Computer Networks

计算机网络（42034403）

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Office hour: 17:00 – 18:00 in A310 or by appointment

同濟大学
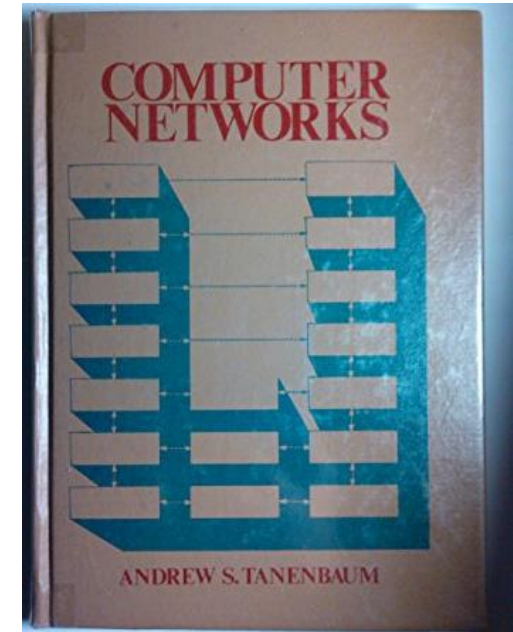TONGJI UNIVERSITY

09
Review Session

Tips for Review

- **For each chapter**
  - *Concepts:*
    - *Definitions/Functions*
    - *Comparisons*
  - *Mechanisms: a diagram or pseudo code*

