计算机网络

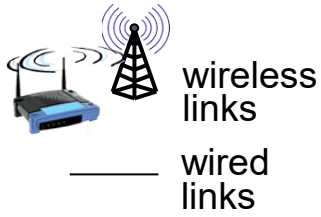
SiChuan University

COMPUTER NETWORK

- Part 1: Introduction
- Part 2: Datalink Layer
- Part 3: Network Layer
- Part 4: Transport Layer
- Part 5: Application Layer

Part 1: introduction

- billions of connected computing devices:
  - *hosts* = *end systems*
  - running *network apps* (remote communication)

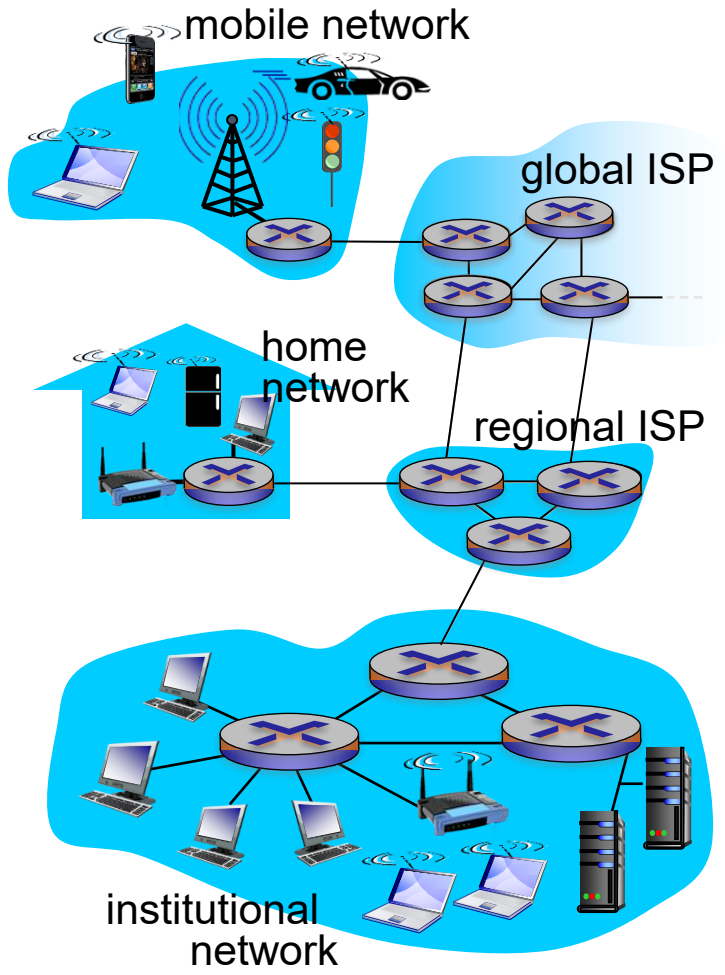


- *communication links*

  fiber, copper, radio, satellite

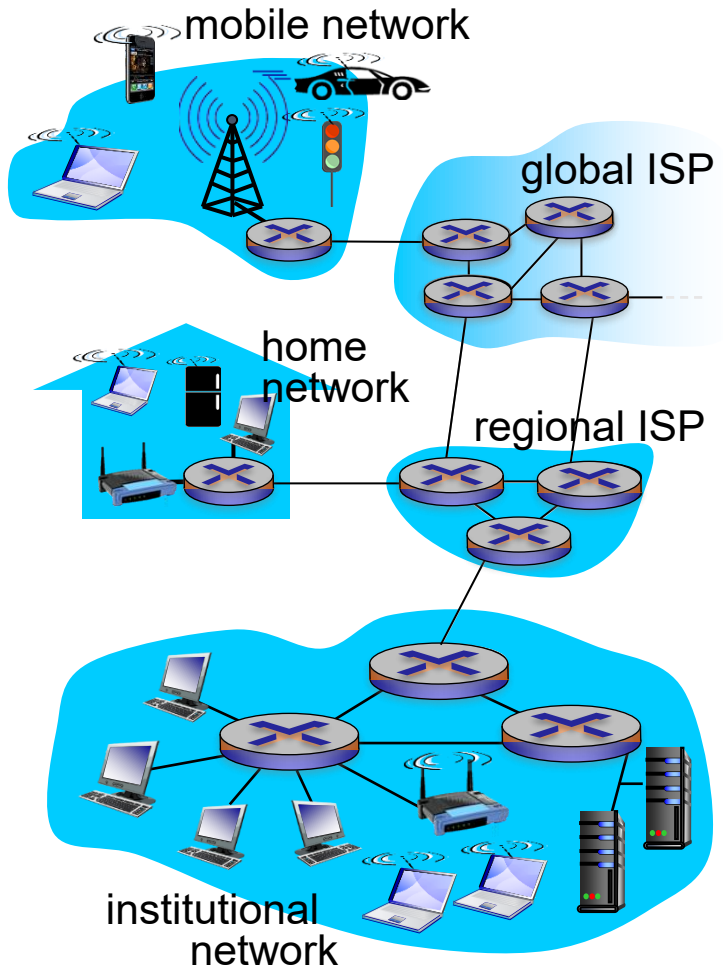
  transmission rate: bandwidth

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



Part 1: introduction

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



Part 1: introduction——Internet Protocol

协议	名称	功能
TCP	Transmission Control Protocol，传输控制协议	创建连接并交换数据包
IP	Internet Protocol，因特网协议	为设备提供唯一的地址
UDP	User Datagram Protocol，用户数据报协议	域名系统、IP 电话以及文件共享所使用的另一种不同于 TCP 的数据传输协议
HTTP	HyperText Transfer Protocol，超文本传输协议	在 Web 上交换信息
FTP	File Transfer Protocol，文件传输协议	在本地计算机和远程主机之间传输文件
POP	Post Office Protocol，邮局协议	将电子邮件从电子邮件服务器传送到客户端收件箱
SMTP	Simple Mail Transfer Protocol，简单邮件传输协议	将电子邮件从客户端计算机传送到电子邮件服务器
VoIP	Voice over Internet Protocol，因特网语音传输协议	在因特网上传送语音会话
IRC	Internet Relay Chat，因特网中继聊天	在线用户之间实时传送文本消息
BitTorrent	BitTorrent，比特洪流	由分散的客户端而不是服务器来传输文件

因特网中用到的协议

Part 1: introduction——Protocol

human protocols:

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

… specific messages sent

… specific actions taken when messages received, or other events

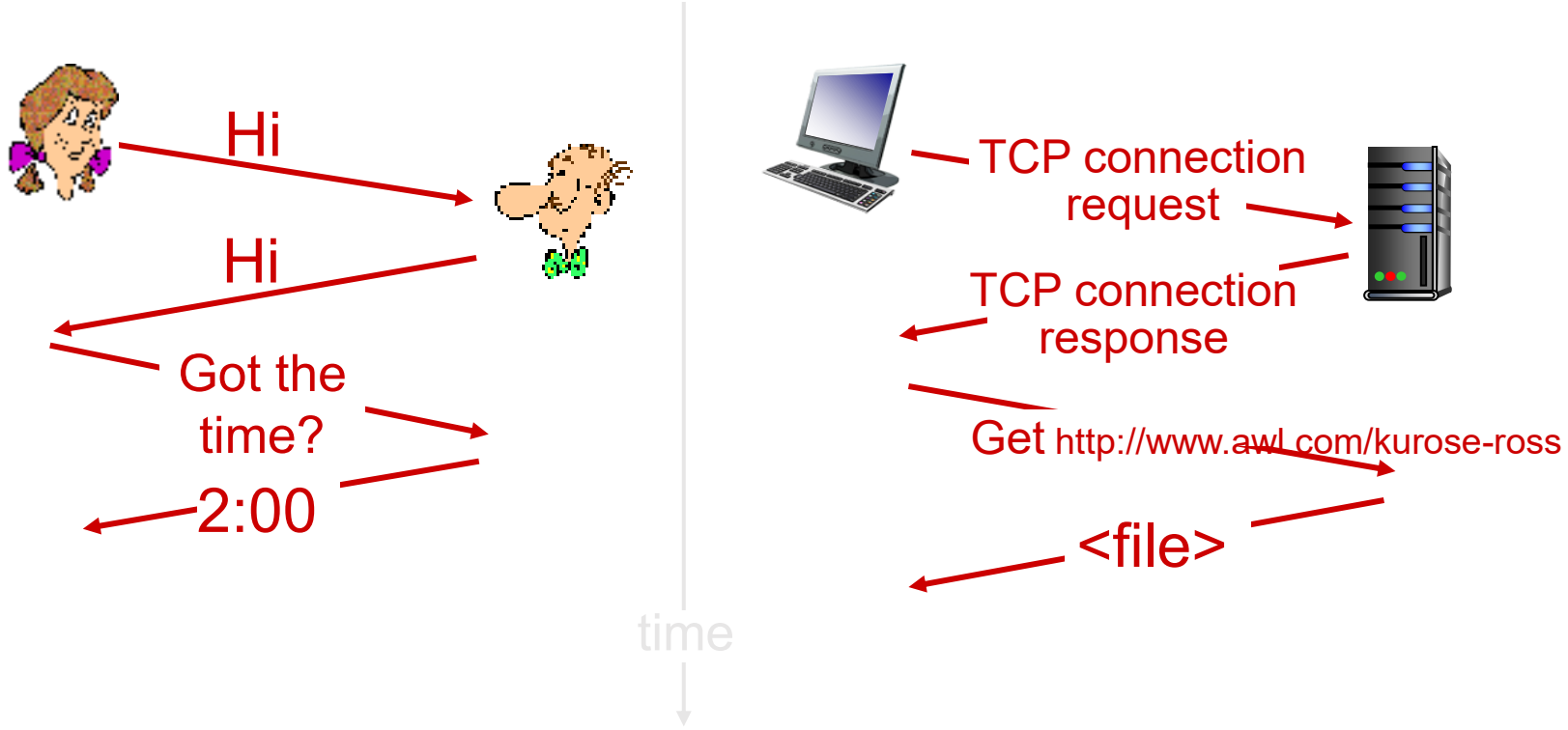
network protocols:

