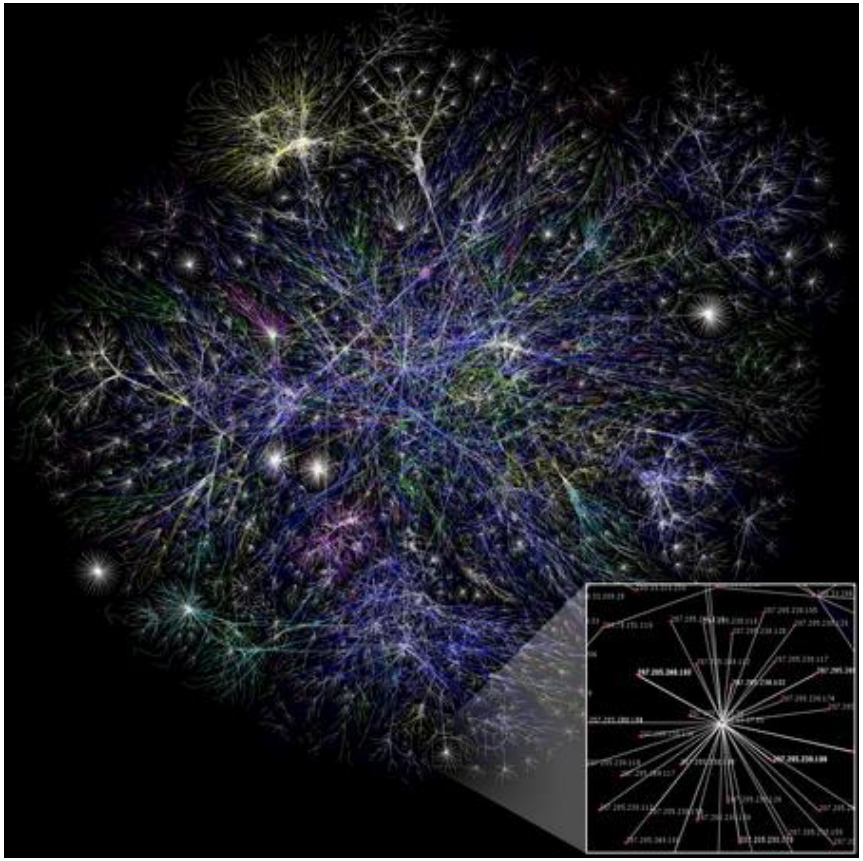
2016 Turing Award

Internet History (5)

2000年以后，新型应用涌现
- 多媒体
- **P2P**网络
- 社交网络（**Facebook**，**Twitter**，人人，微博，微信，**…**）

2007

- ~500 million hosts
- Voice, Video over IP
- P2P applications: BitTorrent (file sharing), Skype (VoIP), PPLive (video)
- More applications: YouTube, online gaming
- Wireless and mobility
- 2015- , blockchain, AINet, 5G, …



Protocol Layers and Service Model

Protocol "layers"

Networks are complex, with many "pieces" :

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

Question:

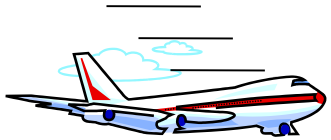
is there any hope of *organizing* structure of network?

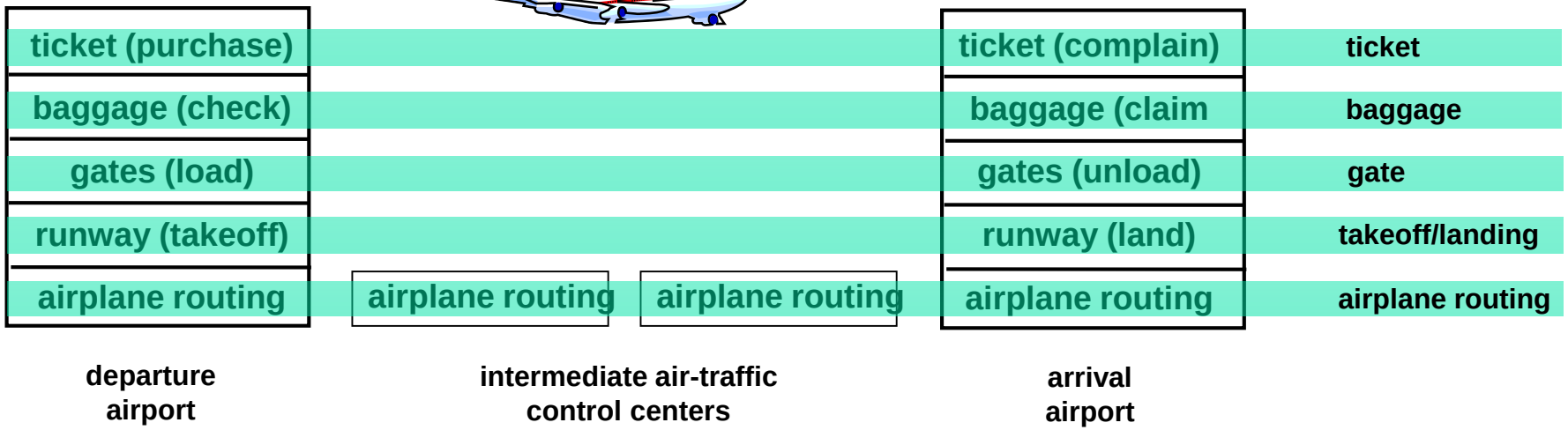
…. or at least our discussion of networks?

Organization of air travel

- a series of steps

Layering of airline functionality





layers: each layer implements a service

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

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 of implementation of layer's service transparent to rest of system
  - e.g., change in gate procedure doesn't affect rest of system

Standard Protocol Architectures

- Two standards:
  - OSI Reference model
    - Never lived up to early promises
  - TCP/IP protocol suite
    - Most widely used
- Others
  - IBM Systems Network Architecture (SNA)
  - DECNet, Netware

ISO-OSI

- Open Systems Interconnection (OSI)
- Developed by the International Organization for Standardization (ISO)
- Seven layers structure

- A theoretical system delivered too late
- TCP/IP is the de facto standard now

OSI – The Model

- A layer model, and flow structure
- Each layer performs a subset of the required communication functions
- Each layer relies on the next lower layer to perform more primitive functions
- Each layer provides services to the next higher layer
- Changes in one layer should not require changes in other layers

OSI Layers

Example：Alice invite Bob to lunch

"请客吃饭"

Application

Provides access to the OSI environment for users and al provides distributed information services.

语言表述

Presentation

Provides independence to the application processes from differences in data representation (syntax).

听说同步

Session

Provides the control structure for communication between applications; establishes, manages, and terminates connections (sessions) between cooperating applications.

摘机拨号

Transport

Provides reliable, transparent transfer of data between end points; provides end-to-end error recovery and flow control

PBX中转

Network

Provides upper layers with independence from the data transmission and switching technologies used to connect systems; responsible for establishing, maintaining, and terminating connections.

信号传输

Data Link

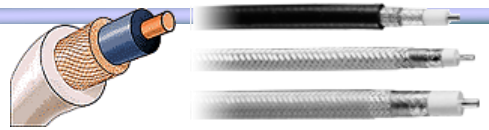
Provides for the reliable transfer of information across the physical link; sends blocks (frames) with the necessary synchronization, error control, and flow control.

插口、双绞线

Physical

Concerned with transmission of unstructured bit stream over physical medium; deals with the mechanical, electrical, functional, and procedural characteristics to access the physical medium.

Physical Layer



- Transfers bits across link
- Specification of the physical aspects of a comm link
  - Mechanical: cable, plugs, pins...
  - Electrical/optical: modulation, signal strength, voltage levels, bit times, …
  - Functional/procedural: activate, maintain, deactivate physical links…
- Physical interface between devices
  - Ethernet, DSL, cable modem, telephone modems, …
  - Twisted-pair cable, coaxial cable, optical fiber, radio, infrared, …

Data Link Layer

- Groups bits into frames
- Activation, maintenance, & deactivation of data link connections

- Transfers frames across direct connections
- Medium access control for local area networks

- Detection of bit errors; Retransmission of frames
- End-to-end flow control

- Higher layers may assume error free transmission

Network Layer

- Transfers packets across multiple links / multiple networks
- Addressing must scale to large networks

- Nodes jointly execute routing algorithm to determine paths across the network
- Forwarding transfers packet across a node
- Congestion control to deal with traffic surges