- **Key Architecture: reference models**
  - OSI Model
  - TCP/IP Model

  The Hybrid Model we used

WHY, WHAT and HOW

Prentice Hall, 1985

9.1
Introduction

Classification of Computer Networks

- **By scale/range:**

  - *The Internet – planet wise 'the one, the only' (previously ARPANET)*

  - *Wide Area Network (**WAN**) – country to continent wise*

    Co-ax, fiber, satellite…

  - *Metropolitan Area Network (MAN) – city wise*

  - *Local Area Network (**LAN**) – ranges from several Km to 10 m*

    Ethernet, WiFi

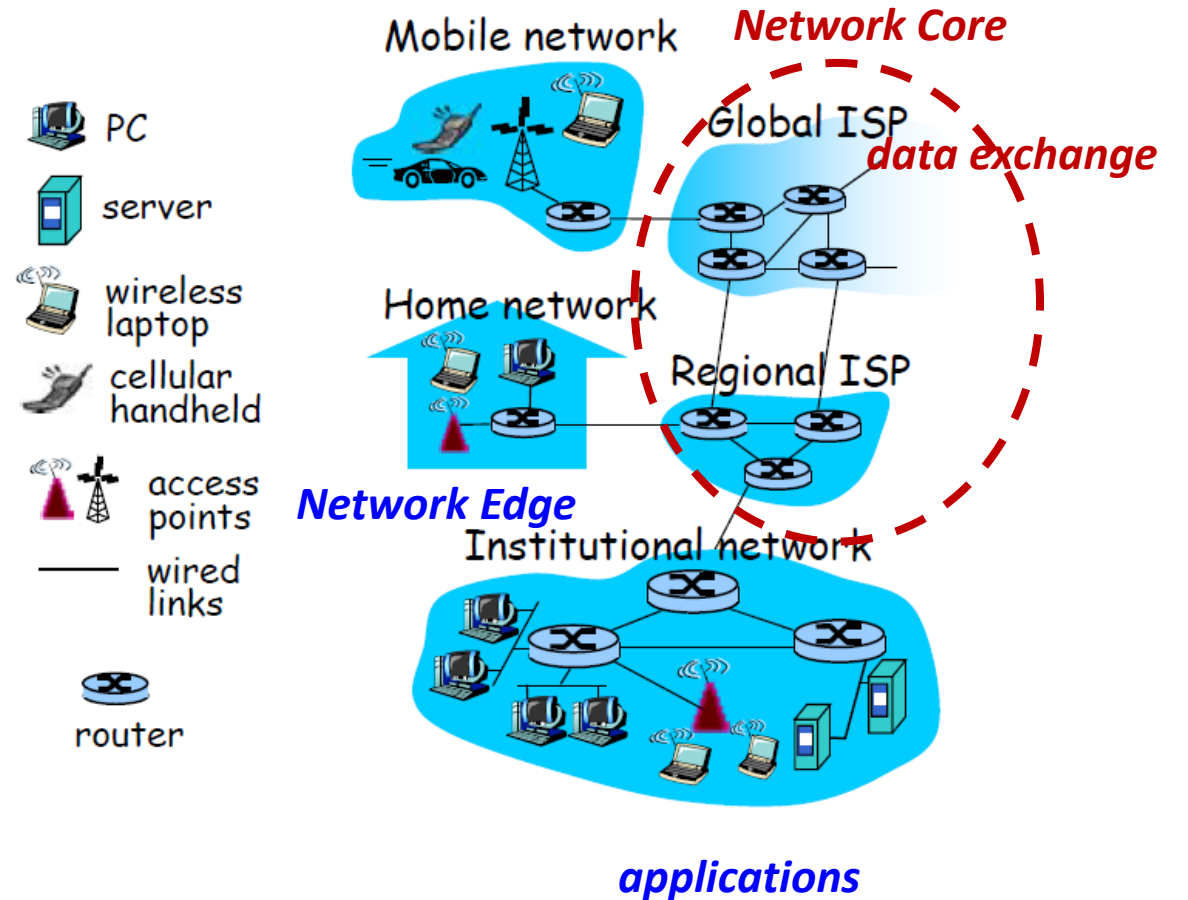 - *Personal Area Network (PAN) – <10 m*

    Bluetooth, Zigbee

Composition of the Internet

- **Access Network - edge**
  - **ADSL**: *asymmetric digital subscriber line*
    - *downlink - higher speed*
    - *uplink - lower speed*
  - *FTTH: fiber-to-the-home*
  - *Wireless: WiFi, cellular(4G,5G)*

- **Core Network**
  - *IP: connectionless*
  - *Frame Relay and ATM (asynchronous transfer mode) - seldomly used.*

