Computer Networks

计算机网络（42034403）

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

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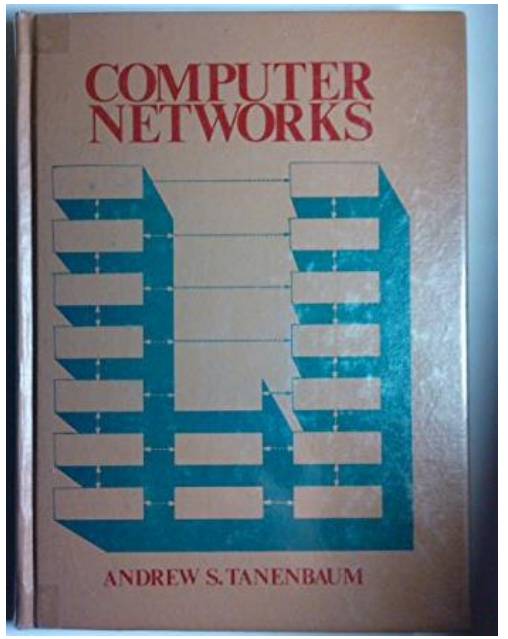
09 Review Session

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*

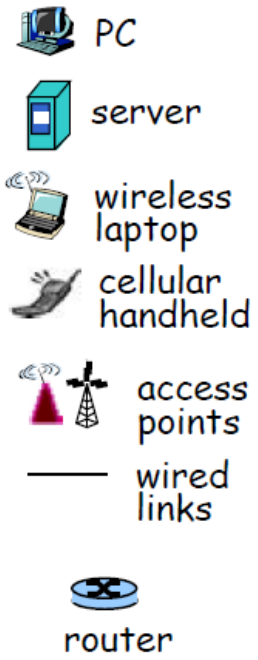
    Co-ax, fiber, satellite…
  - *Metropolitan Area Network (MAN) – city wise*
  - *Local Area Network (**LAN**) – ranges from several Km to 10 m*

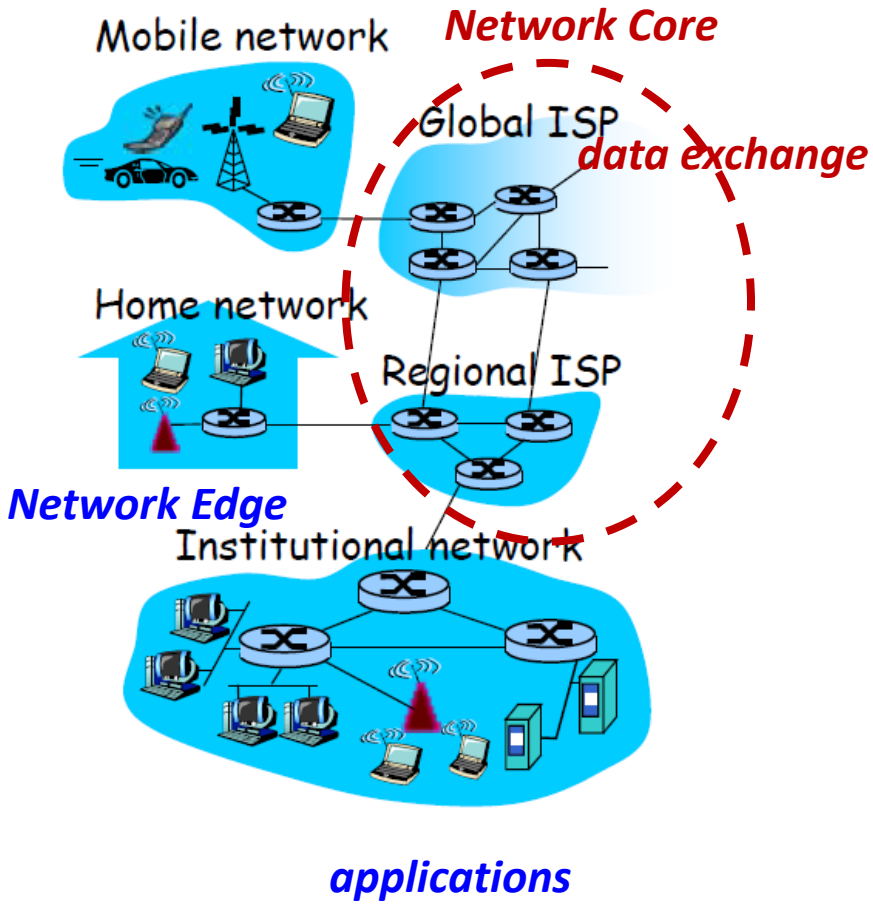
    Ethernet, WiFi
  - *Personal Area Network (PAN) – <10 m*