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

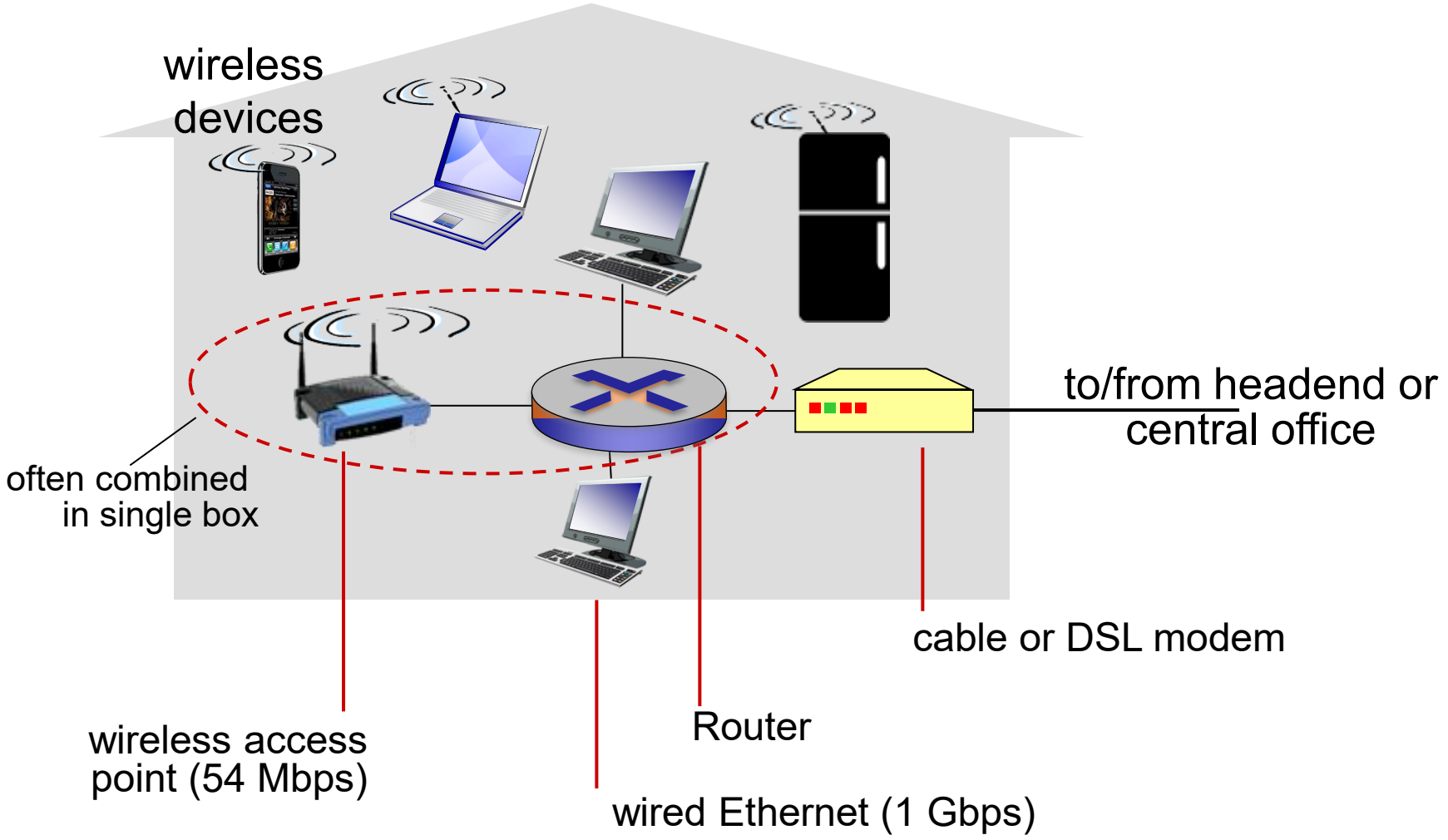
protocols define format, order of messages sent and received among network entities, and actions taken on message transmission, receipt

Part 1: introduction——Protocol

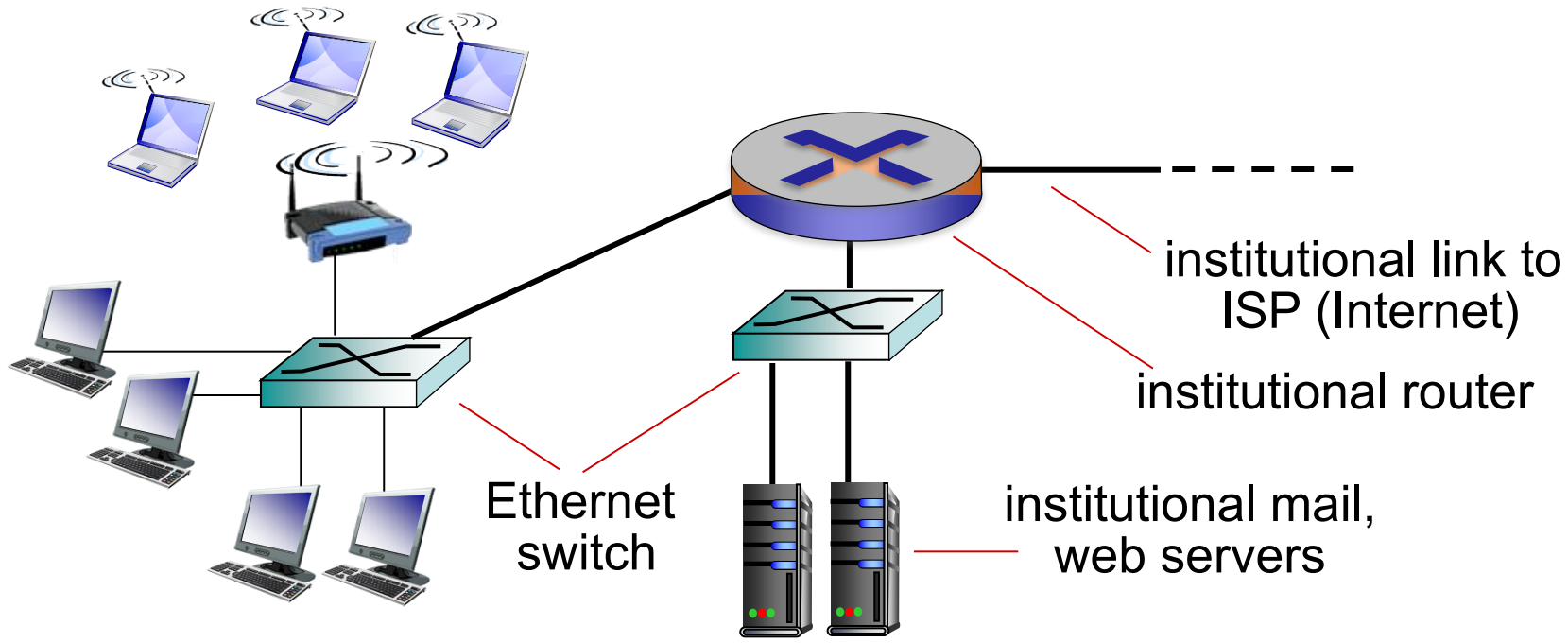
A human protocol and a computer network protocol:



Part 1: introduction——Home Network



Part 1: introduction——dorm



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

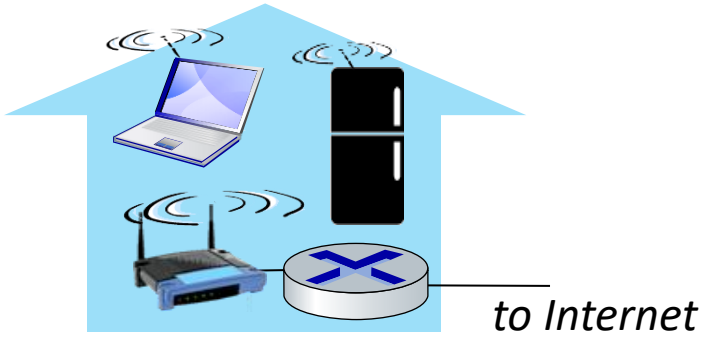
Part 1: introduction ——Wireless access

Shared *wireless* access network connects end system to router

- via base station aka “access point”

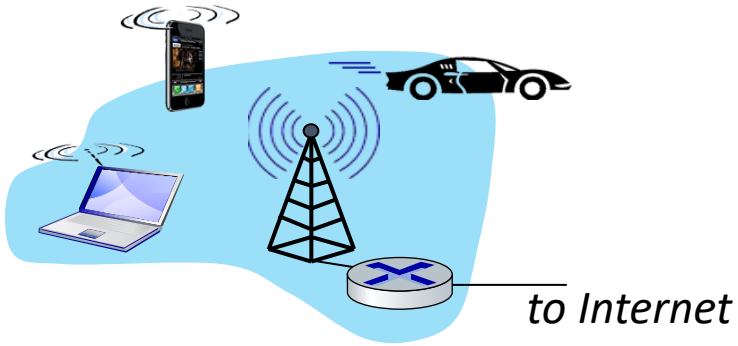
Wireless local area networks (WLANs)

- typically within or around building (~100 ft)
- 802.11b/g/n (WiFi): 11, 54, 450 Mbps transmission rate



Wide-area cellular access networks

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



Part 1: introduction——Protocol “layers”

Networks are complex, with many “pieces”:

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

Question:

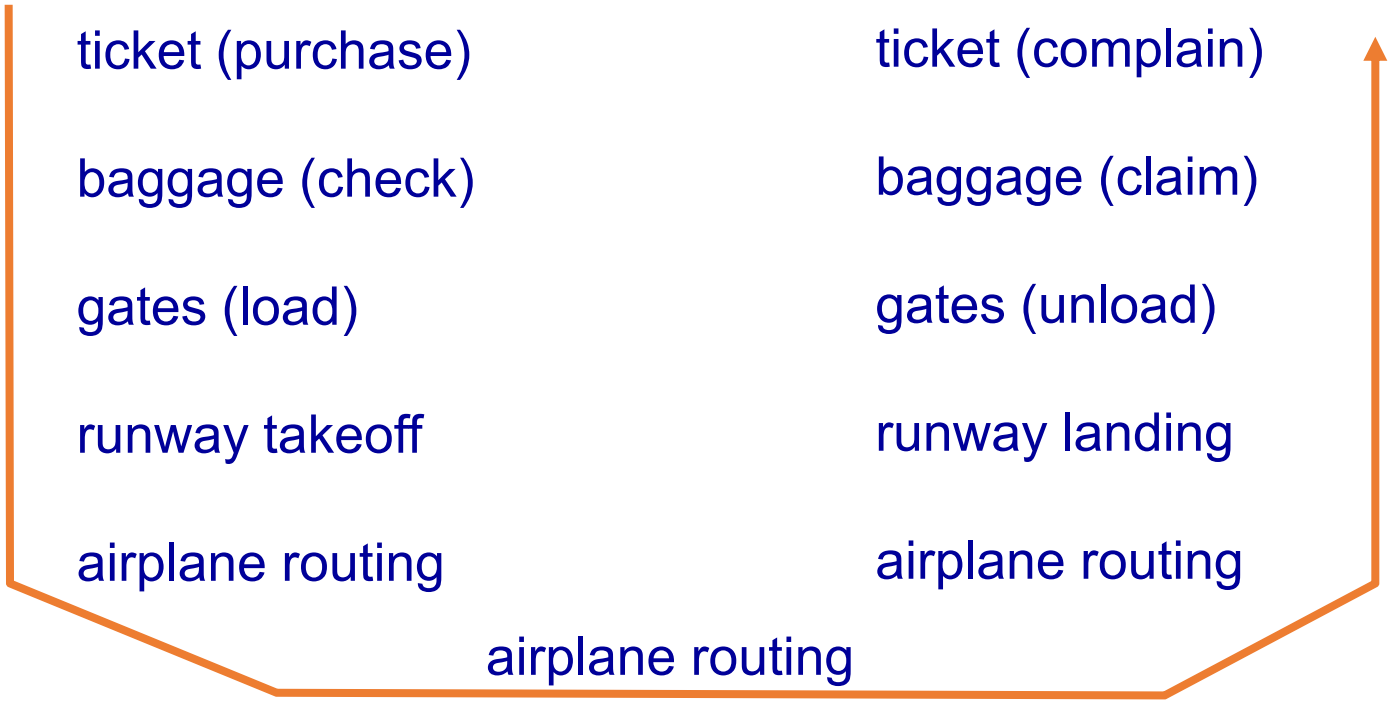
Is there any hope of *organizing* structure of network?

Part 1: introduction——Protocol “layers”

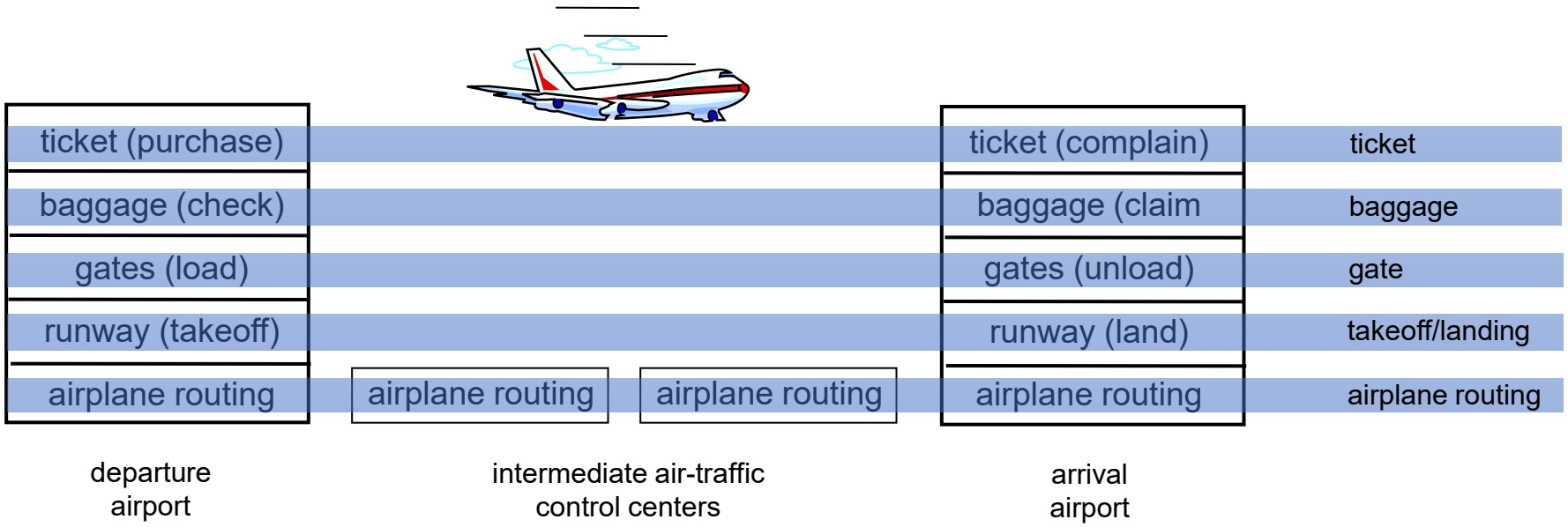
- How would you find the structure to describe this complex system：

- ticketing agents, baggage checkers, gate personnel, pilots, flight crew, airplanes, air traffic control, a worldwide system for routing airplanes?

Part 1: introduction——Protocol “layers”



Part 1: introduction——Protocol “layers”

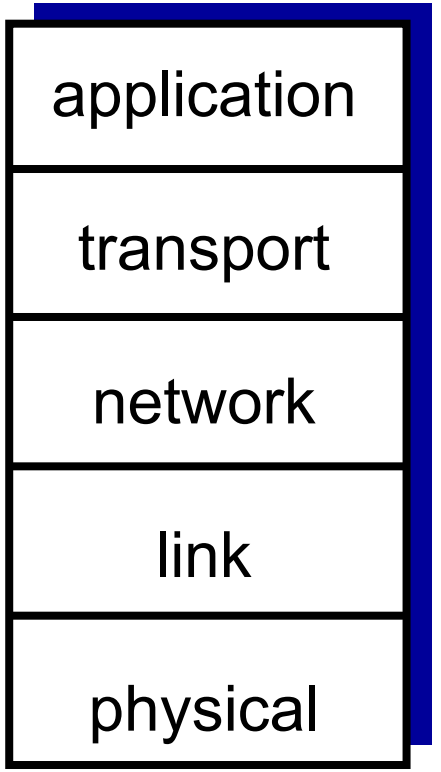


layers: each layer implements a service

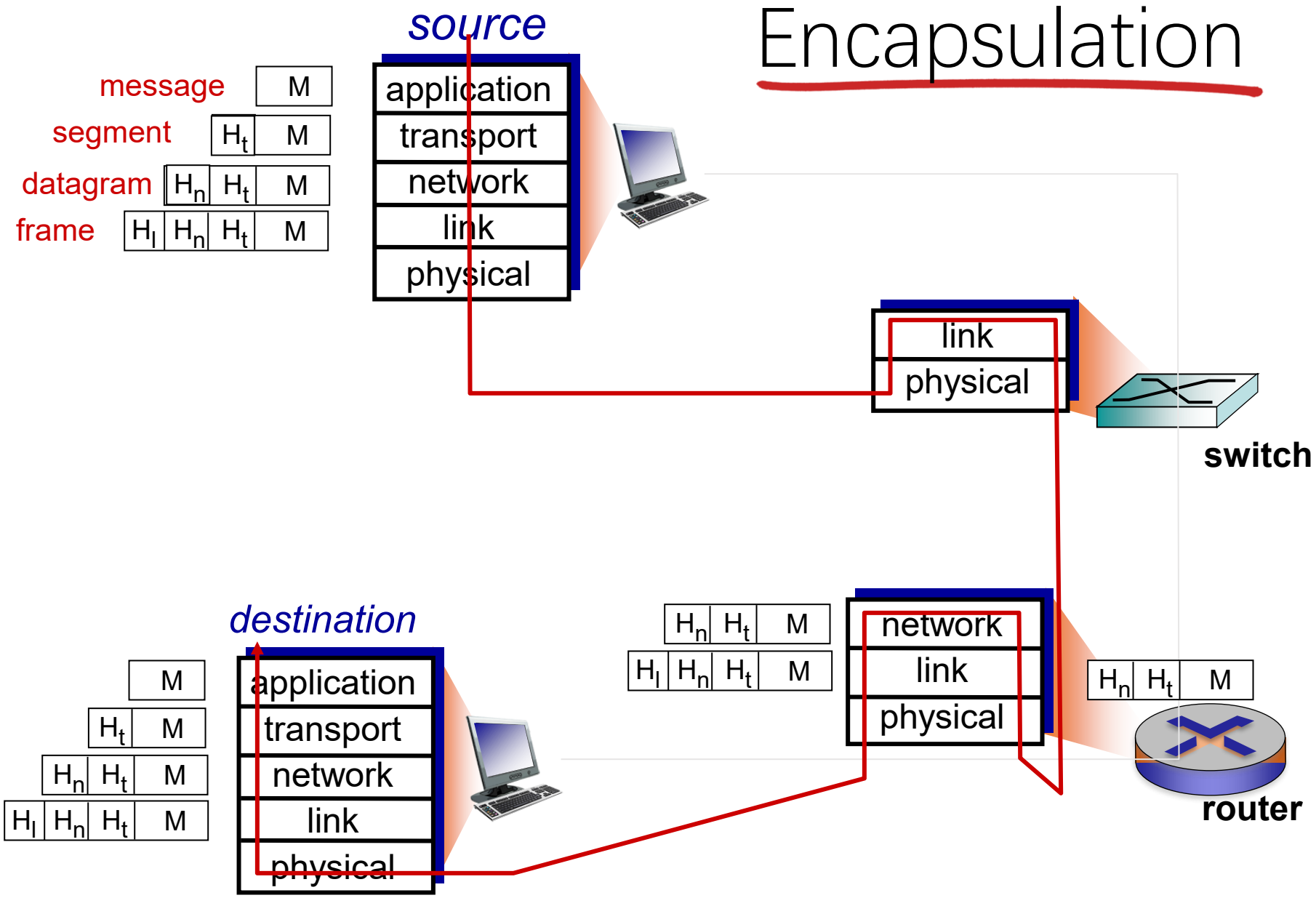
- via its own internal-layer actions
- relying on services provided by layer below