Consider the technologies we learned, where do they belong?

Packet Switching v.s. Circuit Switching

- **Packet Switching:** *store-and-forward, each packet handled individually.*

- **Circuit Switching**: *connection-oriented, need to setup.*

	Circuit Switching	Packet Switching
Delay	Constant	Variable
Order	Data arrive in order	Packets may arrive out of order
BW Efficiency	Inefficient (dedicated)	Efficient (on-demand)
Routing	Simple	Complex
QoS	'All or nothing'	'Graceful degradation'
Control	Low complexity	High complexity
Scenario	Voice communication	Data communication

Modem (MOD/DEMOD)

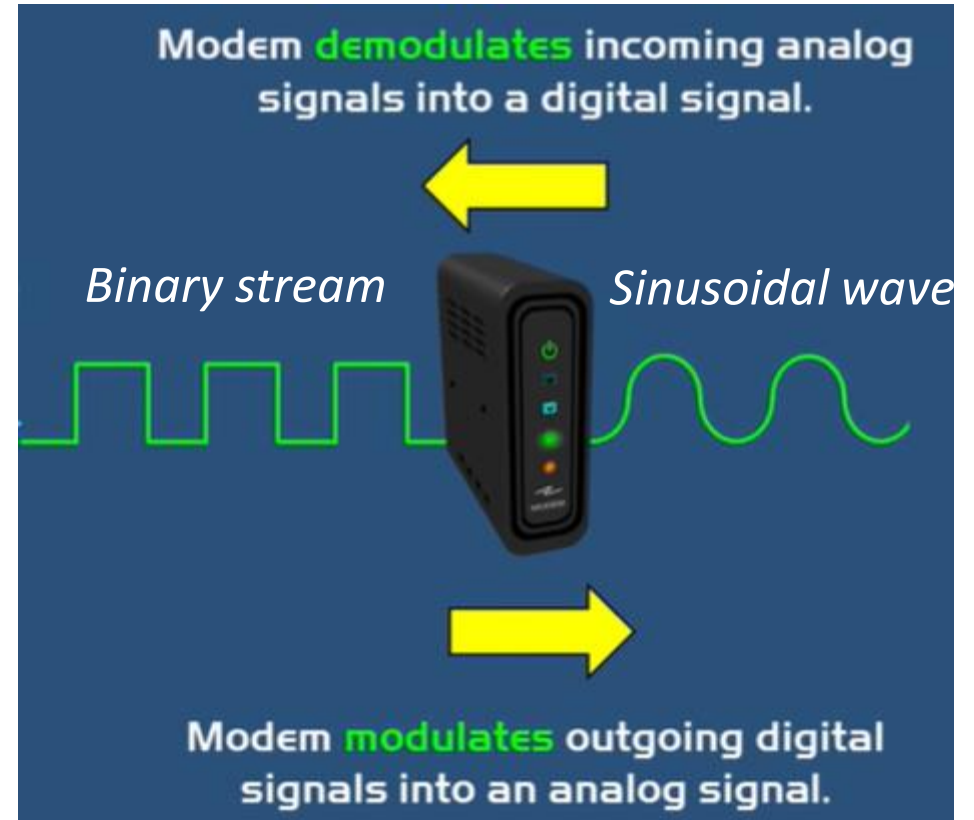- **Modem:** *converts between digital and analog signal.*

  - *Baud rate, or symbol rate*

  - *Bit rate, or data rate*

    = Baud rate * X bit/symbol

- **Modulation**

  - *AM, FM, PM*

  - *carrier: electro-magnetic waves*

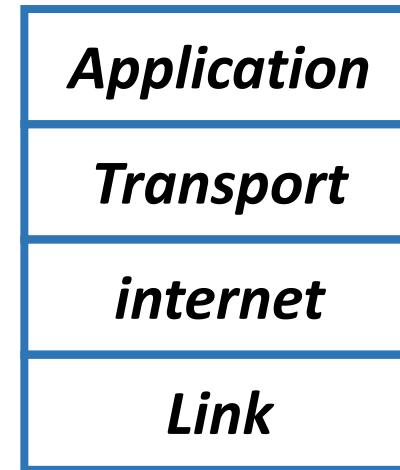Modem **demodulates** incoming analog signals into a digital signal.