    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

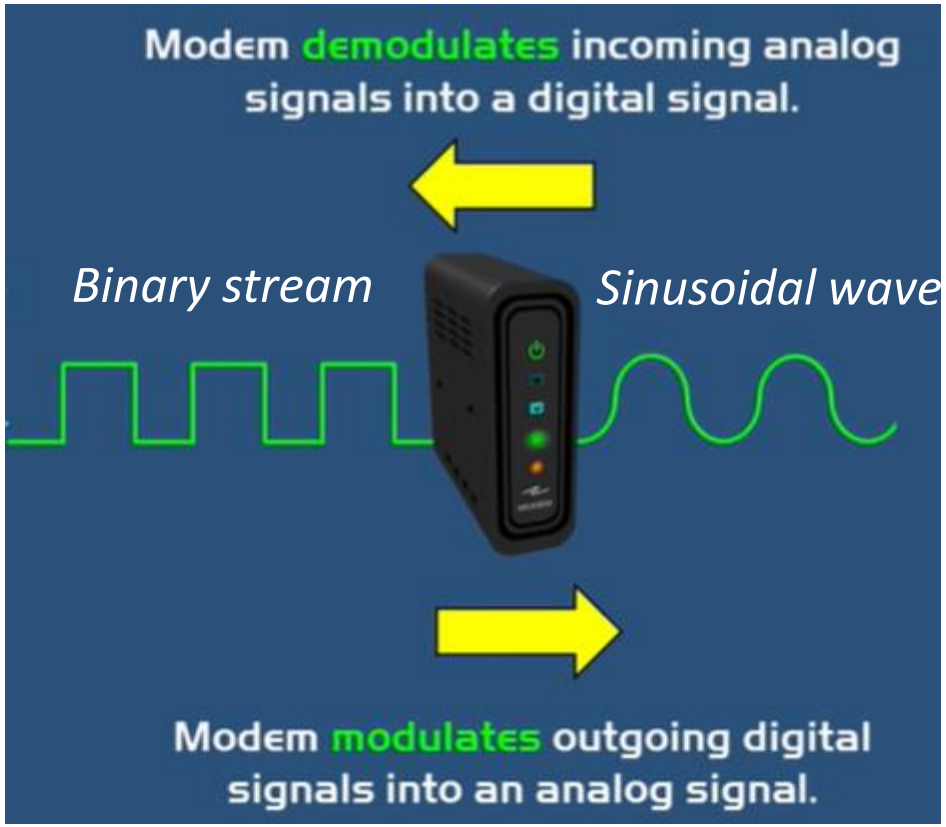
- ***Packet Switching:*** *store-and-forward, each packet handled individually.*
- ***Circuit Switching****: connection-oriented, need to setup.*

	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)