- Connection setup, maintenance, and teardown when connection-based

Transport Layer

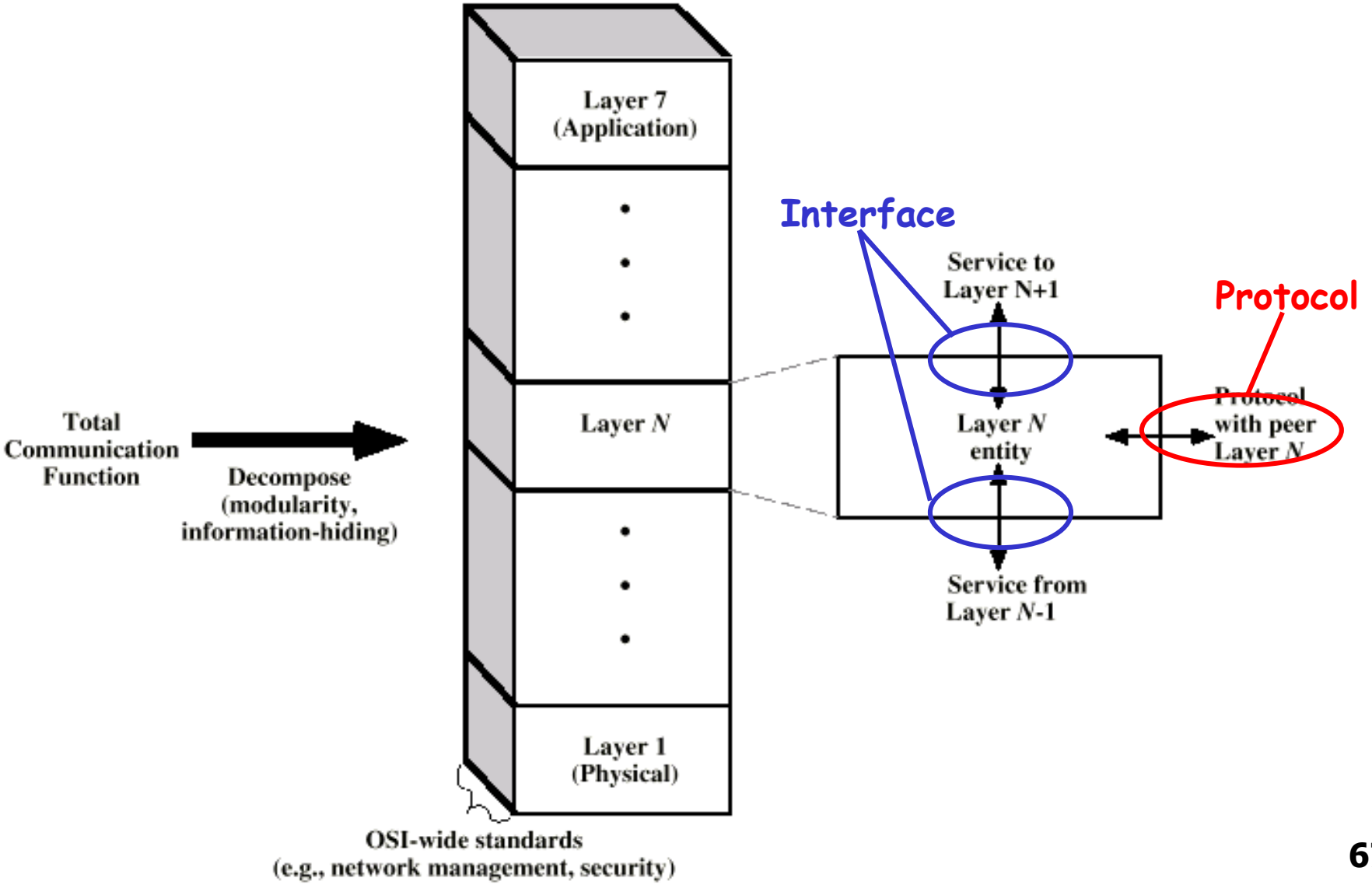
- Exchange of data between end systems
  - Transfers data end-to-end from process in one host to process in another host
- Reliable stream transfer or quick-and-simple single-block transfer
  - Error free
  - In sequence
  - No losses
  - No duplicates
- Connection setup, maintenance, and release

Upper Layers

- Session
  - Control of dialogues between applications
  - Dialogue discipline
  - Grouping data
  - Checkpoint recovery
- Presentation
  - Machine-independent representation of data
  - Data formats and coding
  - Data compression & encryption
- Application
  - Means for applications to access OSI environment

Incorporated into Application Layer Now

OSI as Framework for Standardization



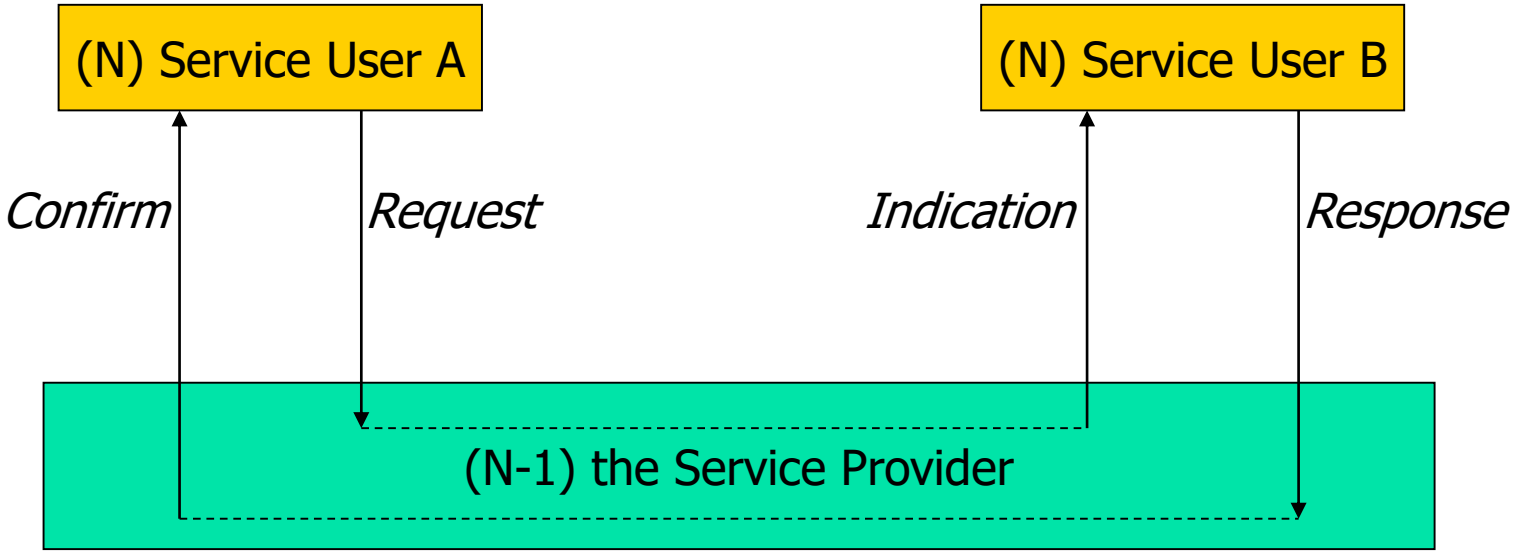
Service Primitives and Parameters

REQUEST	•Issued by a user (upper layer) to invoke some service •Parameters fully specify the requested service
INDICATION	•Issued by a service provider (lower layer) either to: •Indicate that a procedure has been invoked by peer service user, or •Notify the service user of a provider-initiated action
RESPONSE	•Issued by peer user to acknowledge or complete previously invoked procedure
CONFIRM	•Issued by service provider to acknowledge or complete previously invoked procedure

服务原语是**OSI**模型中的一个抽象概念，其具体实现可以通过中断、函数调用、系统调用或者操作系统提供的进程控制机制来完成。

Service Primitives

connect.request → connect.indication →
connect.response → connect.confirm

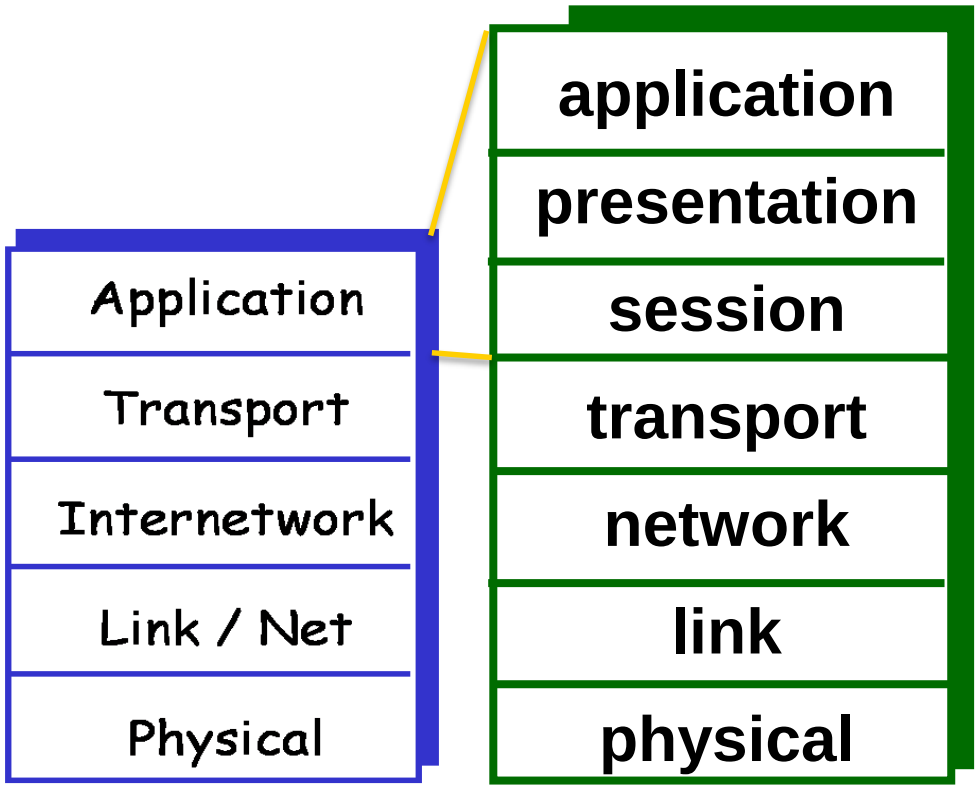


TCP/IP Protocol Architecture

Used by the global Internet

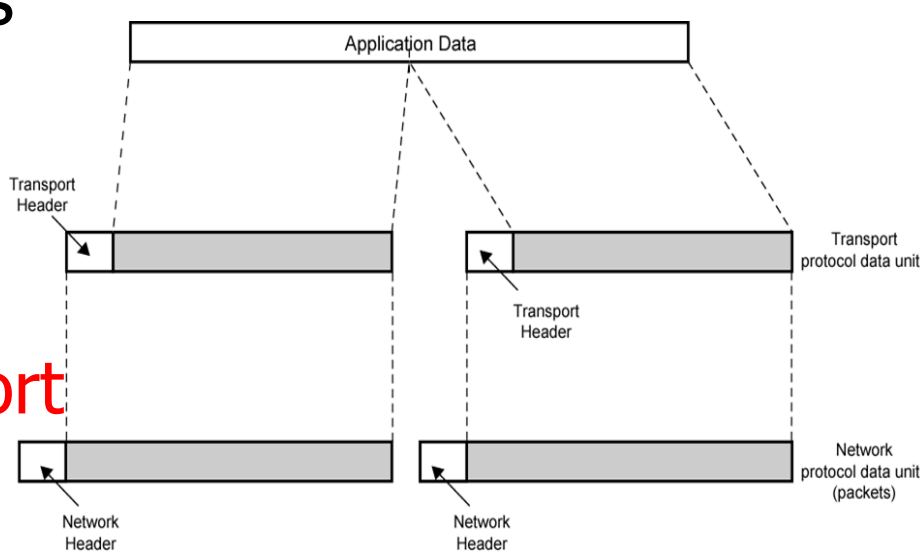
- Application: supporting network applications
  - FTP, SMTP, HTTP
- Transport: process-process data transfer
  - TCP, UDP
- Internetwork: routing of datagrams across net of nets
  - IP, routing protocols
- Link: data transfer between neighboring routers / hosts
  - PPP, Ethernet
- Physical: bits "on the wire"