Binary stream   *Sinusoidal wave*

Modem **modulates** outgoing digital signals into an analog signal.

Reference Models: OSI v.s. TCP/IP

- **OSI: functions of each layer**
- **TCP/IP: protocols on each layer**
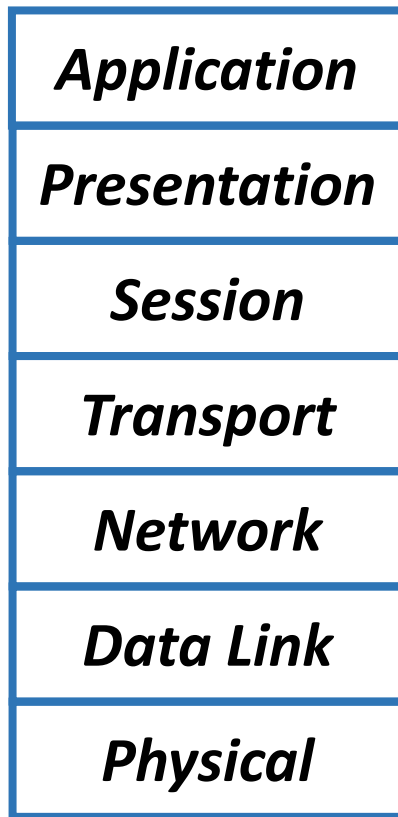
OSI
Application
Presentation
Session
Transport
Network
Data Link
Physical

TCP/IP
Application
Transport
internet
Link

Performances of a Network

- **Traditional:**

  - *Delay*

  - *Throughput/data rate*

  - *Jitter*

  - *Packet Loss*

- **Many others:**

  - *BER of links*

  - *Channel capacity*

  - *Channel efficiency/utilization*
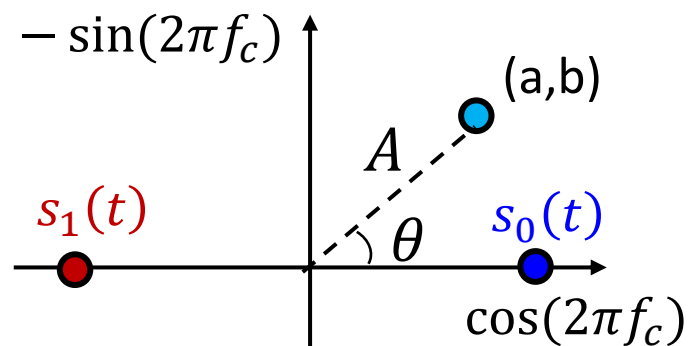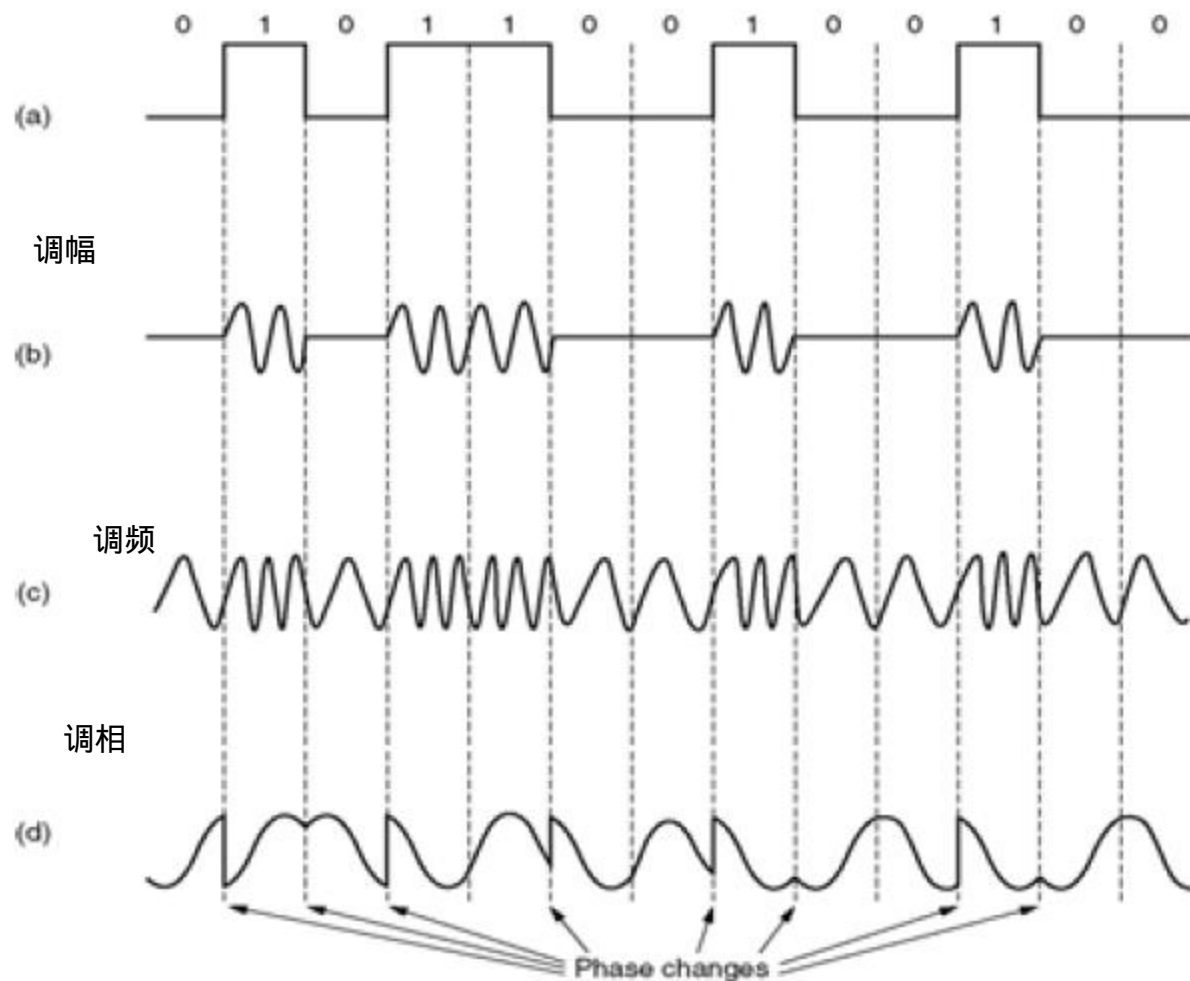
  - *Fairness*