Part 1: introduction——Protocol “layers”

- *application:* supporting network applications
  - FTP, SMTP, HTTP
  - Over multiple end systems
- *transport:* process-process data transfer
  - TCP, UDP
- *network:* routing of datagrams from source to destination
  - IP, routing protocols
- *link:* data transfer between neighboring network elements
  - Ethernet, 802.11 (WiFi), PPP
- *physical:* bits “on the wire”



Encapsulation



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Part 2: DataLink Layer

terminology:

Nodes: hosts and routers

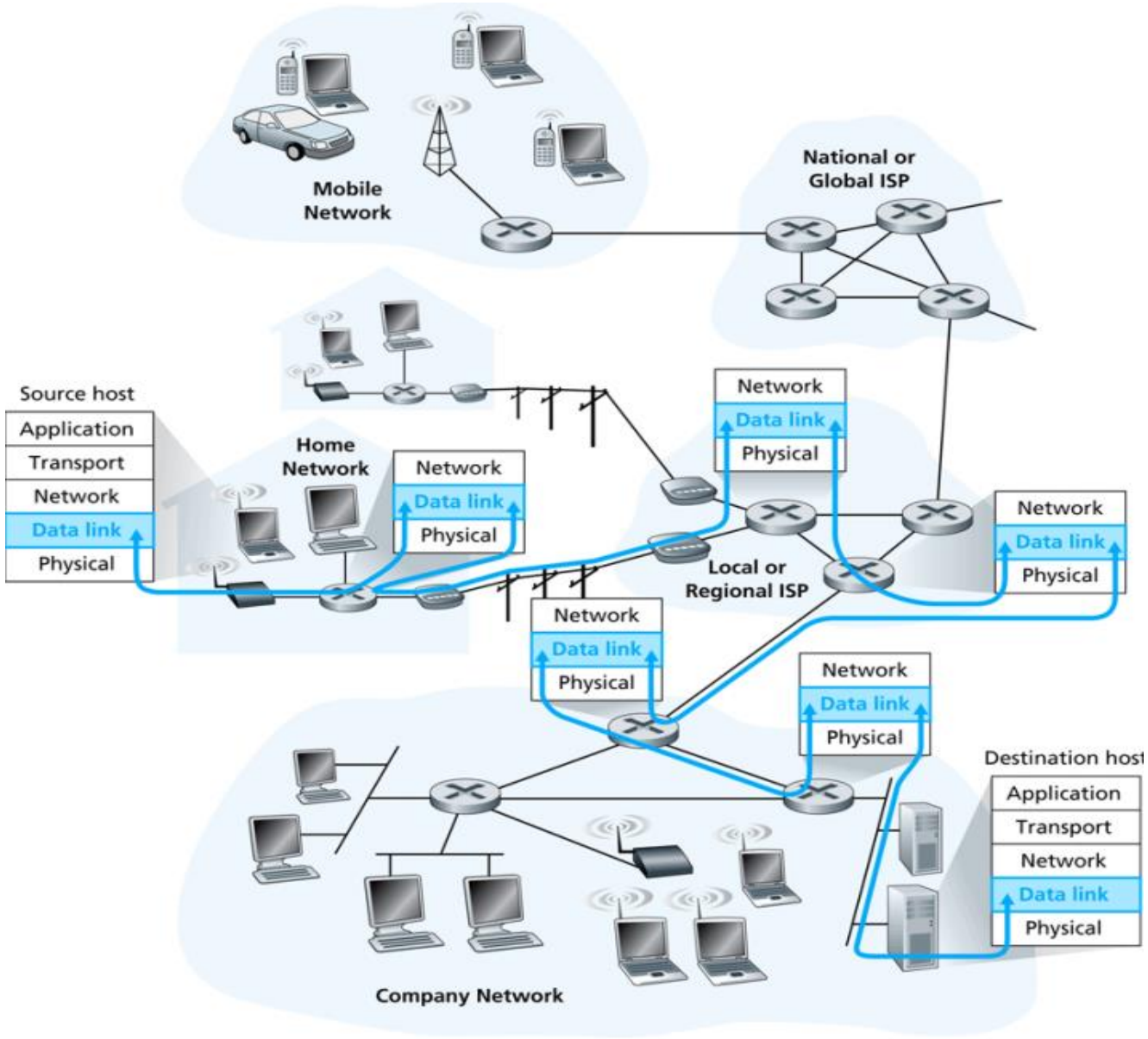
Links: communication channels that connect adjacent nodes along communication path

- wired links
- wireless links
- LANs

Frame: layer-2 packet

encapsulates datagram

data-link layer has responsibility of transferring datagram from one node to *physically adjacent* node over a link



Part 2: DataLink Layer

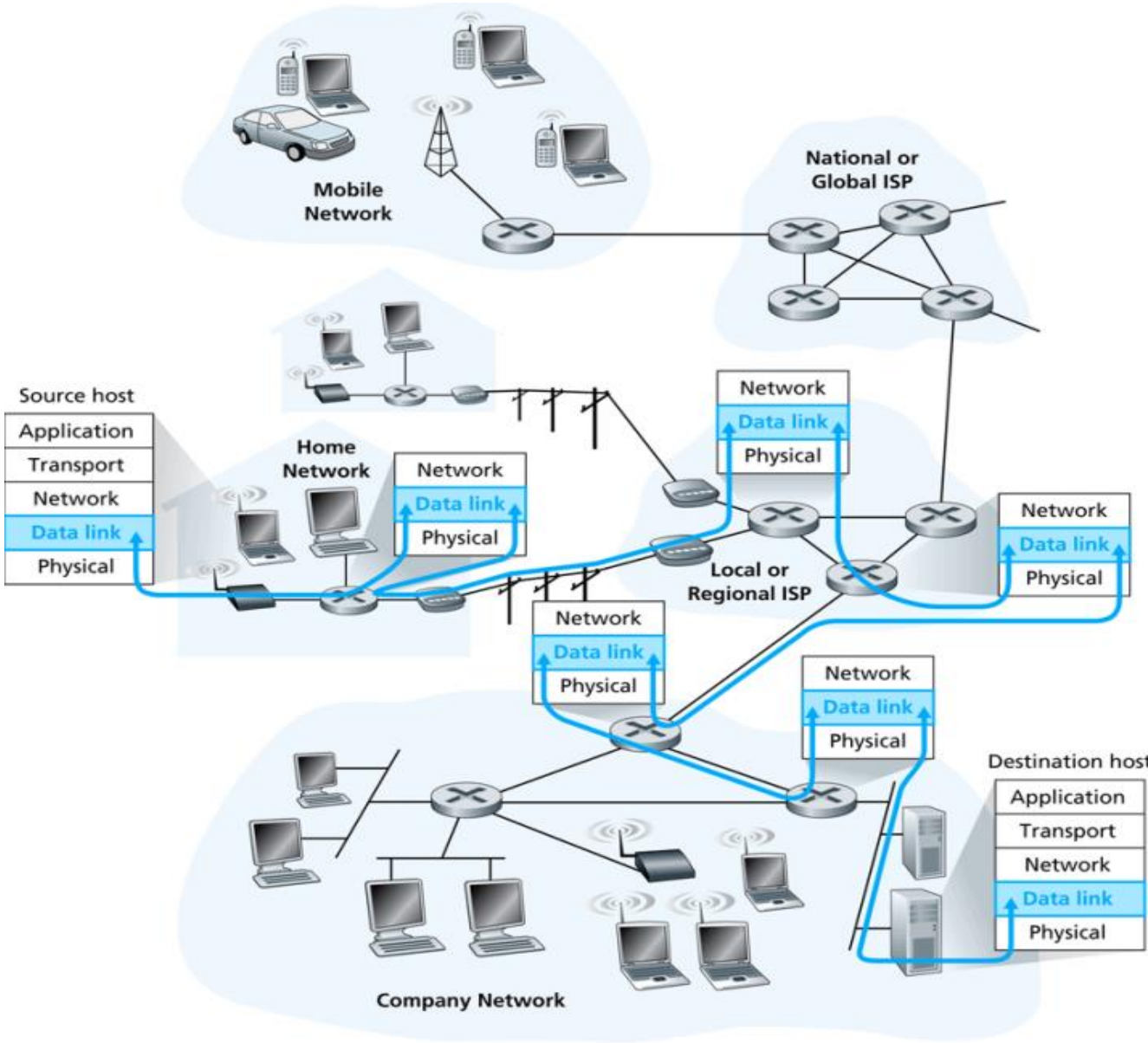
framing, link access:

- encapsulate datagram into frame, adding header, trailer
- channel access if shared medium
- "MAC" addresses used in frame headers to identify source, destination

  different from IP address!

reliable delivery between adjacent nodes

- seldom used on low bit-error link (fiber, some twisted pair)
- wireless links: high error rates



Part 2: DataLink Layer

flow control:

pacing between adjacent sending and receiving nodes

error detection:

errors caused by signal attenuation, noise.

receiver detects presence of errors:

signals sender for retransmission or drops frame

error correction:

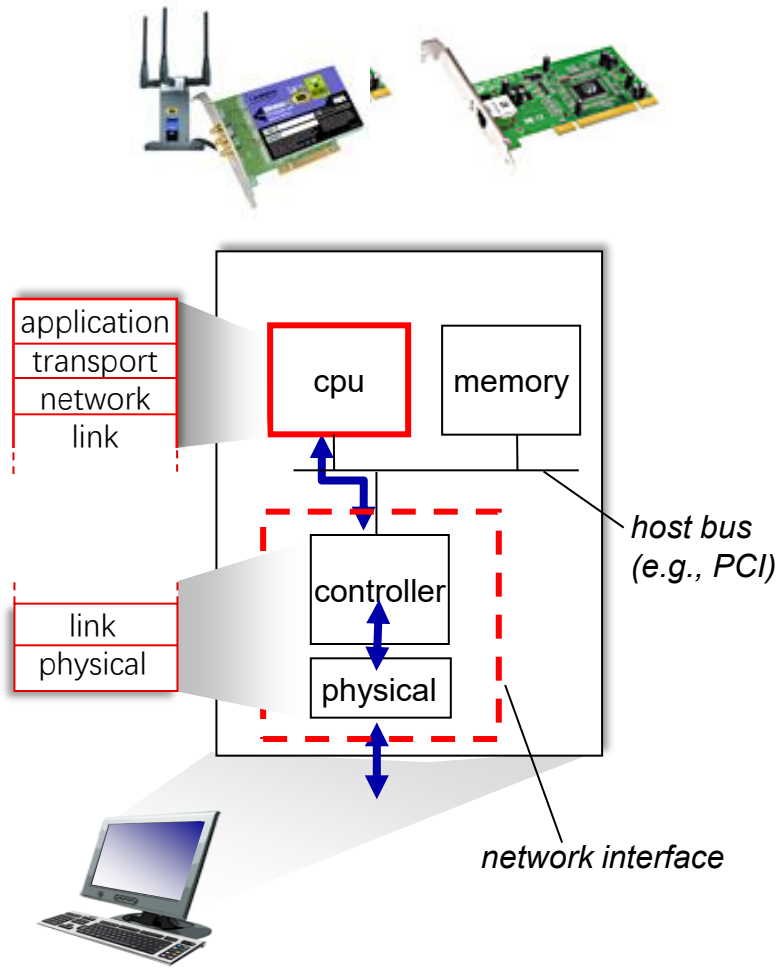
receiver identifies *and corrects* bit error(s) without resorting to retransmission

half-duplex and full-duplex

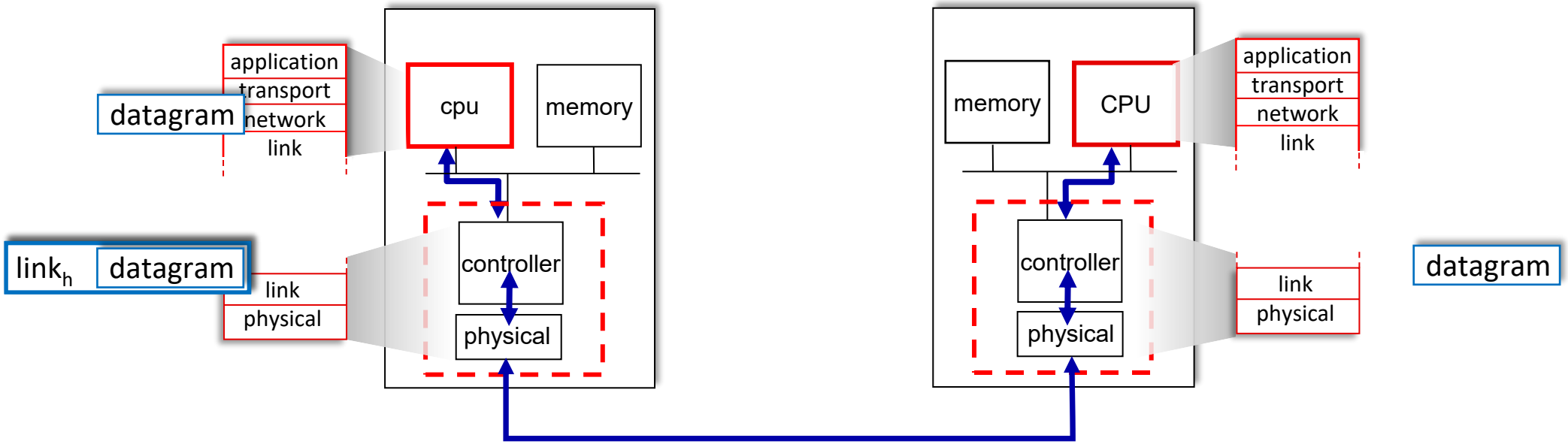
with half duplex, nodes at both ends of link can transmit, but not at same time

Part 2: DataLink Layer

- in each-and-every host
- link layer implemented in *network interface card* (NIC) or on a chip
  - Ethernet, WiFi card or chip
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



Part 2: DataLink Layer



sending side:

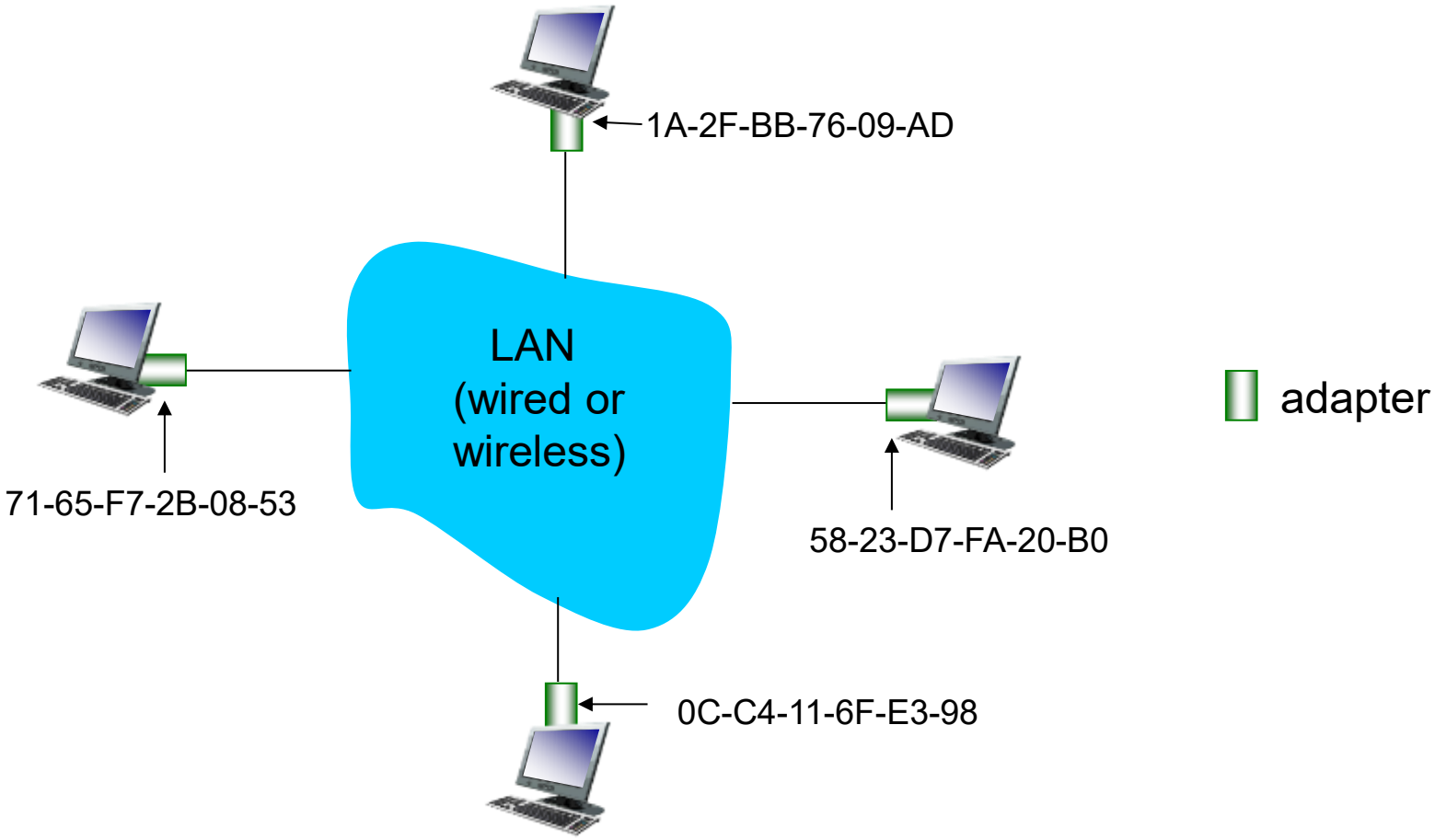
- encapsulates datagram in frame
- adds error checking bits, reliable data transfer, flow control, etc.

receiving side:

- looks for errors, reliable data transfer, flow control, etc.
- extracts datagram, passes to upper layer at receiving side

Part 2: DataLink Layer

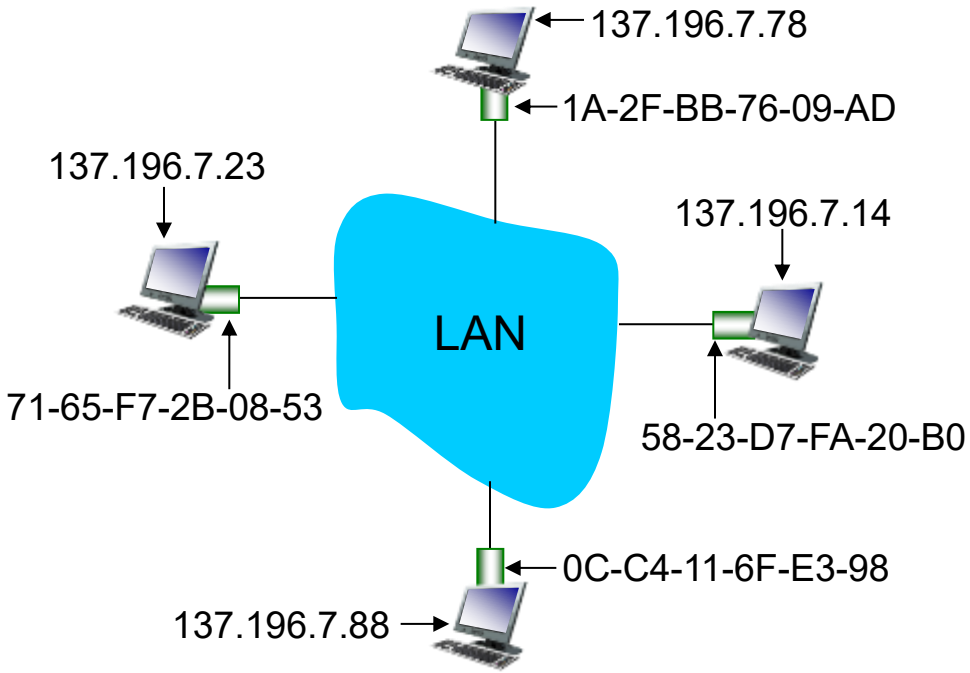
each adapter on LAN has unique *LAN* address（MAC address）



Part 2: DataLink Layer

Question: how to determine interface's MAC address, knowing its IP address?