TCP/IP protocol stack vs. OSI

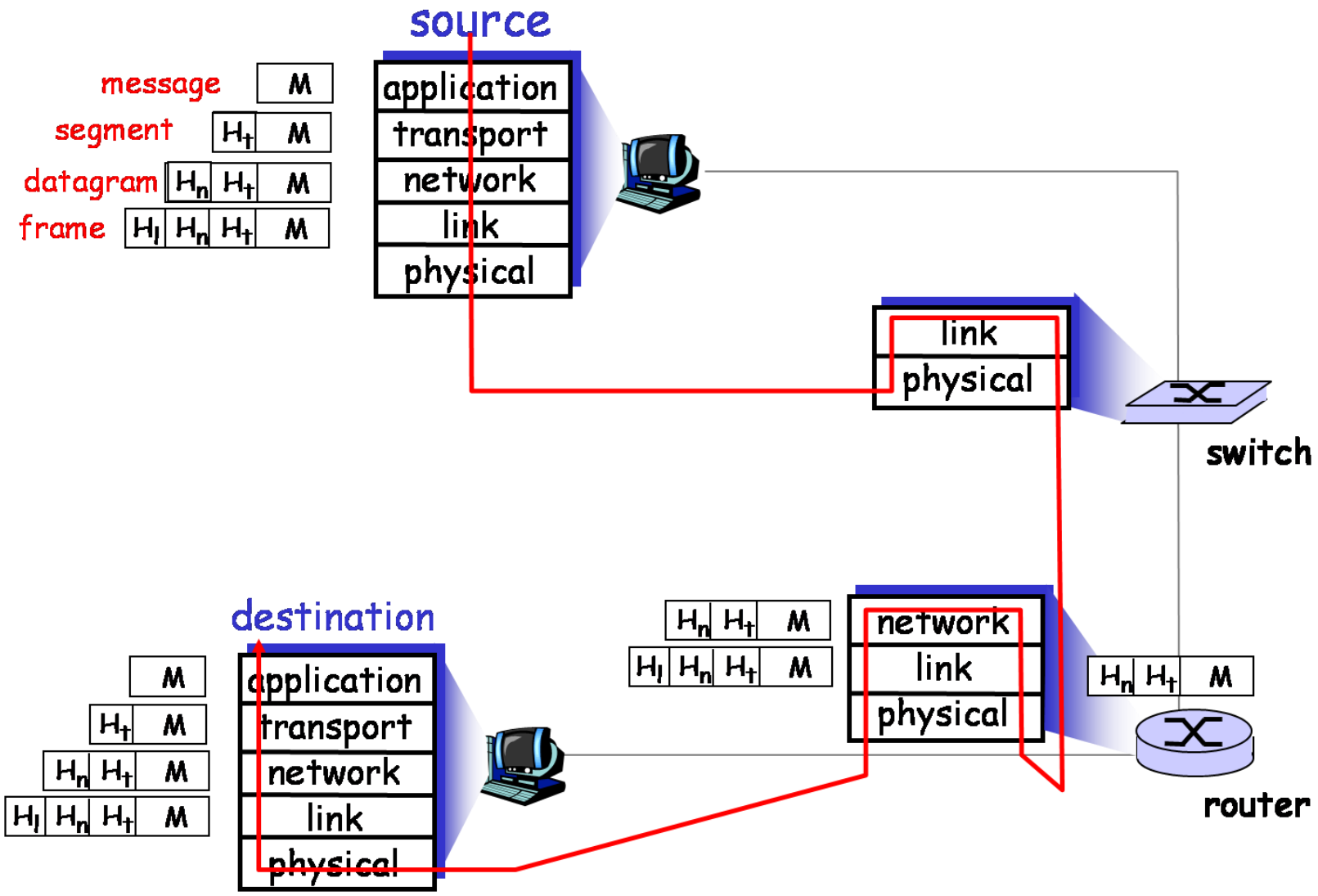


Protocol Data Units

- At each layer, Control info is added to user data to ease communication, e.g.
- Transport layer segments application data
- Each segment has a transport header added
  - Destination port
  - Sequence number
  - Error detection code
- This gives a transport protocol data unit (PDU)



Encapsulation



Network Security

Networks under Attack: Security

- Attacks on Internet infrastructure
  - Infecting/attacking hosts: malware, spyware, worms, unauthorized access
  - Packet sniffing, replay, masquerade
  - Denial of service: deny access to resources (servers, link bandwidth)

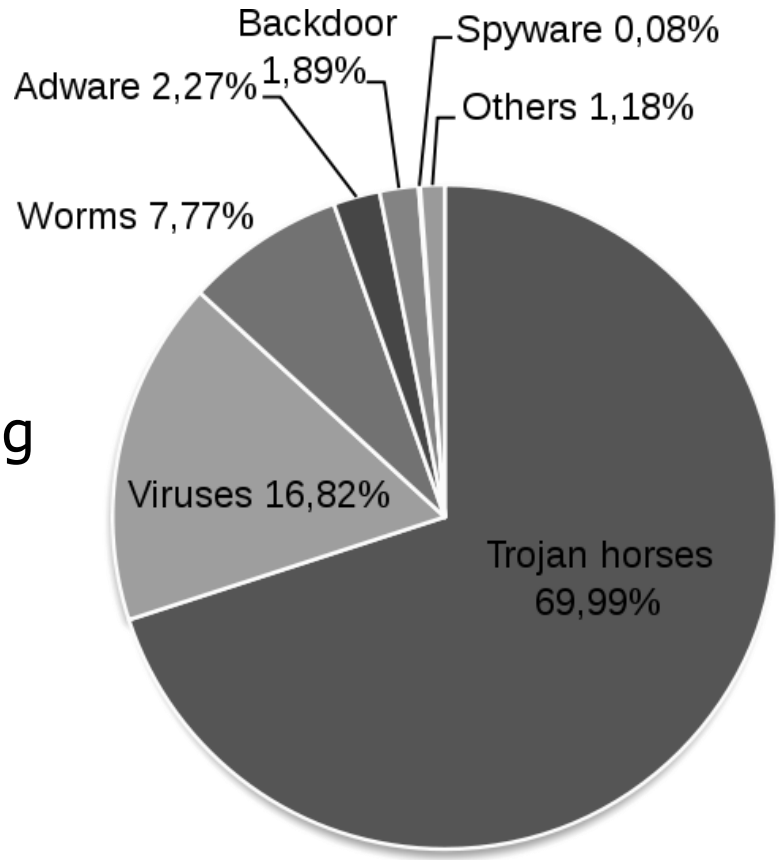
- Internet not originally designed with security in mind
  - Original vision: "a group of mutually trusting users attached to a transparent network"
  - Internet protocol designers playing "catch-up"
  - Security considerations in all layers!

Different Types of Malware

- Virus
  - Infection by receiving and running (unwarily) executables
  - Self-replicating: propagate itself to other executables
- Worm
  - Actively transmitting itself over a network to infect other hosts
- Trojan horses
  - Disguised as something innocuous or desirable, tempting the user to run it

Different Types of Malware

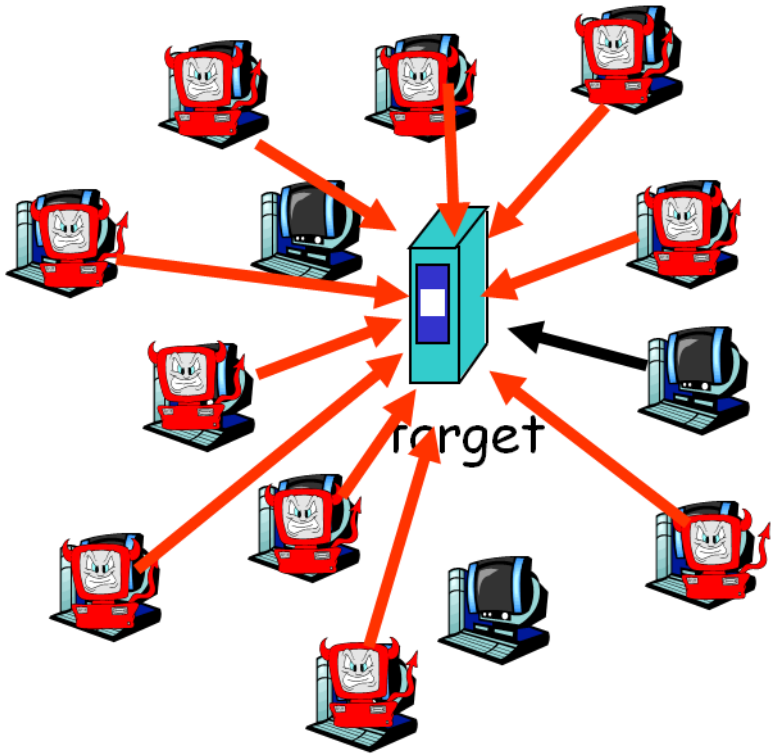
- Backdoor
  - Providing a method of bypassing normal authentication procedures
- Adware
  - Playing, displaying, or downloading advertisements to the user host
- Spyware
  - Infecting in the same way as Trojan horses
  - Recording keystrokes, web sites visited, uploading info to collection site



Denial of Service (DOS)