Definition (how to calculate)

9.2

PHY

Modulation

Modulation: *switching (also called keying) the* *amplitude(幅度)**,* *frequency(频率)**, or* *phase(相位)* *of the carrier (载波) in accordance with the information (binary digits, 0s and 1s)*

$-\sin(2\pi f_c)$

(a,b)

A

θ

$s_1(t)$ $s_0(t)$

$\cos(2\pi f_c)$

Constellation
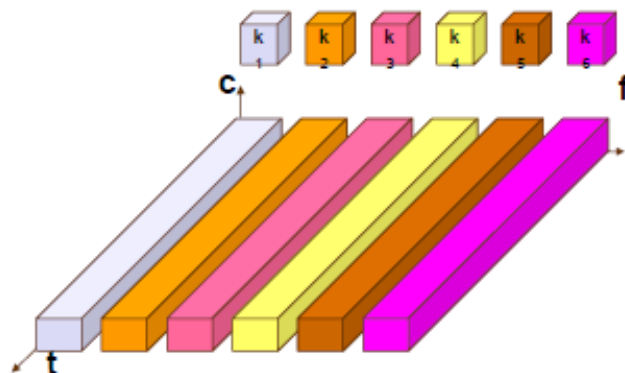
Transmission Medium

- **Guided media:** *signal propagates along a direction, usually solid media,*

  e.g. copper (wire), fiber, co-ax cable

  - *data rate*

  - *performance against interference*

- **Unguided media:** *signal propagates freely,*

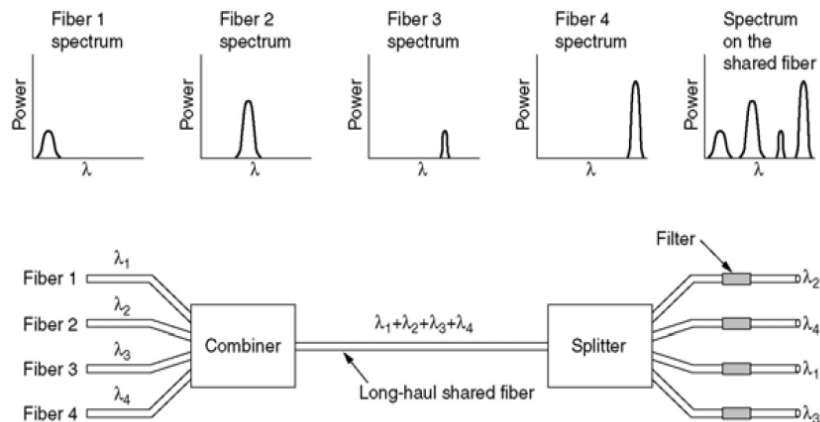 *e.g. air, vacuum*

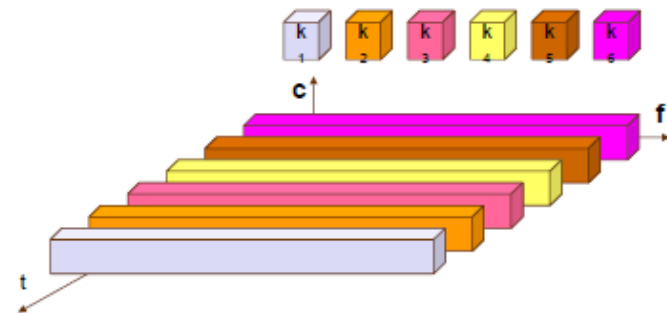# Multi-Access, Multiplexing

WDMA   FDMA

- ***FDMA***

- ***WDMA***

- ***TDMA***

- ***CDMA***
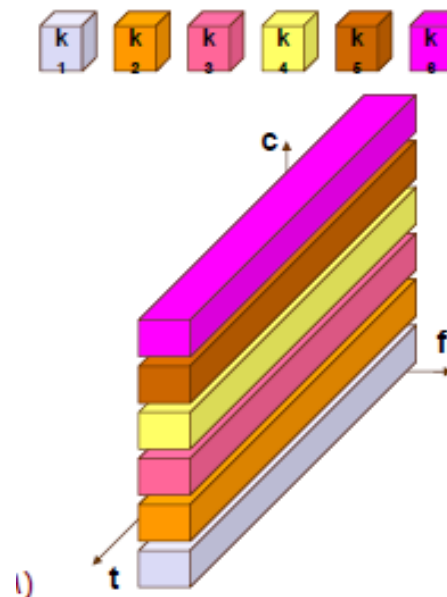
9.3
Link-DLC

Functions of DLC

- *Framing*

- *Error control*

- *Regulating data flow*

Error Control Coding

- **Even Parity**

- **CRC**

- **Hamming Code**

- **Codeword**

- **Hamming distance**

- **Detection v.s. Correction**

- **How does each one work?**

ARQ Mechanisms

- ***Stop-And-Wait (SAW)***

  - *transmit -> wait for the ACK -> carry on*

  - *"half-duplex" because of ACK*

- ***Go-Back-N (GBN)***

  - *sometimes called the "sliding window" 滑动窗口*

  - *increases utilization (compared to SAW)*

- ***Selective Repeat Protocol (SRP)***

  TCP

  - *(further) increases efficiency*

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9.4
Link-MAC

Medium Access Control (MAC)

- **Multiple Access: Allocation of a single broadcast channel**

- *Random Access MAC protocols*

  - *Collision*: When 2 or more nodes are transmitting

  - Key questions/ what random access protocols specify:

    1. *How to detect collisions?*

    2. *How to recover from collisions?*

  - **Contention System**: multiple users share a common channel in a way that leads to conflicts.

    - *contention/collision zone/domain*

CSMA

- ***CSMA***

CSMACDA

- ***CSMA/CD***

- ***CSMA/CA***

- ***What does each name mean?***

- ***How does each one work?***

- ***Main differences?***

- ***Application scenarios?***

Addressing

- **MAC Address, PHY address, Ethernet Address**

- **Stick to the device/NIC**

- **48 bit, or 6 groups of Hex numbers**

- **Range of each byte: 00 to FF**

- **Special addresses:**
  - *00:00:00:00:00:00 - unknown*
  - *FF:FF:FF:FF:FF:FF - broadcast*
  - *01:00:5E:XX:XX:XX - groupcast (historically only half of these addresses(23 bit))*

9.5
Network

The Network Layer

- ***Functions of the Network Layer: routing from the source to destination***

  - ***Routing****: protocols - algorithms*

    - *Link State Routing, e.g., Dijkstra - OSFP*

    - *Distance Vector Routing, e.g., Bellman-ford - RIP*

    - *Hierarchical Routing, intra-AS, inter-AS - BGP*

  - **Congestion Control** *and* **QoS**

    - *Queue: FIFO, PQ*

    - *Scheduling: Round Robin, WFQ*

    - *Traffic Shaping: Leaky bucket, Token bucket*

  - ***Addressing****: IP addresses, subnetting, Forwarding Table*

IP Addressing

- **Format:** *32-bit, usually in dot-decimal form*

- **Function:** *Specifies **an interface** (network connection), not a host!*
  - *IP address may change. A (multi-homed) host may have multiple addresses.*

- **Hierarchical:** *2-level (roughly) : network id + host id*

|	
Dotted decimal IP address	152 . 1 . 54 . 48 /24
32-bit IP address	1001 1000 0000 0001 0011 0110 0011 0000
Subnet Mask	1111 1111 1111 1111 1111 1111 0000 0000
Subnetwork address	1001 1000 0000 0001 0011 0110 0000 0000
Dotted decimal subnet address	152 . 1 . 54 . 0