ARP protocol



ARP table: each IP node (host, router) on LAN has table

- IP/MAC address mappings for some LAN nodes:

  < IP address; MAC address; TTL>

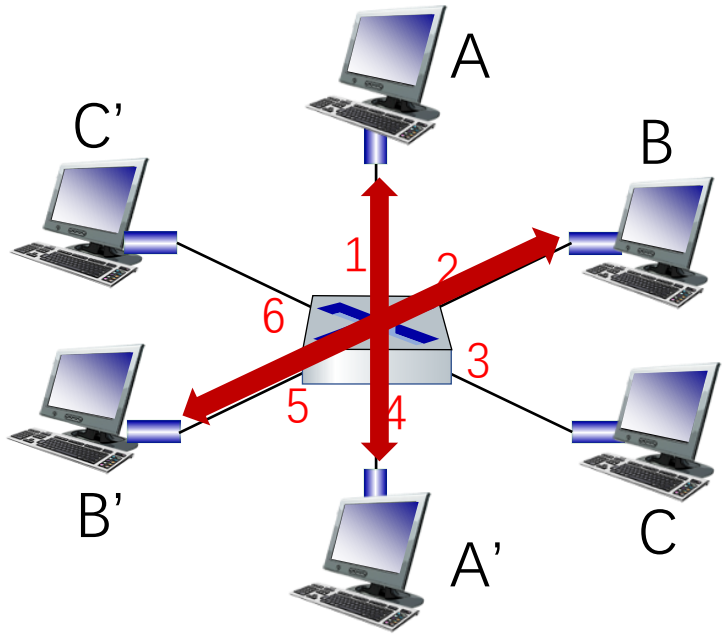
- TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

Part 2: DataLink Layer

- _____ is a link-layer device: takes an *active* role
  - store, forward Ethernet frames
  - examine incoming frame's MAC address, *selectively* forward frame to one-or-more outgoing links when frame is to be forwarded on segment, uses CSMA/CD to access segment
- transparent: hosts *unaware* of presence of switches
- plug-and-play, self-learning
  - switches do not need to be configured

Part 2: DataLink Layer

- hosts have dedicated, direct connection to switch
- switches buffer packets
- Ethernet protocol used on *each* incoming link, so:
  - no collisions; full duplex
  - each link is its own collision domain
- switching: A-to-A' and B-to-B' can transmit simultaneously, without collisions



switch with six interfaces (1,2,3,4,5,6)

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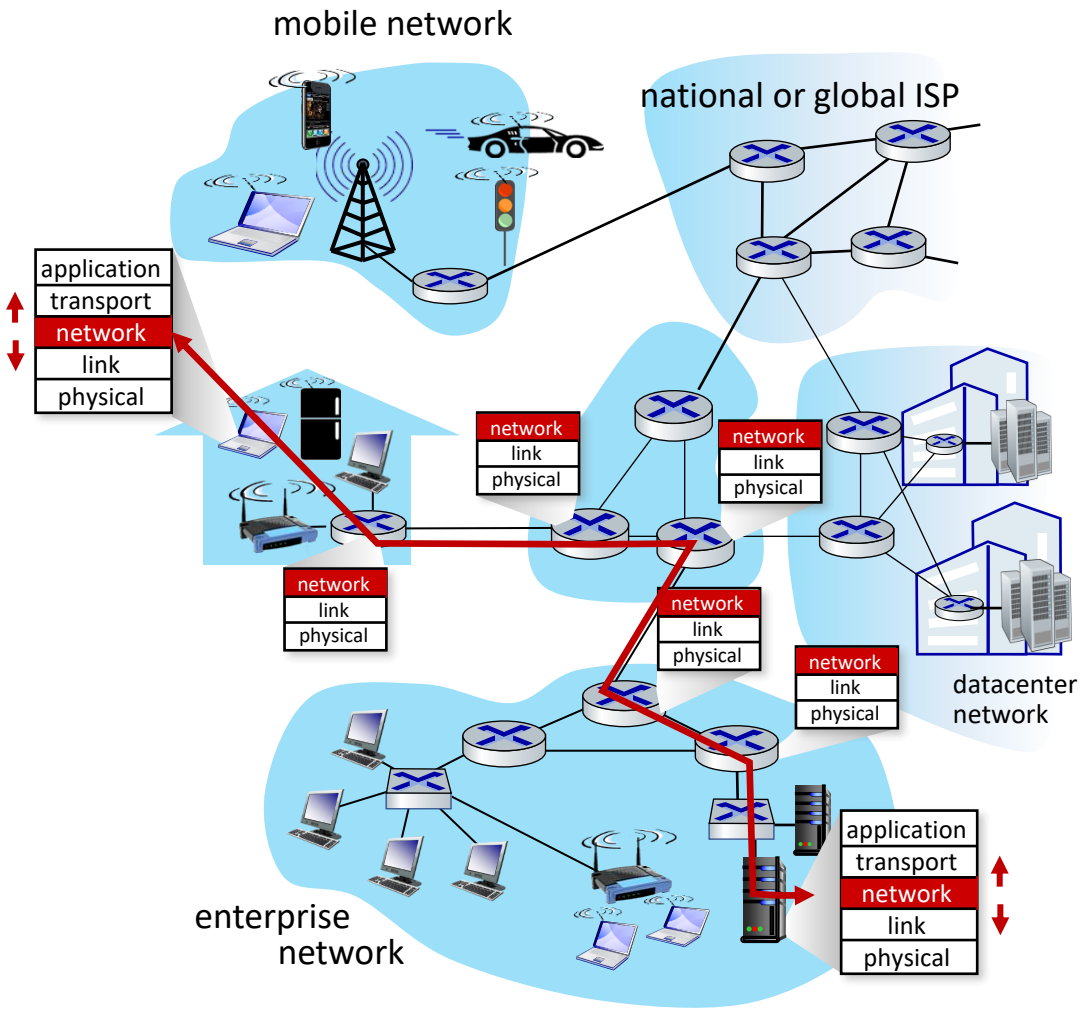
Part 3: Network Layer

- transport segment from sending to receiving host
  - sender: encapsulates segments into datagrams, passes to link layer
  - receiver: delivers segments to transport layer protocol
- network layer protocols in *every Internet device*: hosts, routers
- routers:
  - examines header fields in all IP datagrams passing through it
  - moves datagrams from input ports to output ports to transfer datagrams along end-end path



Part 3: Network Layer

network-layer functions:

- *forwarding:* move packets from a router's input link to appropriate router output link
- *routing:* determine route taken by packets from source to destination
  - *routing algorithms*

analogy: taking a trip

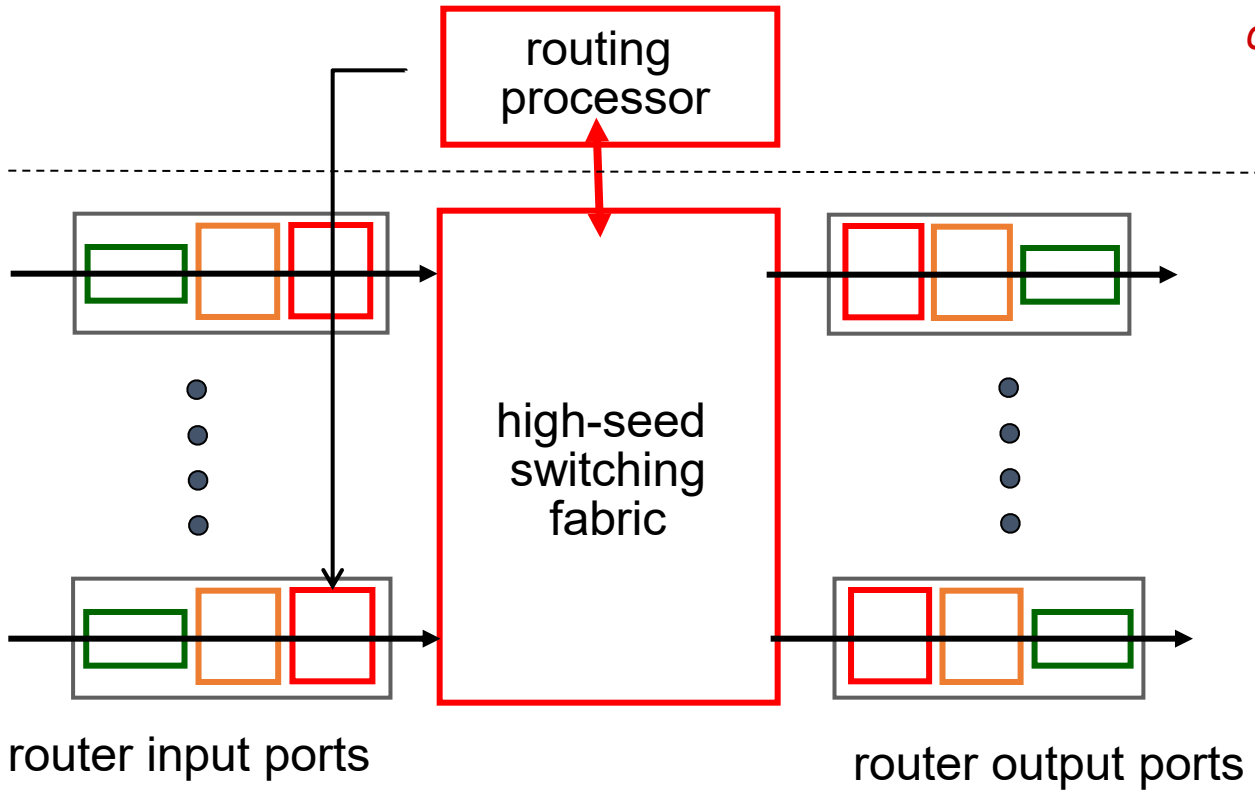
- *forwarding:* process of getting through single interchange
- *routing:* process of planning trip from source to destination

forwarding

routing

Part 3: Network Layer

high-level view of generic **router** architecture:



routing, management control plane (software) operates in millisecond time frame

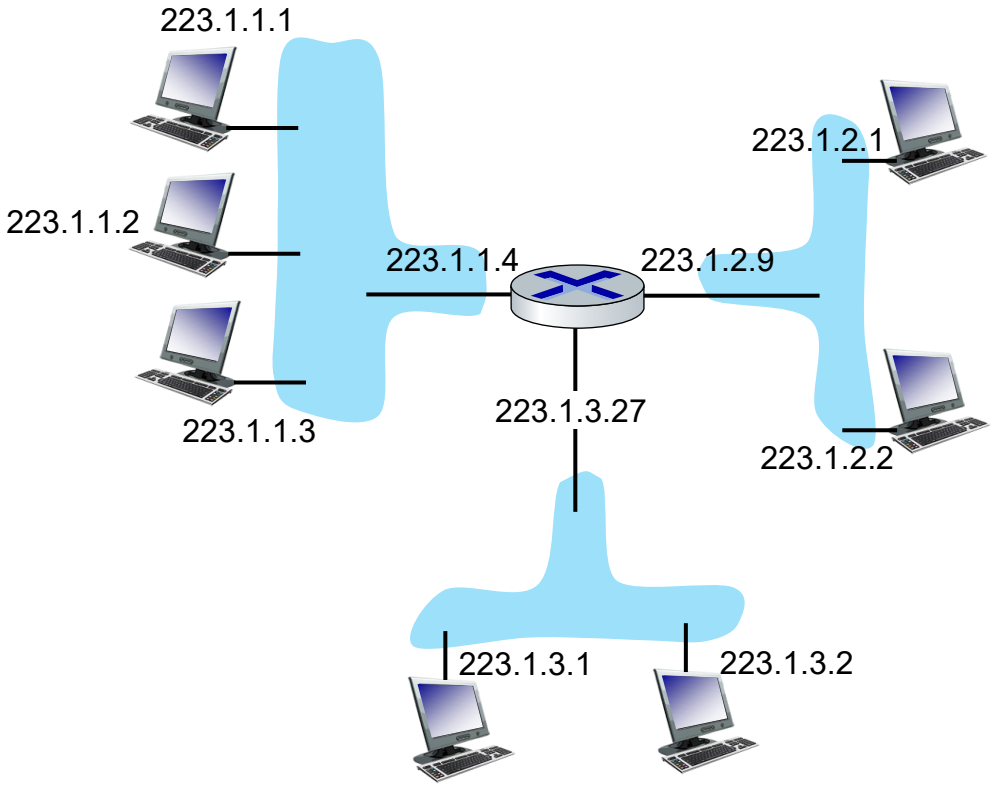
forwarding data plane (hardware) operttes in nanosecond timeframe

What are the basic functions of a router?

Part 3: Network Layer

- interface: connection between host/router and physical link
  - router's typically have multiple interfaces
  - host typically has one or two interfaces (e.g., wired Ethernet, wireless 802.11)
- *IP addresses associated with each interface*
- *IP address:* 32-bit identifier for host, router *interface*
  - 2^{32} possible IP address (40亿)

IP address ⟷ Device ?



dotted-decimal IP address notation:

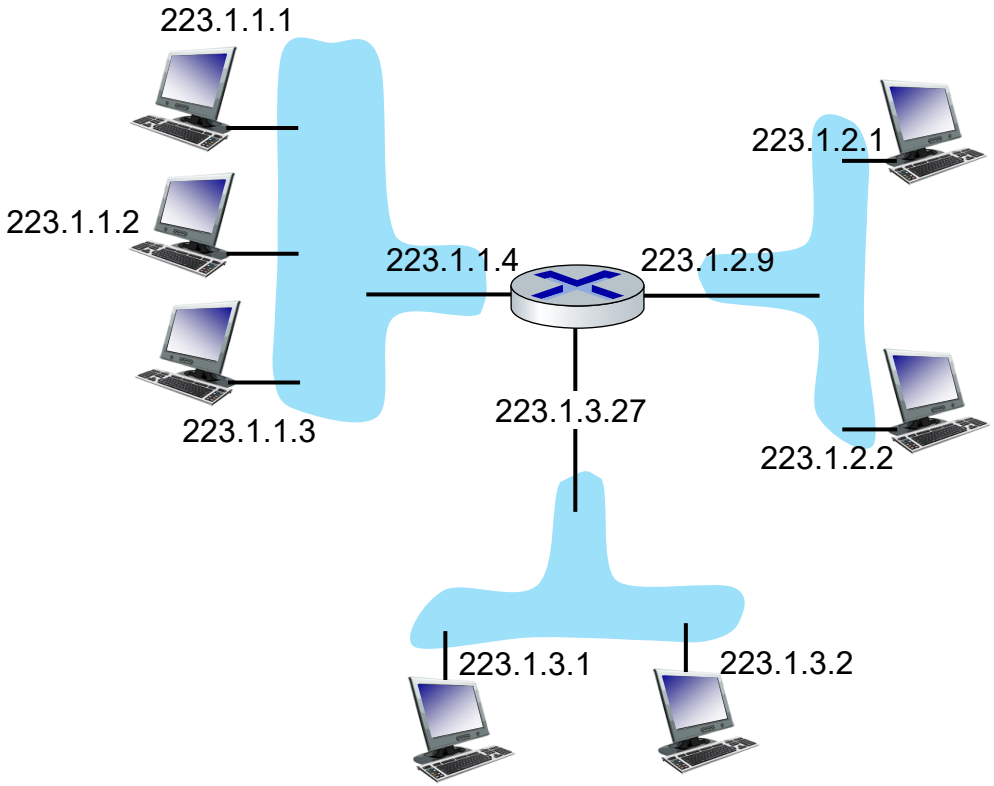
223.1.1.1 = 11011111 00000001 00000001 00000001

223 1 1 1

Part 3: Network Layer

- IP addresses have structure:
  - subnet part: devices in same subnet have common high order bits
  - host part: remaining low order bits

- *What's a subnet ?*
  - device interfaces with same subnet part of IP address
  - that can physically reach each other without passing through an intervening router

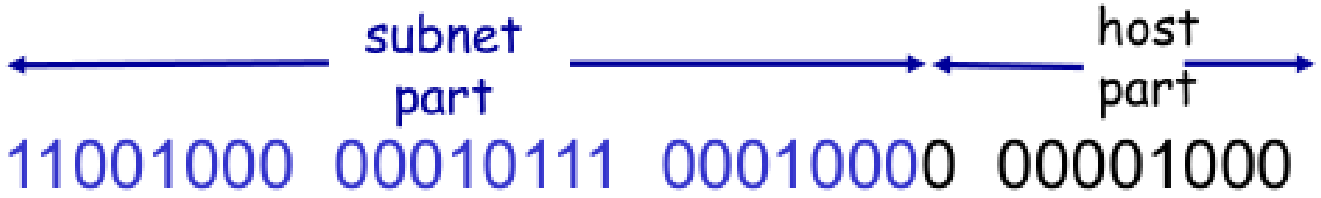


network consisting of 3 subnets

处于同一子网的计算机间数据直接传输
处于不同子网的计算机间数据由路由器转发

Part 3: Network Layer

- IP addresses have structure:
  - subnet part: devices in same subnet have common high order bits
  - host part: remaining low order bits



  - subnet mask(子网掩码):32bit
    - 1-subnet part 0-host part

Part 3: Network Layer

■How to obtain subnet address?

●IP address & subnet mask = subnet address

```
  11001000  00010111  00001000  00001000
& 11111111  11111111  11111111  00000000
-----------------------------------------
  11001000  00010111  0001000   00000000
```