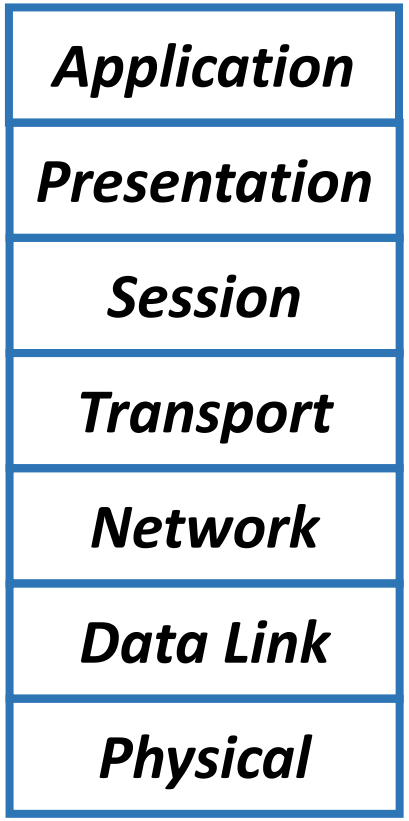
- ***Modem:*** *converts between digital and analog signal.*
  - *Baud rate, or symbol rate*
  - *Bit rate, or data rate*

    *= Baud rate * X bit/symbol*
- ***Modulation***
  - *AM, FM, PM*
  - *carrier: electro-magnetic waves*

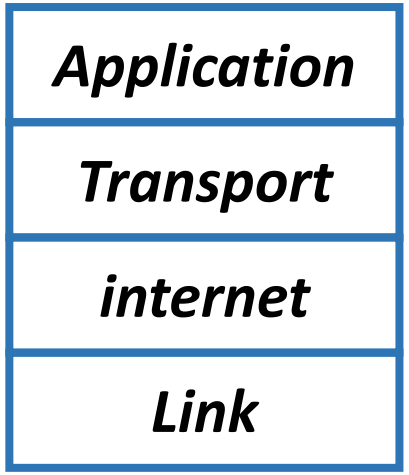


Reference Models: OSI v.s. TCP/IP

- ***OSI: functions of each layer***



- ***TCP/IP: protocols on each layer***



Performances of a Network

- ***Traditional:***
  - *Delay*
  - *Throughput/data rate*
  - *Jitter*
  - *Packet Loss*
- ***Many others:***
  - *BER of links*
  - *Channel capacity*
  - *Channel efficiency/utilization*
  - *Fairness*

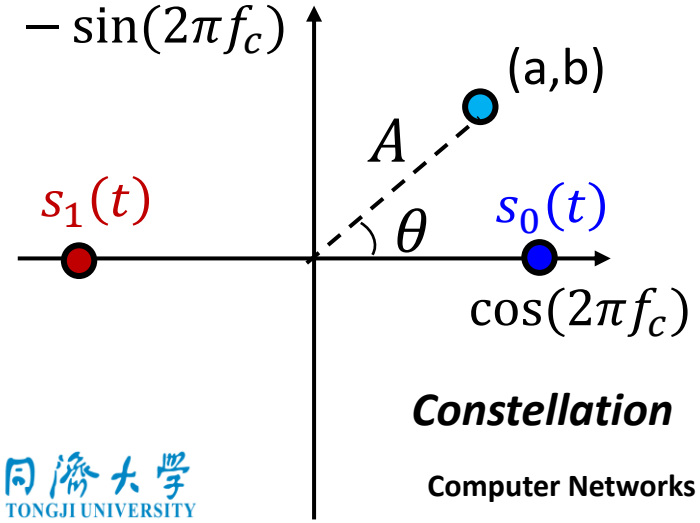
Definition (how to calculate)