CIDR:

- *collapse a block of contiguous addresses into a single logical network*

- *Net. Addr/mask*

Network Configuration and Forwarding Table

A Simple Static Configuration Example

*Try it: **route print** on your laptop/desktop*
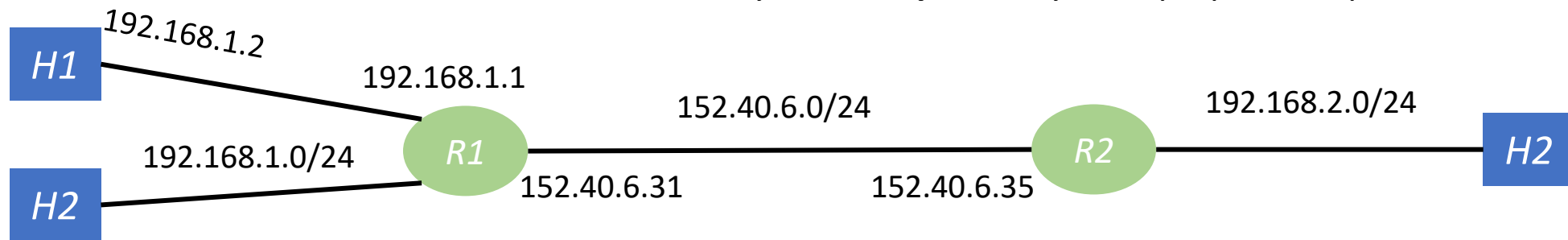
Configuration of H1

- *IP address: 192.168.1.2*
- *Subnet Mask: 255.255.255.0*
- *Default Gateway: 192.168.1.1*

Forwarding Table at R1

Destination	Mask	Next-Hop
192.168.1.0	255.255.255.0	direct
152.40.6.0	255.255.255.0	direct
0.0.0.0	0.0.0.0	152.40.6.35

Aiding Protocols for IP − ICMP, NAT

- **ICMP (RFC792): Internet Control Message Protocol**
  - *Communicate network-level errors or information about unexpected circumstances.*
  - *Only report errors, no handling actions.*
  - *Encapsulated in IP datagrams.*

- **NA(P)T: Network Address (Ports) Translation**
  - *IPv4: exhaustion of addresses - share a public address*
  - *IPv6: security reasons*
  - *IPv4 - IPv6: NAT-PT*

I P

ICMP IGMP IP ARP RARP
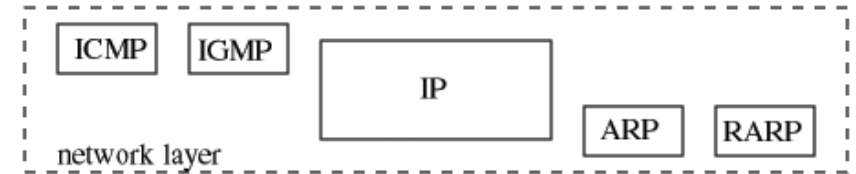
network layer

(a) Position of ICMP in the network layer

ICMP message

IP header IP data

Frame header Frame data Trailer

(b) ICMP encapsulation

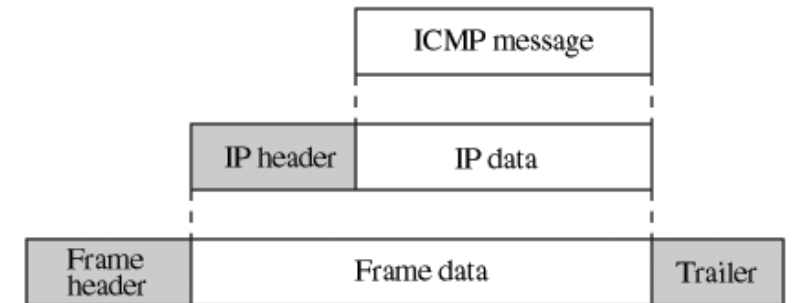# *Aiding Protocols for IP - ARP*

- **ARP (RFC 826): Address Resolution Protocol**

  - *(Dynamically) mapping between IP and MAC addresses*

  - *For broadcast networks, e.g. Ethernet, Token Ring.*

  - *RARP: MAC -> IP*

  - *ARP: IP -> MAC*

Who has IP address 152.14.88.52 ? Tell me (58:b0:35:b4:f3:c0) your physical address