■节点发送数据分组时，将分组的目标IP地址和节点自身的IP地址分别与子网掩码做按位与操作

●结果相同(同一子网)，直接传输

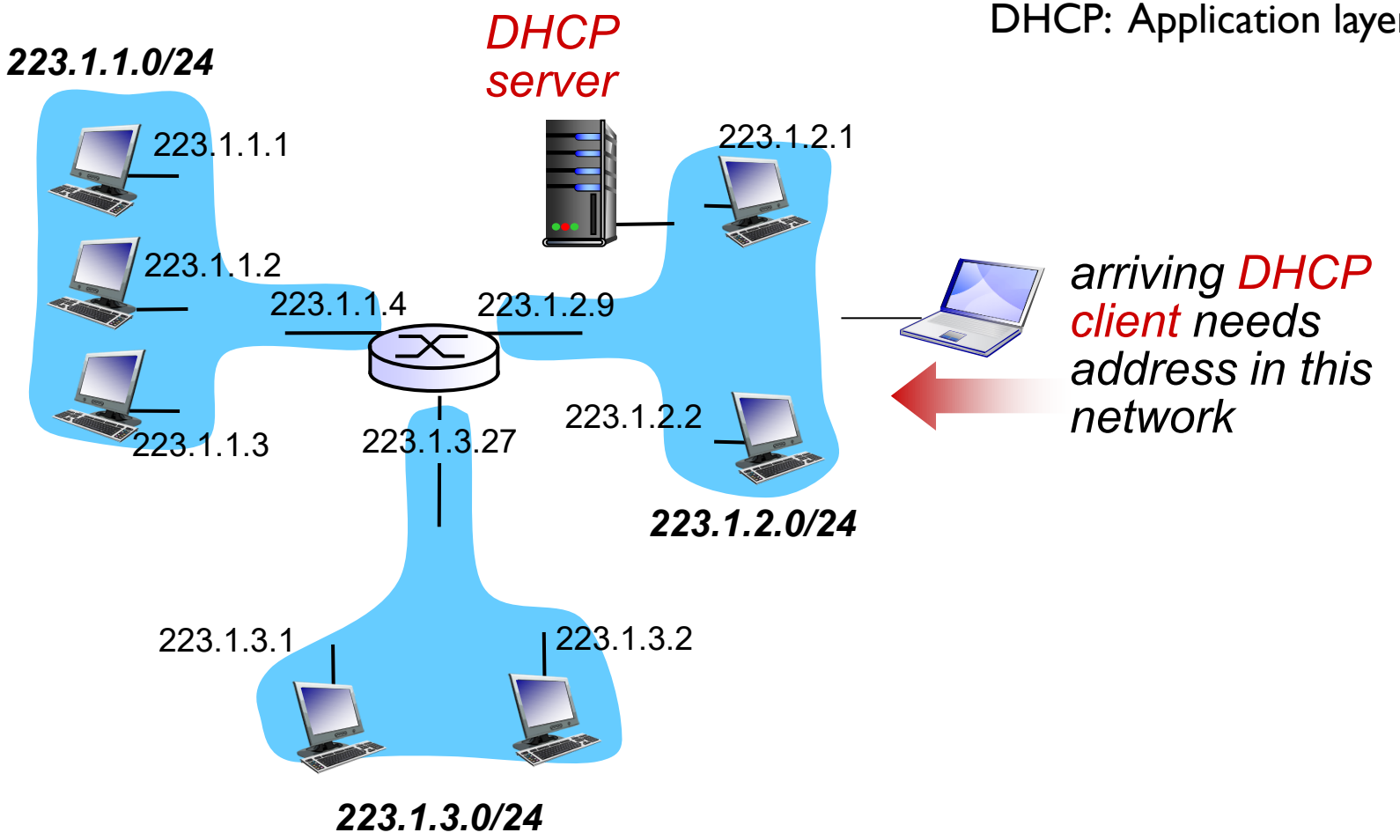
●结果不同(不同子网)，传输给默认路由器

Part 3: Network Layer

■How to get an IP address

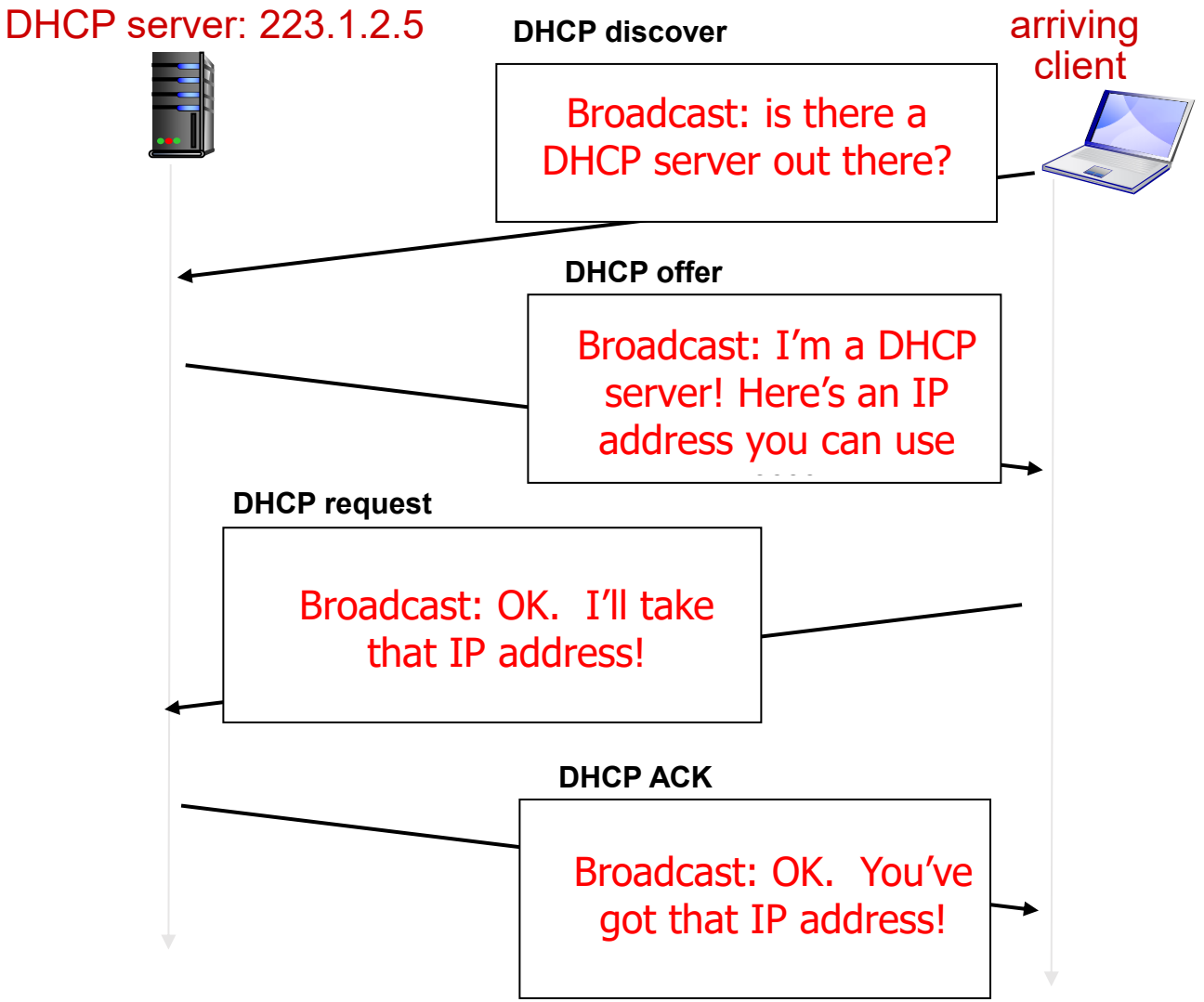
Server: Static IP address

DHCP: Application layer protocol



Part 3: Network Layer

DHCP discover
DHCP offer
DHCP request
DHCP ACK



Ipconfig

■查看本地主机的IP地址，子网掩码，默认路由器地址:**ipconfig**

- ●在开始菜单->运行中键入“cmd”命令，启动命令提示符
- ●在命令提示符中输入“ipconfig”，检查本地计算机的网络配置

```
Ethernet adapter Local Area Connection:

   Connection-specific DNS Suffix  . :
   Description . . . . . . . . . . . : Intel(R) Ethernet Connection I217-LM
   Physical Address. . . . . . . . . : EC-B1-D7-46-2C-C8
   DHCP Enabled. . . . . . . . . . . : No
   Autoconfiguration Enabled . . . . : Yes
   Link-local IPv6 Address . . . . . : fe80::f0cd:605e:be22:d93%11(Preferred)
   IPv4 Address. . . . . . . . . . . : 192.168.1.99(Preferred)
   Subnet Mask . . . . . . . . . . . : 255.255.255.0
   Default Gateway . . . . . . . . . : fe80::8ed:ae41:fcc9:1955%11
                                       192.168.1.254
   DHCPv6 IAID . . . . . . . . . . . : 250393047
   DHCPv6 Client DUID. . . . . . . . : 00-01-00-01-21-4B-1B-7F-EC-B1-D7-46-2C-C8

   DNS Servers . . . . . . . . . . . : 192.168.1.1
   NetBIOS over Tcpip. . . . . . . . : Enabled
```

Ping

- **Ping**命令 检查两台计算机是否连通与往返时延
- 工作原理:
  - -向目标主机发送一个分组，要求目标主机回复这个分组，根据收到回复的时间确定连接的时延
- 语法:
  - ping域名
  - ping IP地址
    - -在开始菜单->运行中键入“cmd”命令，启动命令提示符
    - -在命令提示符中输入“ping baidu.com"

Tracert

■**Tracert路由追踪**：用于确定IP数据包访问目标所采取的路径。

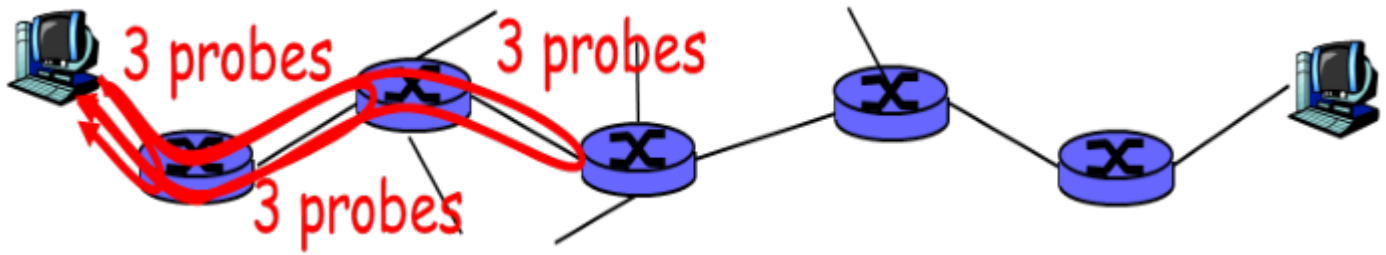
■工作原理:

- ●- Tracert命令用数据分组的生存时间(TTL)字段和错误消息来确定从一个主机到网络上其他主机的路由。
- ●-路径上的每个路由器在转发数据包之前至少将数据分组上的TTL减1。数据包上的TTL减为O时，路由器会将错误消息发回源主机。
- ●–源主机通过错误消息可以获知丢弃数据分组的路由器的IP地址

Tracert(续)

■工作过程:

- ●向目标主机发送3个TTL=1的分组，第一个路由器将丢弃这三个分组，并返回错误信息，可获知第一个路由器的地址和往返时延
- ●向目标主机发送3个TTL=2的分组，获取第二个路由器的地址和往返时延
- ●。 。 。
- ●直至分组到达目标主机



Tracert(续)

```
C:\Users\chengyh>tracert www.scu.edu.cn

通过最多 30 个跃点跟踪
到 www.scu.edu.cn [202.115.32.43] 的路由:

  1    <1 毫秒   <1 毫秒   <1 毫秒 192.168.1.1
  2     4 ms     4 ms     4 ms  1.112.237.221.broad.cd.sc.dynamic.163data.com.cn [221.237.112.1]
  3     5 ms     *        *     125.71.138.17
  4     *        *        *     请求超时。
  5     *        *        *     请求超时。
  6     *        *        *     请求超时。
  7    34 ms    32 ms    32 ms  101.4.117.157
  8    36 ms    37 ms    35 ms  101.4.118.170
  9     *        *        *     请求超时。
 10    50 ms    50 ms    51 ms  101.4.112.194
 11     *        *        *     请求超时。
 12    53 ms    53 ms     *     202.115.255.14
 13    17 ms    16 ms     *     2.32.88.218.broad.cd.sc.dynamic.163data.com.cn [218.88.32.2]
 14    50 ms    49 ms    50 ms  202.115.39.206
 15     *        *        *     请求超时。
 16    59 ms    54 ms    54 ms  202.115.39.102
 17    52 ms    52 ms    52 ms  po.scu.edu.cn [202.115.32.43]

跟踪完成。
```