9.2

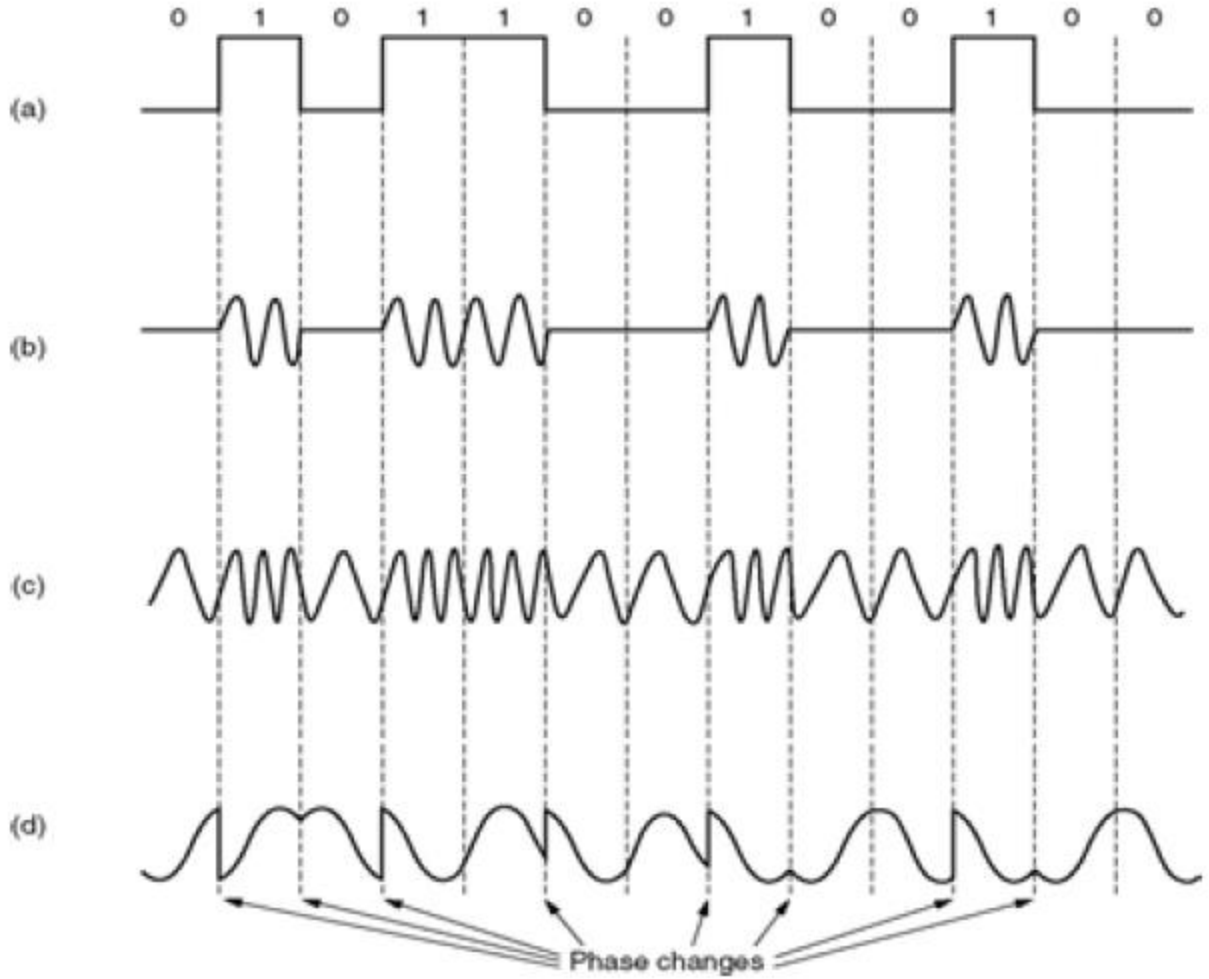
PHY

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)*



Constellation



Transmission Medium

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

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

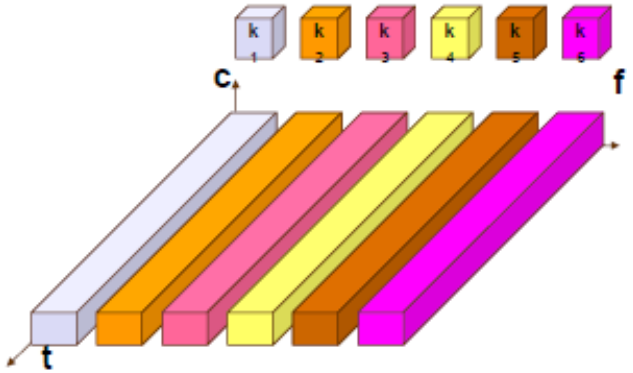
  - *data rate*
  - *performance against interference*