Request

I have IP address 152.14.88.52 , and physical address 00:80:77:f0:b0:88

Reply
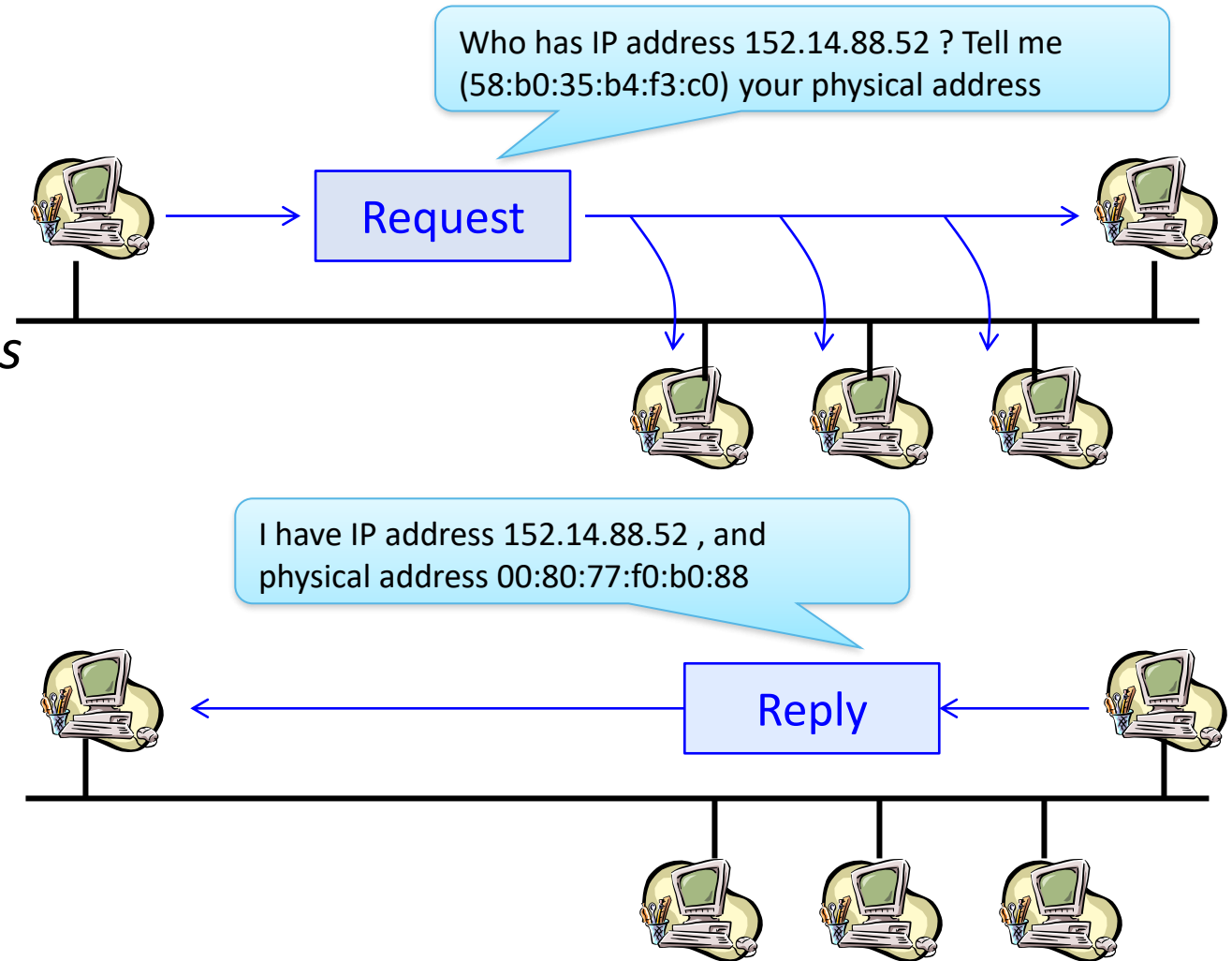
9.6
Transport

Function of the Transport Layer

- ***Functionality of the Transport Layer***

  - *Reliability -> ACK and retransmission (UDP does not have this!)*

  - *Flow Control -> rwnd (of receiver)*

  - *Congestion Control -> cwnd (of sender)*

- **Transmission Control Protocol (TCP)**

  - *Endpoints: IP + port*

  - *Connection: 3-way handshake, 4-way handshake*

  - *Congestion Control: phases, variables, flavors, performances*

- ***Client-Server model***

Transport Layer Protocols

- ## *UDP*

  - *Unreliable, unordered - NO ACK*

  - *Unicast/multicast delivery*

  - *Connectionless*

  - *Addressing: IP + Port*

  - *Upper layer protocols:*

- ## *TCP*

  - *Reliable, in-order*

  - *Unicast delivery*

  - *Connection-oriented*

  - *Addressing: IP + Port*

  - *Upper layer protocols:*

TCP Congestion Control

- ***Basic mechanism: Sliding Window*** $W = \min\{rwnd, cwnd\}$ ***+ Timer***

- ***Control variables: cwnd, ssthresh***

- ***Two phases:***
  - *slow start: exponential growth*

    How cwnd changes?
  - *congestion avoidance: AIMD*

- ***Two loss events: timeout, (3) dupACKs***

- ***Two flavors/versions: Tahoe v.s. Reno***

9.7
Application

Application Layer Protocols

- **Application Layer Protocols: too many**
  - *Key Questions:*
    1. *What do they do?*
    2. *(On a very basic level) How do they do it?*
    3. *Which transport layer protocol do they run on? And why?*