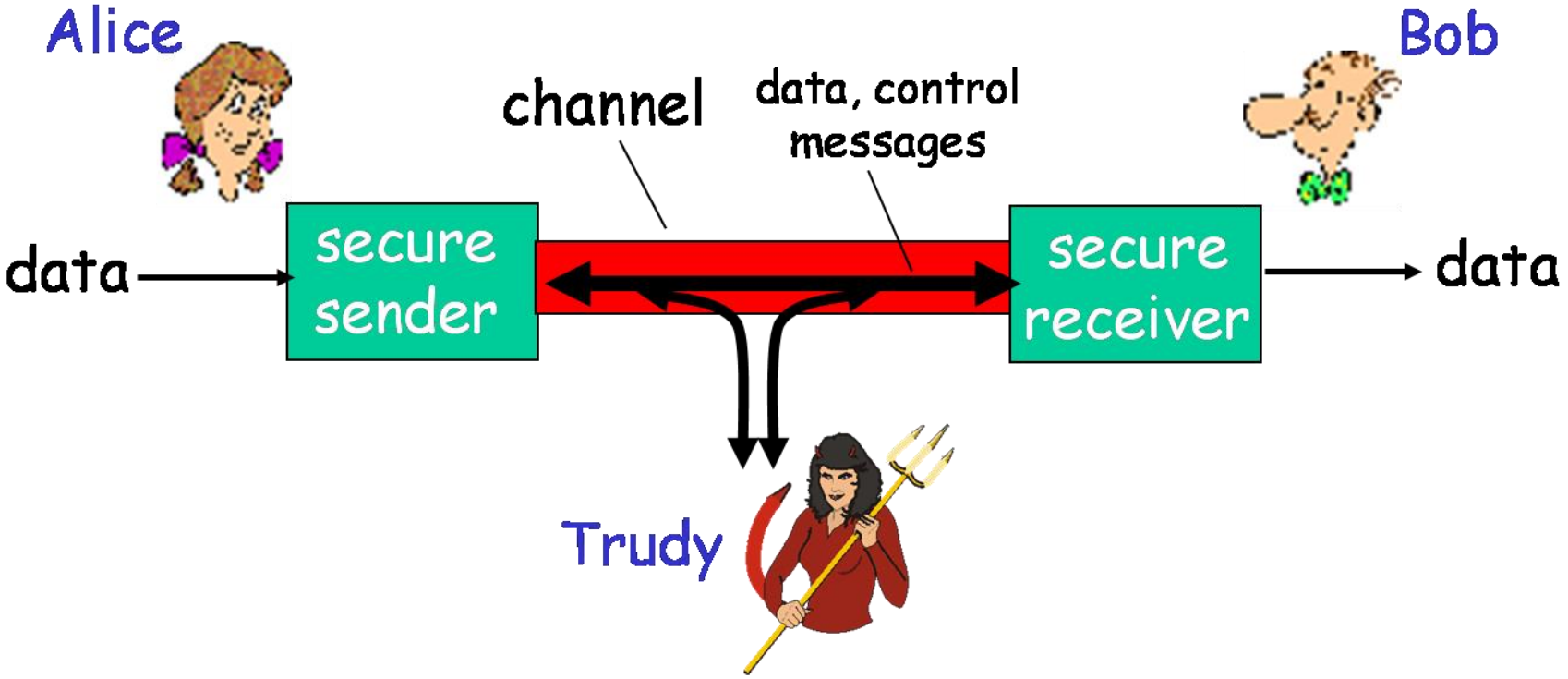
- Attackers make resources (server, bandwidth) unavailable by overwhelming resource with bogus traffic
- e.g. multiple coordinated sources swamp server with TCP SYN message

1. Select target
2. Break into hosts around the network using malware
3. Send packets toward target from compromised hosts



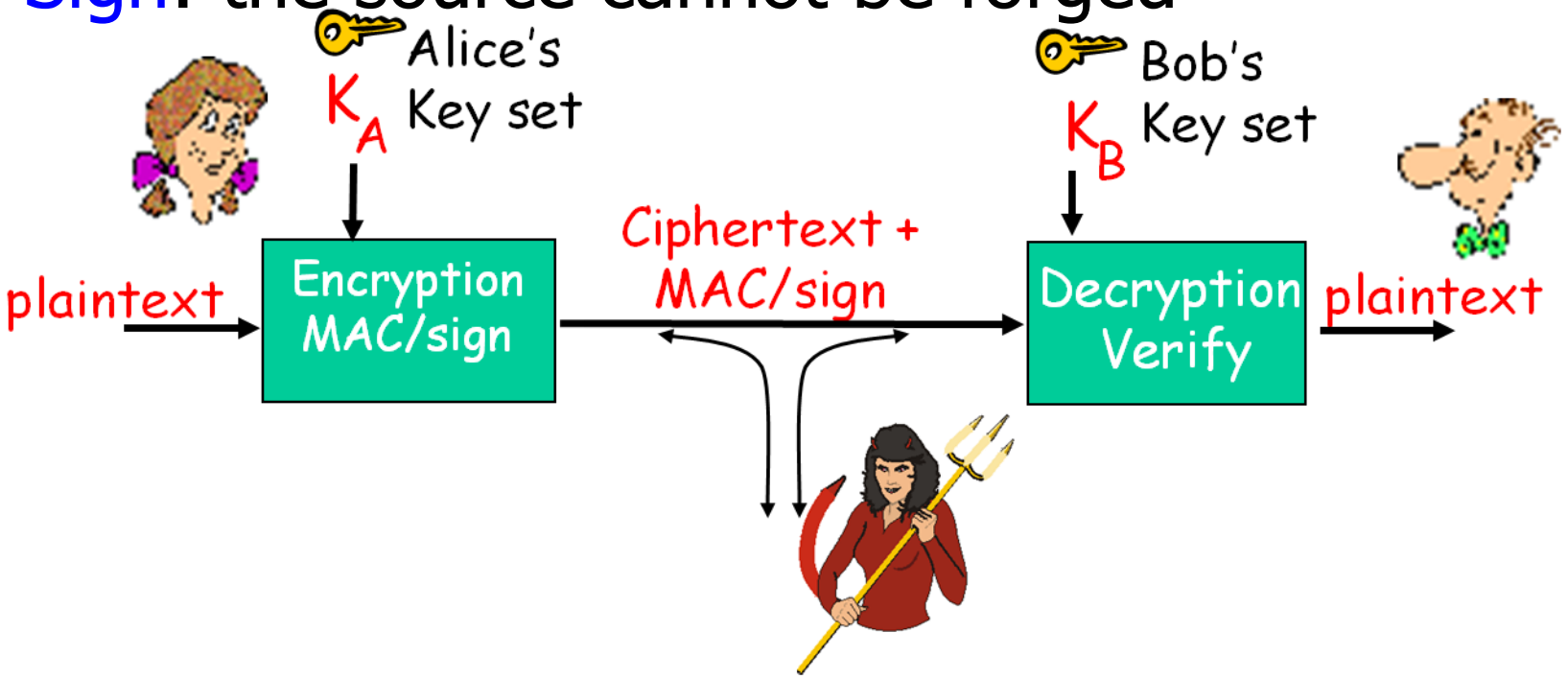
Common Scenario of Network Security

- Bob, Alice want to communicate "securely"
- Trudy (intruder) may intercept, delete, add messages



How to Handle This

- Encryption: the message cannot be understood
- Message Authentication Code (MAC): the message cannot be altered
- Sign: the source cannot be forged



Typical Network Applications

Typical Network Applications

- Client-Server Applications
  - Electronic Mail
  - FTP
  - Web and HTTP
  - Social Networks
- Peer-to-Peer Applications
  - Skype
  - BitTorrent