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

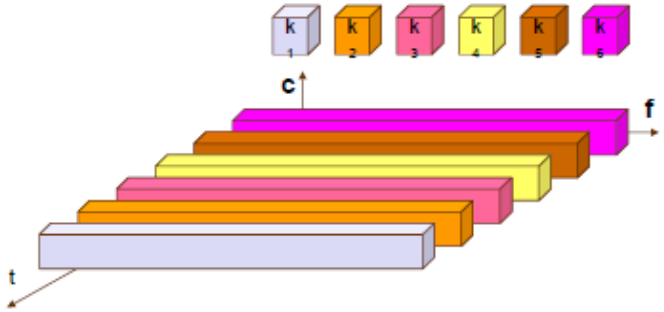
  e.g. air, vacuum

Multi-Access, Multiplexing

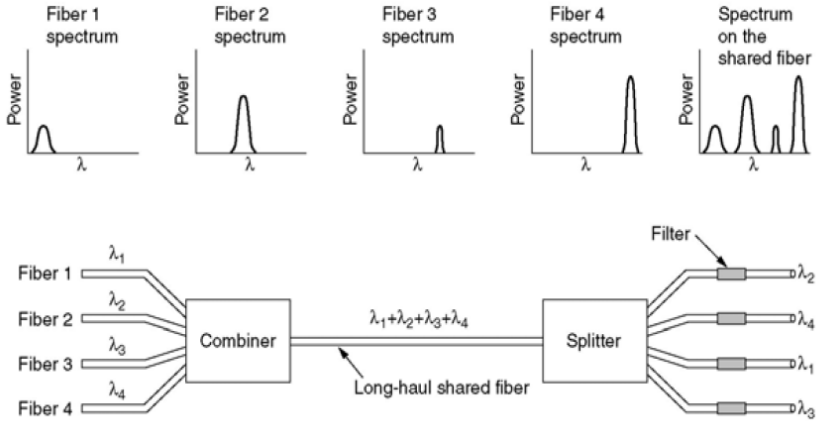
- ***FDMA***



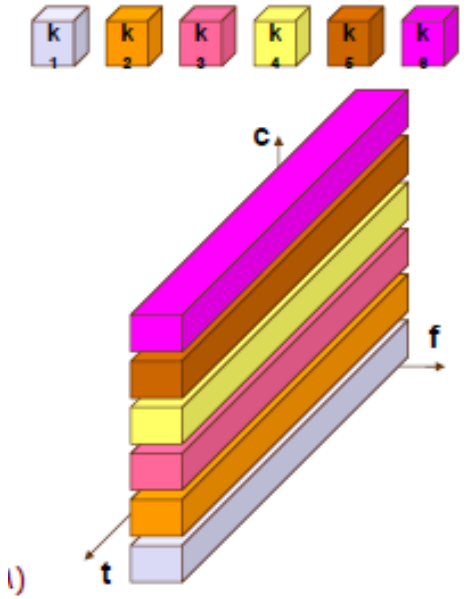
- ***TDMA***



- ***WDMA***



- ***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)***
  - *(further) increases efficiency*