- **Check for yourself if you know**

  - *Addressing: DNS, DHCP*
  - *Web: URL, HTTP*
  - *Streaming: RTP, RTSP*
  - *File transfer: FTP*

  - *Routing: BGP, OSPF, RIP*
  - *Network Management: SNMP*
  - *Email: SMTP, IMAP, POP*
  - *Conferencing: H.323, SIP*

9.8
Network Security

Network Security

- **Cryptography -> Confidentiality**
  - **symmetric key**: same key, shared
  - **public key**: encrypt w/ which key, decrypt w/ which key

- **Authentication: to prevent playback attacks, man-in-the-middle attack**
  - KDC
  - CA

- **Message Integrity: Digital signature (public key crypto.)**

- **Access/Availability: Firewall**

Comparisons of Related Concepts

Simplex, Half-Duplex, Duplex

- **Simplex:** *can only receive, or can only send*

  - *E.g. Loud-speaker, light-house, one-way road (obeying traffic rules)*

- **Half-Duplex:** *can receive/send, but can not do it the same time*

  - *E.g. Walkie-talkie, narrow road, fax, (most) wireless devices*

- **(Full-)Duplex:** *can receive/send at the same time*

  - *E.g. Highway, wired connections, (roughly) Telephone*

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Most widely used LAN Technologies

- **Ethernet - IEEE 802.3**
  - *wired - Ethernet cables*

    types, data rates, range limits
    - *10BaseT, 100BaseT… "twisted pairs"*
    - *10Base2 - "Thinnet"*
    - *10Base5 - "Thicknet"*
  - *CSMA/CD*

- **WiFi - IEEE 802.11 family**
  - *wireless - problems*
    - *attenuation, noise/interference*
      - *Hidden terminal problem*
      - *Exposed terminal problem*
  - *Modes*
    - *Infrastructure (infra) mode: AP + STAs*
    - *Ad hoc mode: STAs*
  - *CSMA/CA*

Addresses

- **MAC Address**

  - *Layer 2*

  - *48 bits - 6 Octets*

  - *usually written in hex format*

  - *Tied to NIC*

  - *Special addresses*

    - *Unkown: 00:00:00:00:00:00*

    - *Groupcast: 01:00:5E:XX:XX:XX*

    - *Broadcast: FF:FF:FF:FF:FF:FF*

- **IP Address**

  - *Layer 3*

  - *24 bits - 4 Octets*

  - *usually in dot-decimal format*

  - *Changeable*

  - *Special addresses*

    - *(Subnet) network address: end with 0s.*

    - *Groupcast: 224.0.0.0 - 239.255.255.255 (Class D addresses, start with 1110...)*

    - *Broadcast: end with 1s.*

how many? determined by net size

Routing Protocols (on Application Layer)

- **OSPF**
  - intra-domain
  - static, global
  - link state
  - directly on IP
  - Dijkstra

- **RIP**
  - intra-domain
  - dynamic, local
  - distance vector
  - on UDP
  - Bellman-Ford

- **BGP**
  - inter-domain
  - admin over performance
  - path vector
  - on TCP

*Try it: **show ip route (on routers)** in your experiment class*

Network Devices

- **Modem**
  - PHY
  - Analog <-> Digital

- **Hub/Repeater**
  - PHY
  - Broadcast to all other ports what it receives from one port
  - One contention zone
  - Broadcast storm

- **Switch/Bridge**
  - Link layer -> use MAC address
  - Connect different network segments -> multiple contention zones
  - Filter: local frames stay local
  - Bridge may have broadcast storm; Switch does not (Spanning tree).

- **Router**
  - Network layer -> use IP address
  - Connect different subnetworks

Application Layer Protocols

Application Layer protocols	Functionality	Corresponding Transport Layer protocols
DNS		UDP + TCP
HTTP		TCP
SMTP		TCP
SIP		TCP/UDP
OSPF		No transport (in IP)
RIP		UDP
BGP		TCP
H.323 (protocol stack)		TCP/UDP
FTP		TCP

4 Modes of NIC

- **Broadcast:** *accept* broadcast *frames (address FF:FF:FF:FF:FF:FF)*

- **Multicast:** *accept* all groupcast *frames (even if it is not a member of the group)*

- **Direct:** *accept frames only destinated to itself (unicast address)*

- **Promiscuous** 混杂*: accept* all *frames - that's how Wireshark works*
  - *NIC of a switch/bridge works in this mode.*

- **Note**
  - *default mode of a NIC: Broadcast + Direct*