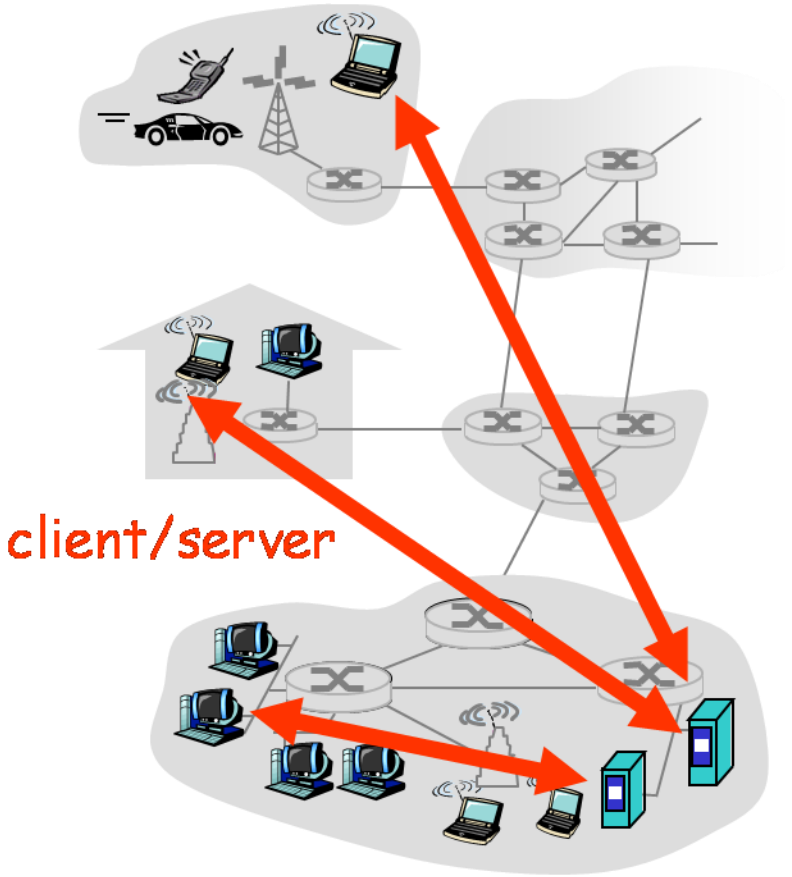
Client-Server Architecture

Server

- Always-on host
- Permanent IP address
- Server farms for scaling

Clients

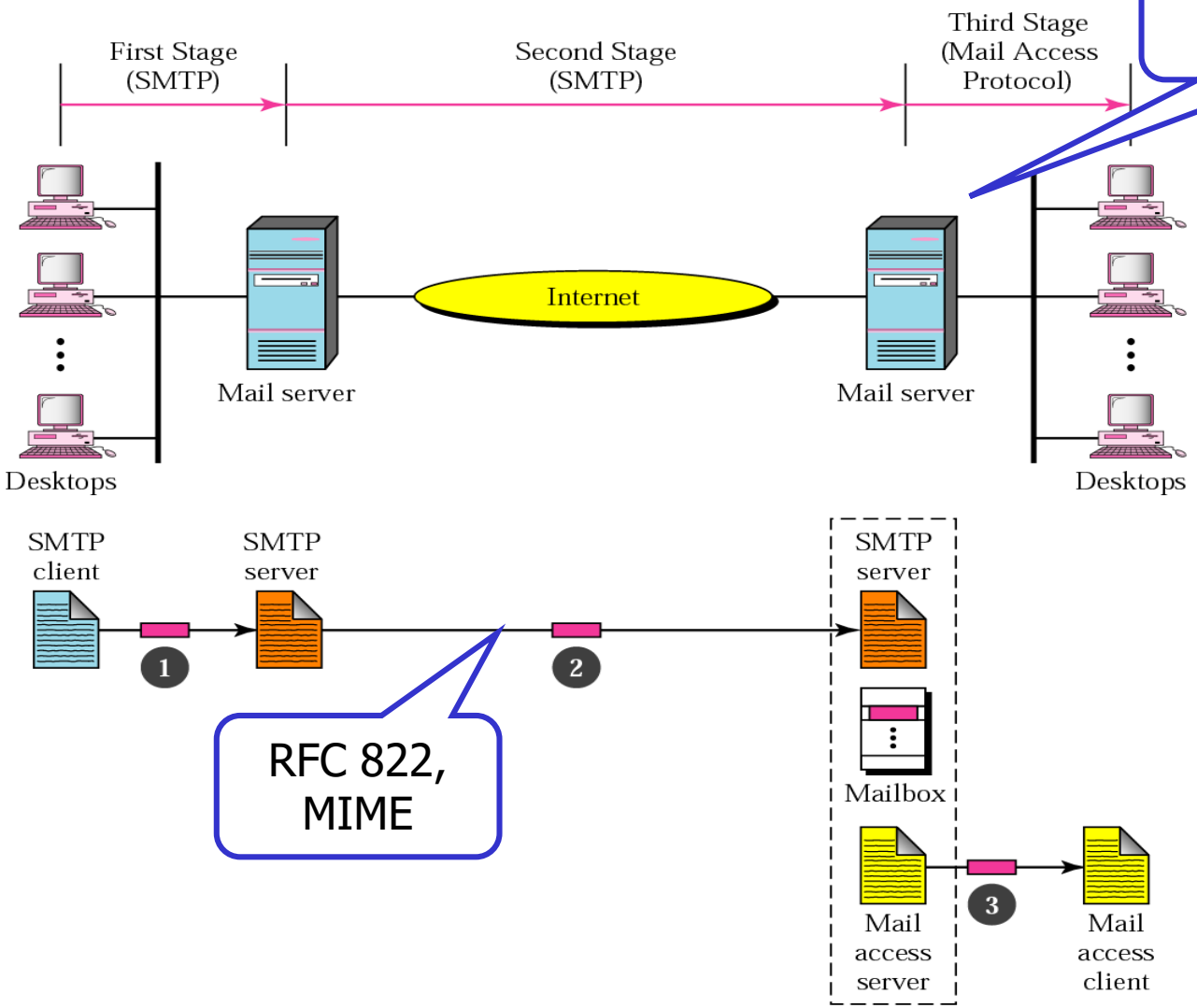
- Communicate with server
- May be intermittently connected
- May have dynamic IP addresses
- Do not communicate directly with each other



Electronic Mail

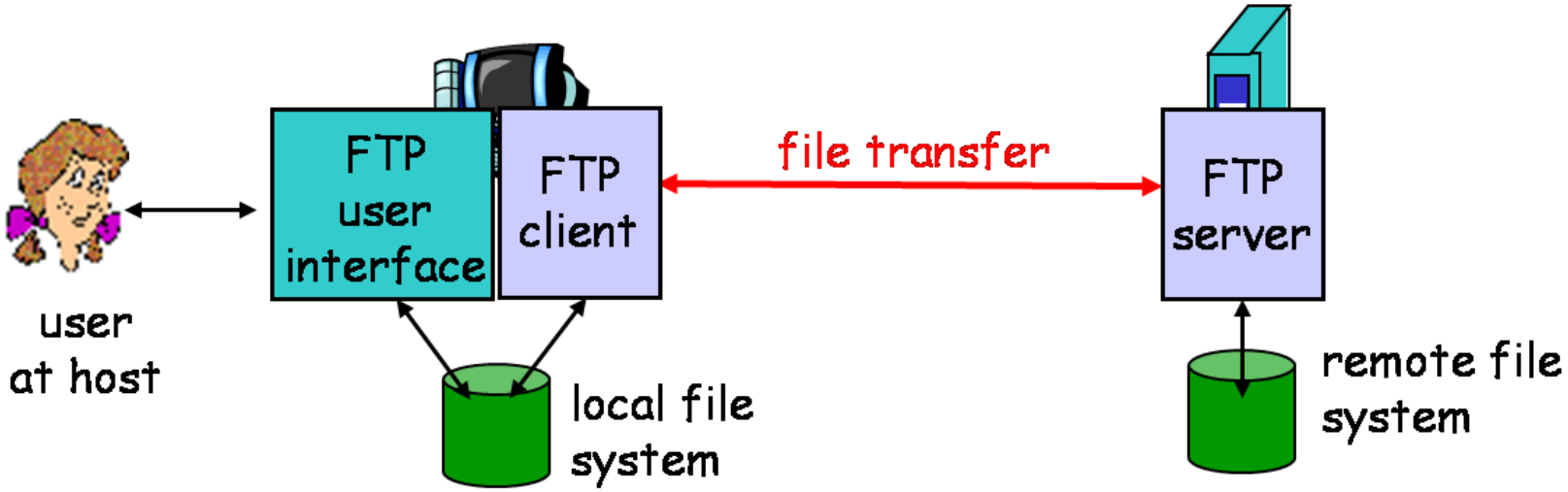
- SMTP: Simple Mail Transfer Protocol
  - Delivery of simple text mail
- MIME: Multi-purpose Internet Mail Extension
  - Express of other types of data, e.g. voice, images, video clips
- POP: Post Office Protocol
  - Mail retrieval from server, including authorization and download
- IMAP: Internet Mail Access Protocol
  - Manipulation of stored mails on server

Illustration of A Mail System



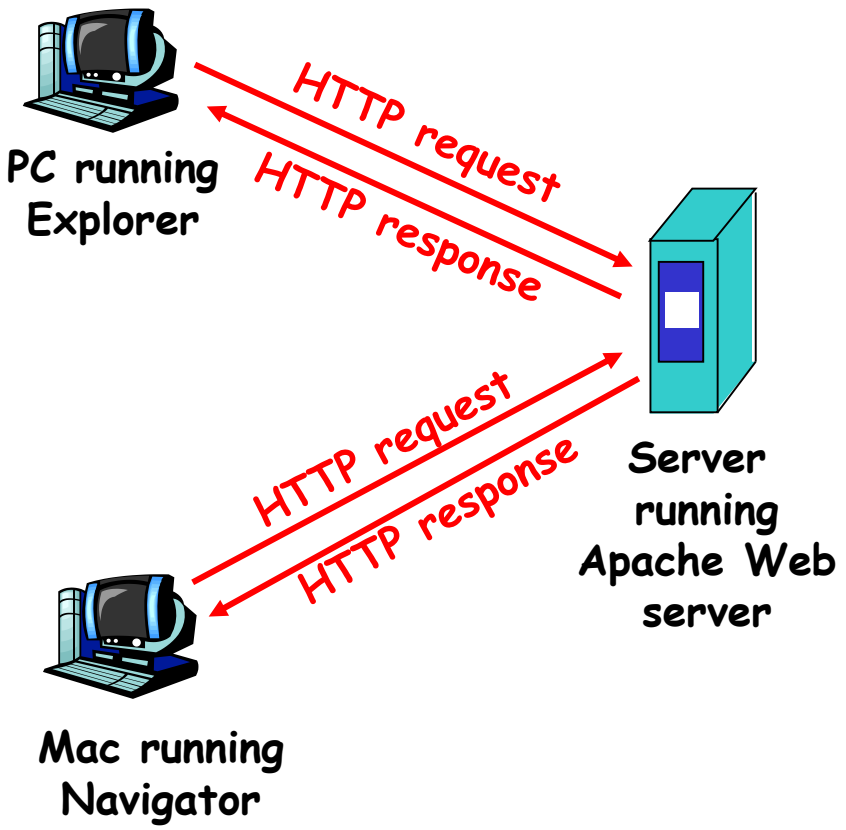
FTP

- Transfer file to/from remote host
- Control connection
  - Login/logout, file transfer command/reply
- Data connection
  - Transferring file contents
  - Client side initiates file transfer

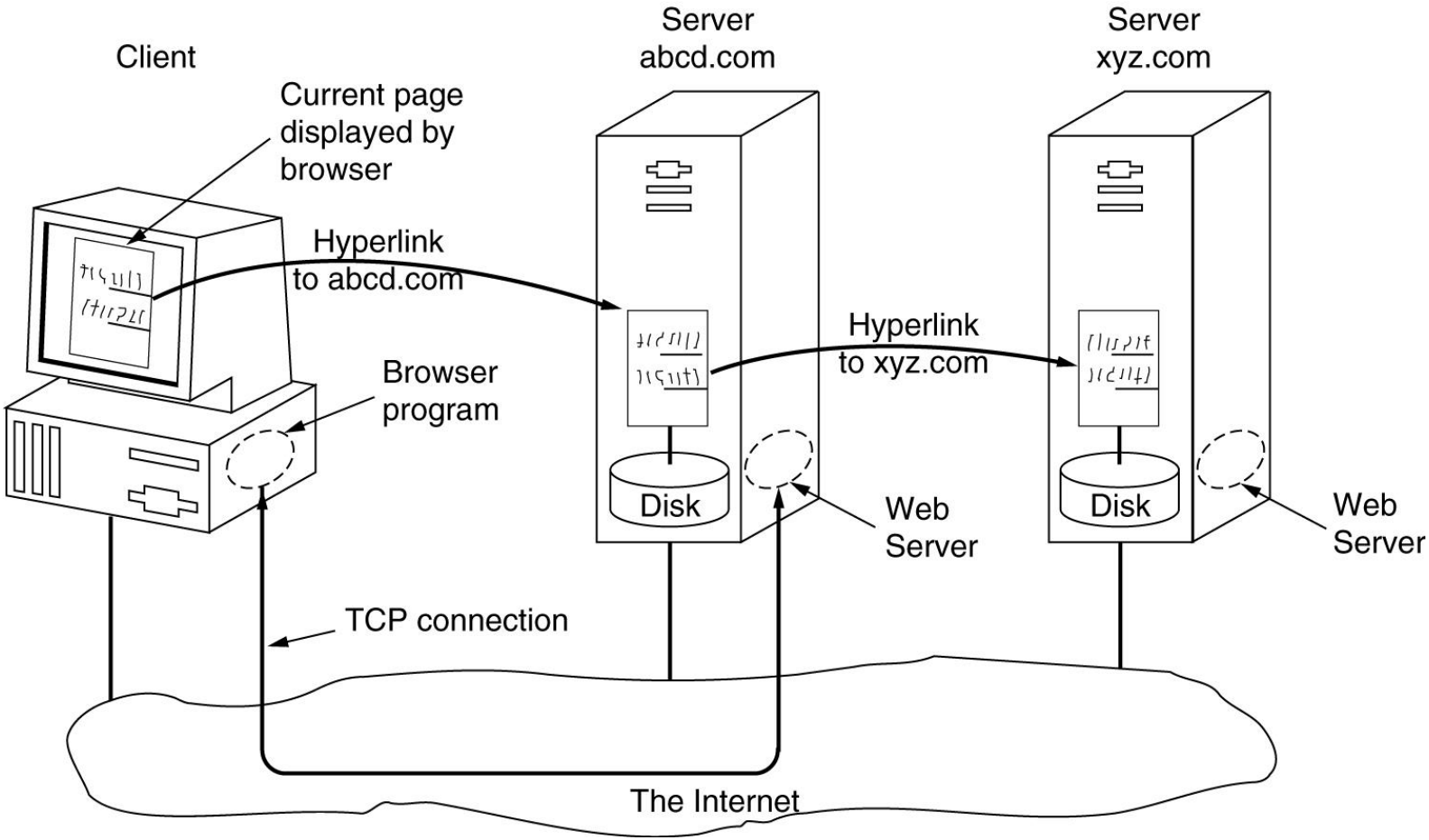


Web and HTTP

- Clients use browser to send URL(URI)s via HTTP to servers requesting a Web page
- Web pages constructed using HTML (or other markup language), inter-connected by URL
- Servers (or caches) respond with requested Web page
- Client's browser displays Web page returned by server

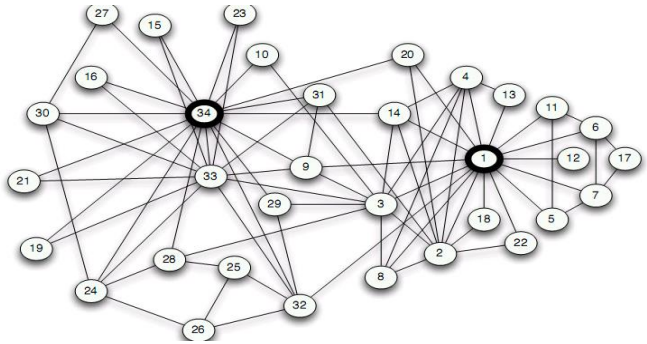


WWW Architecture

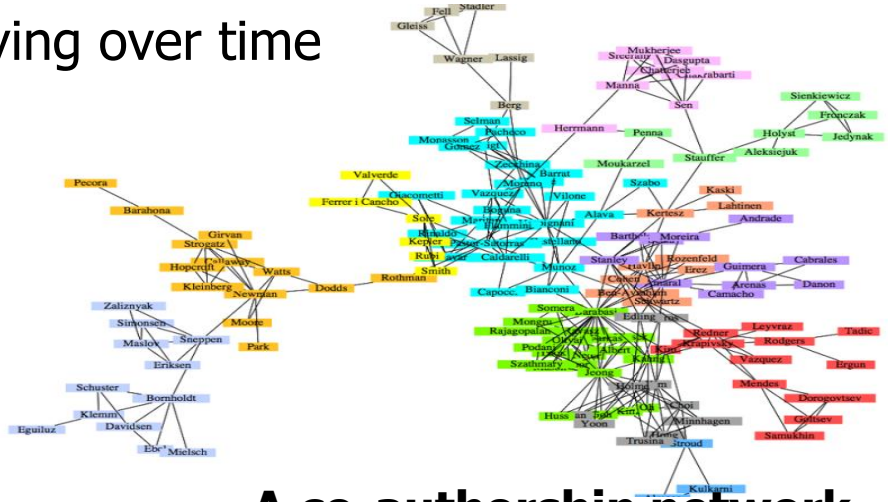


Social Networks

- Social Network
  - A network made up by a set of individuals interconnecting with each other basing on social relationships (such as friendships, partnerships, etc.)
- Characteristics
  - Virtual: it is not physically exists
  - Complex: it consists of a large scale number of nodes
  - Grouping: it forms communities due to different interests
  - Dynamic: it's structure is evolving over time



A friendship network in a karate

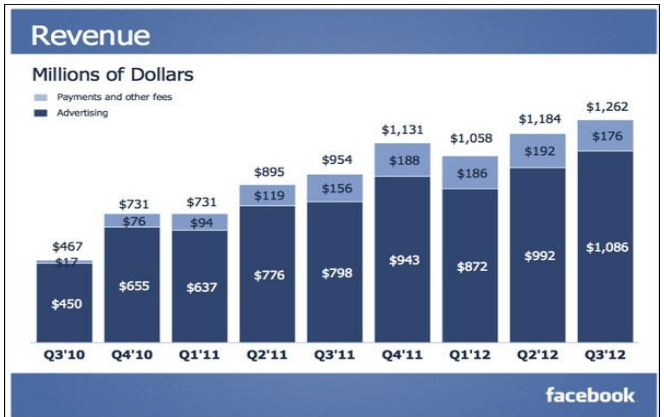


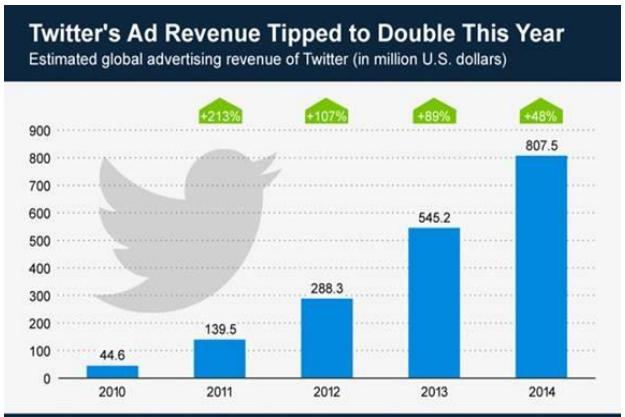
A co-authorship network

Social Network Applications

- Online Social Networks: Facebook, Twitter, etc.

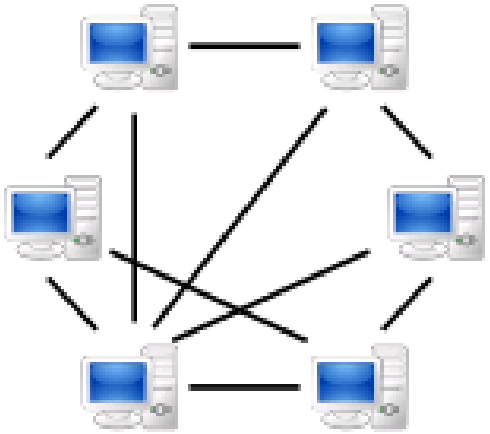
- Population of online social networks grows rapidly
  - Facebook: 1.28 billion (active March 2014, Wikipedia)
  - Twitter: 200 million (active February 2013, Wikipedia)
  - Renren: 160 million (Feb 2011, Wikipedia)

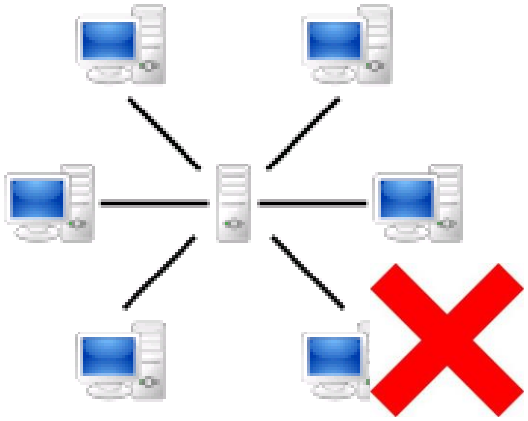




Peer-to-Peer Architecture

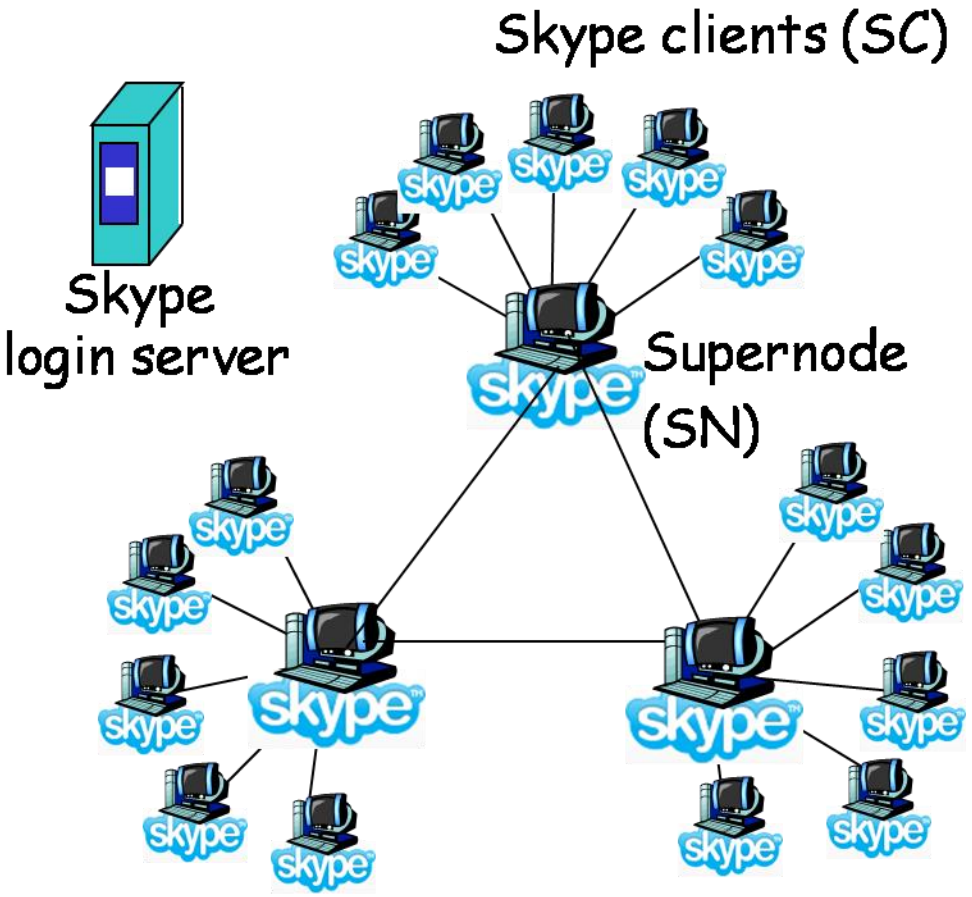
- Peer-to-peer (abbreviated to P2P) refers to a computer network in which each computer in the network can act as a client or server for the other computers in the network, allowing shared access to files and peripherals without the need for a central server [Wiki]





Skype

- P2P Voice-Over-IP (VoIP) application
  - pc-to-pc, pc-to-phone, phone-to-pc
- Proprietary application-layer protocol

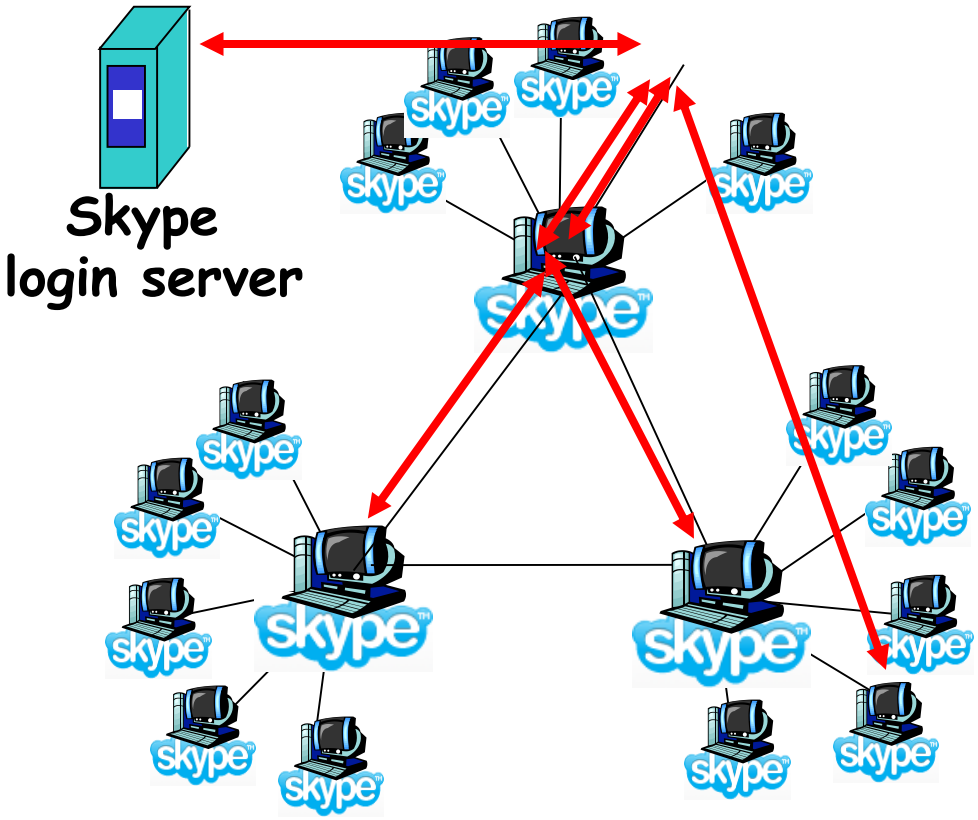


Skype: Making a Call

- User starts Skype
- SC registers with SN
- SC logs in (authenticate)

- Call: SC contacts SN with callee ID
- SN contacts other SNs to find address of callee

- SC directly contacts callee, over TCP

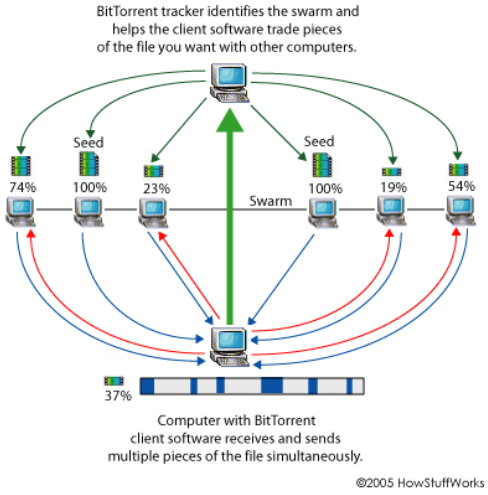


BitTorrent

- A new popular approach to sharing large files
  - It accounts for 30-50% of all Internet traffic
- Originally used for distributing legal content
  - Linux distributions, software updates
  - Official movies
  - Games, …
- Goal:
  - Quickly and reliably replicate one file to a large number of clients
- Call it "P2P content distribution"

Basic Idea

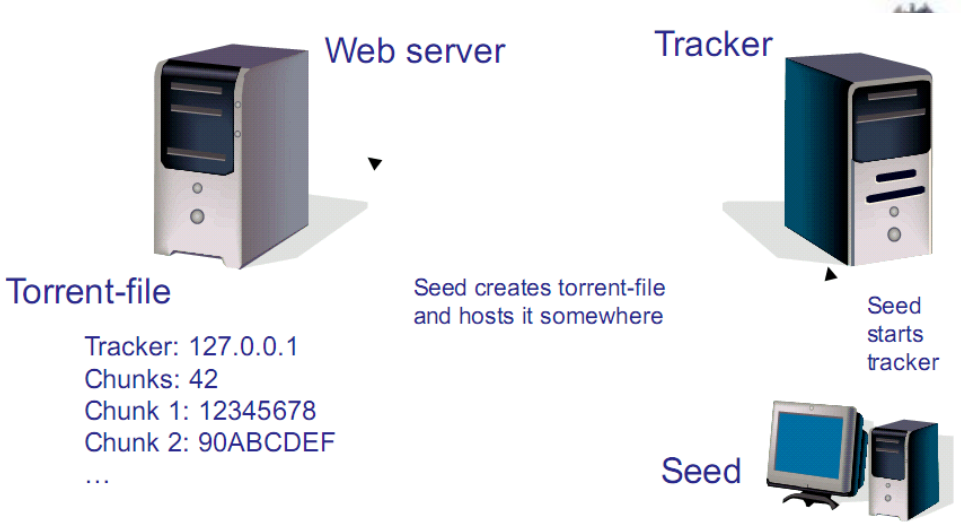
- Chucking:
  - Files split into smaller pieces or chunks
  - Chunks can be downloaded in parallel
  - Downloading order does not matter
- Swarming
  - Clients join a crowd of peers uploading and downloading the same content
  - Nodes request chucks from neighbors and download content in parallel
- Use the web server to publish content
- Use a central unit to locate resource



Basic Components

- Web server: for content publication
- Tracker: a special central server for running the content distribution system
  - Tracking active peers
  - Mapping from file name to peers
- Peer
  - Seed: a peer with a complete copy of the file
  - Leecher: peer still downloading the file
- ".torrent" file: metadata and description of the file
  - The number of chunks
  - The tracker's IP

Operation

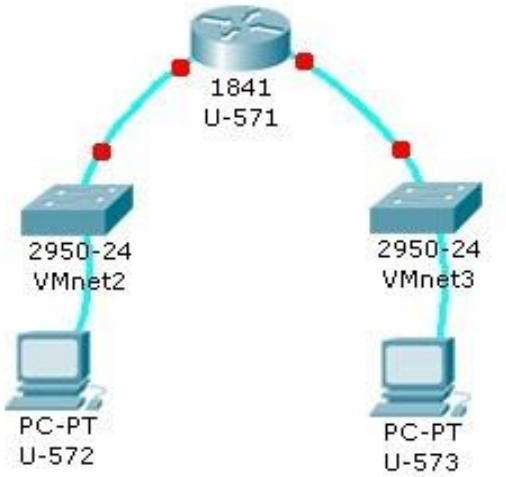


- Sharing a file:
  - (1) Seed generates a ".torrent" file from the file
  - (2) Upload the ".torrent" file to some public web server or sending it to friends by email
- Searching a file:
  - No dedicate search component
  - User can search ".torrent" file from web server
- Downloading a file:
  - (1) Download the ".torrent" file
  - (2) Connect to the tracker to locate the file
  - (3) Choose some fast peers to download chunks in parallel

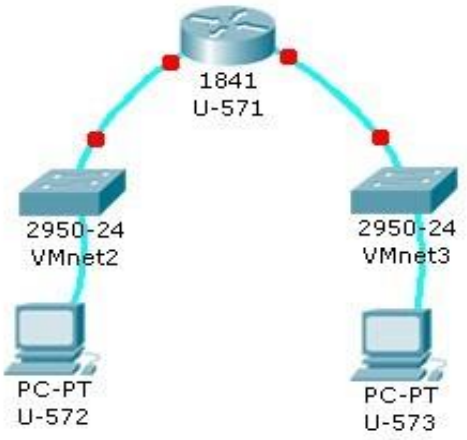
计算机网络实验简介

用WMWare搭建网络

- 虚拟机
  - 虚拟网卡
- 虚拟交换机：WMWare自带
- 路由器：用虚拟机来模拟



建立网络拓扑



U-571

State: Powered off
Guest OS: Ubuntu
Location: D:\VMware\U-571\U-571.vmx
Version: Workstation 6.5 virtual machine

Commands

- Power on this virtual machine
- Edit virtual machine settings
- Enable ACE features (What is ACE?)

Devices | **Options**

Memory	128 MB
Hard Disk (SCSI)	4 GB
CD/DVD (IDE)	Auto detect
Floppy	Auto detect
Network Adapter	Custom
Network Adapt...	Custom
USB Controller	Present
Sound Card	Auto detect
Display	Auto detect
Processors	1

U-572

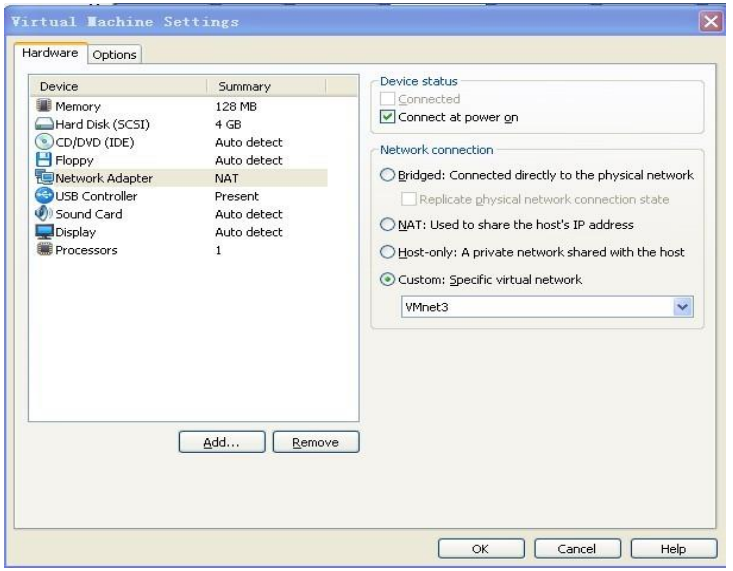
State: Powered off
Guest OS: Ubuntu
Location: D:\VMware\U-572\U-572.vmx
Version: Workstation 6.5 virtual machine

Commands

- Power on this virtual machine
- Edit virtual machine settings
- Enable ACE features (What is ACE?)

Devices | **Options**

Memory	96 MB
Hard Disk (SCSI)	4 GB
CD/DVD (IDE)	Auto detect
Floppy	Auto detect
Network Adapter	Custom
USB Controller	Present
Sound Card	Auto detect
Display	Auto detect
Processors	1



- 虚拟网卡配置
  - IP地址
  - 子网掩码
  - 网关

sudo ifconfig eth0 192.168.2.1 netmask 255.255.255.0

配置好后再用 ifconfig -a 查看

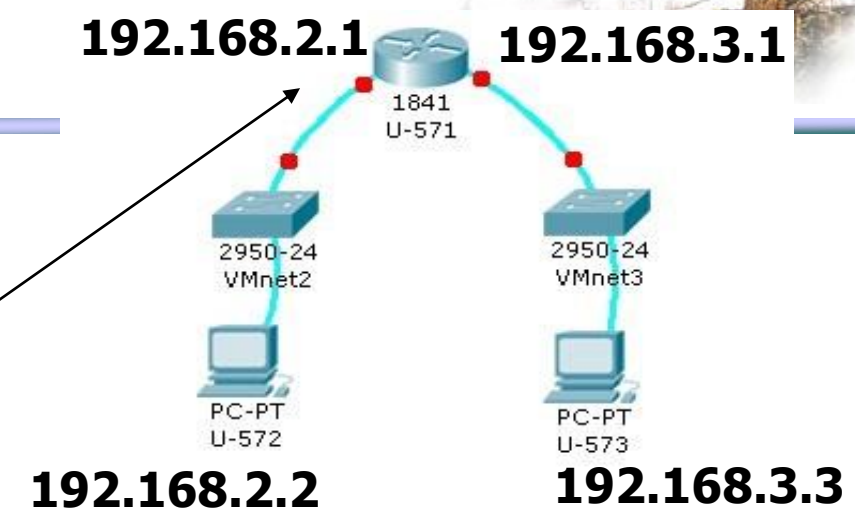
```
eth0      Link encap:以太网  硬件地址 00:0c:29:5c:fb:25
          inet 地址:192.168.2.1  广播:192.168.2.255  掩码:255.255.255.0
          inet6 地址: fe80::20c:29ff:fe5c:fb25/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  跃点数:1
          接收数据包:0 错误:0 丢弃:0 过载:0 帧数:0
          发送数据包:22 错误:0 丢弃:0 过载:0 载波:0
          碰撞:0 发送队列长度:1000
          接收字节:0 (0.0 B)  发送字节:4813 (4.8 KB)
          中断:19 基本地址:0x2000
```

sudo route add default gw 192.168.2.1

用命令 route 查看结果

```
内核 IP 路由表
目标            网关            子网掩码        标志  跃点   引用  使用 接口
default         192.168.2.1     0.0.0.0         UG    0      0        0 eth0
```

- 路由器设置
- 路由规则

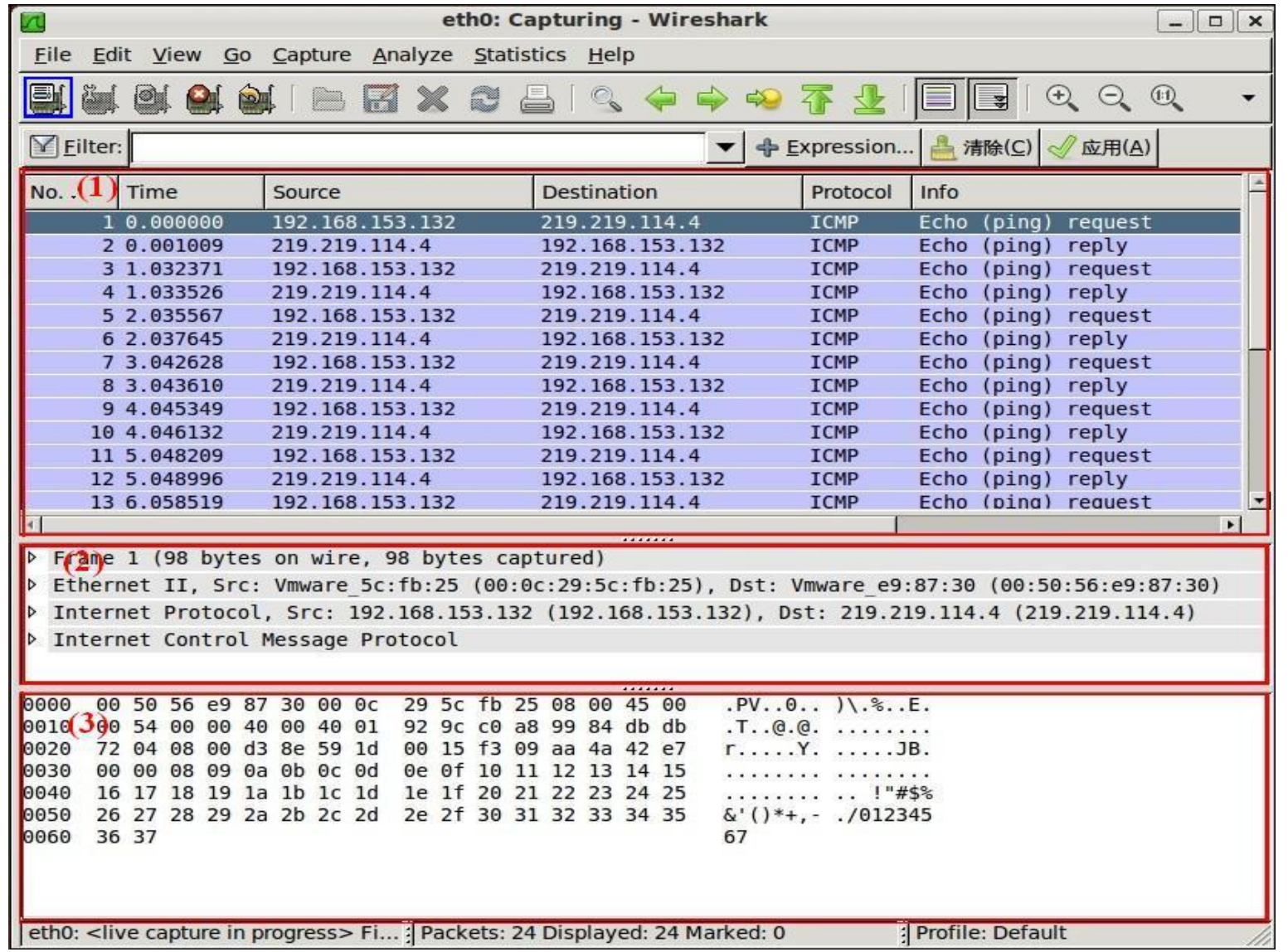


sudo ip route add 192.168.2.0/24 via 192.168.2.1

sudo ip route add 192.168.3.0/24 via 192.168.3.1

echo 1 > /proc/sys/net/ipv4/ip_forward

网络嗅探 Wireshark



Summary

- Internet基本概念
  - 什么是Internet
    - 组成、服务、协议
  - 网络边缘
  - 网络接入
    - 家庭、公司、无线
  - 网络核心
    - 电路交换、分组交换、虚电路
- Internet历史

- 协议层次及模型
  - OSI七层模型
  - TCP/IP协议栈五层模型
- 网络安全基本概念
- Internet应用
  - C/S构架
  - P2P构架

Homework

- 阅读书本第1章
- 书第1章习题：R12, R23, R24, R25

THE INTERNET AGE

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