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**

  Carrier sensing multiple access 侦听载波

- **CSMA/CD** Ethernet

  Collision detection

- **CSMA/CA** WiFi RTS, CTS

  collision avoidance

- ***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))*

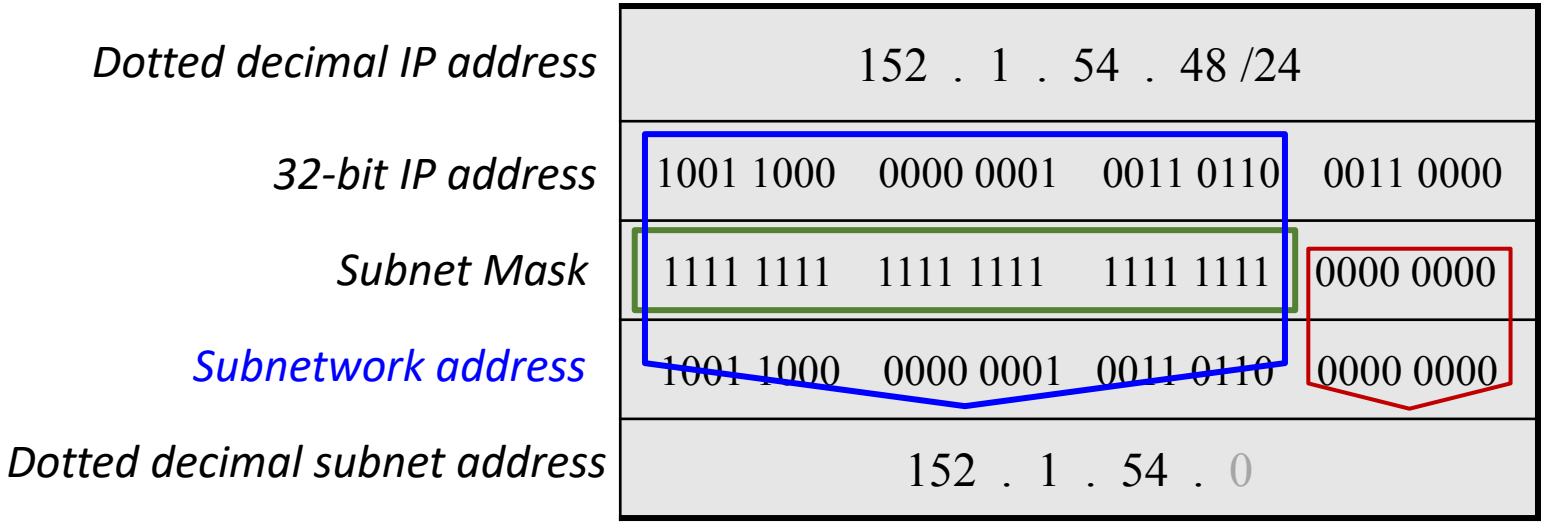
9.5 *Network*

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*



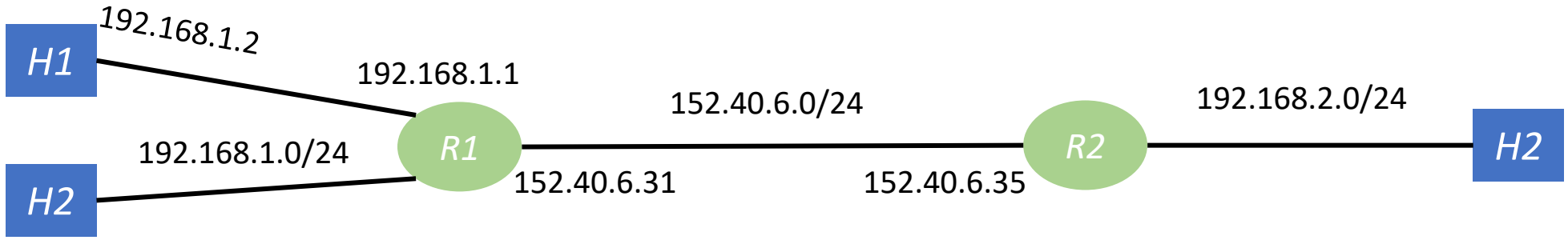
CIDR:

- *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*

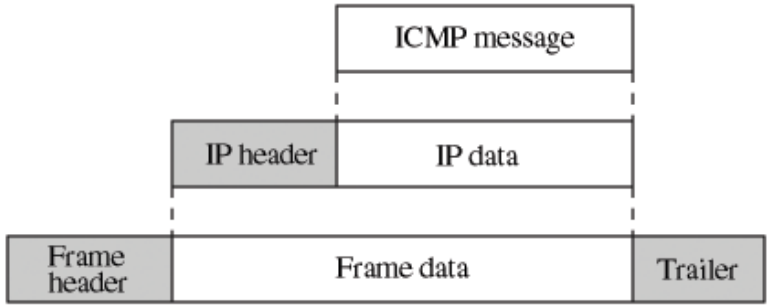
Forwarding Table at R1

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*

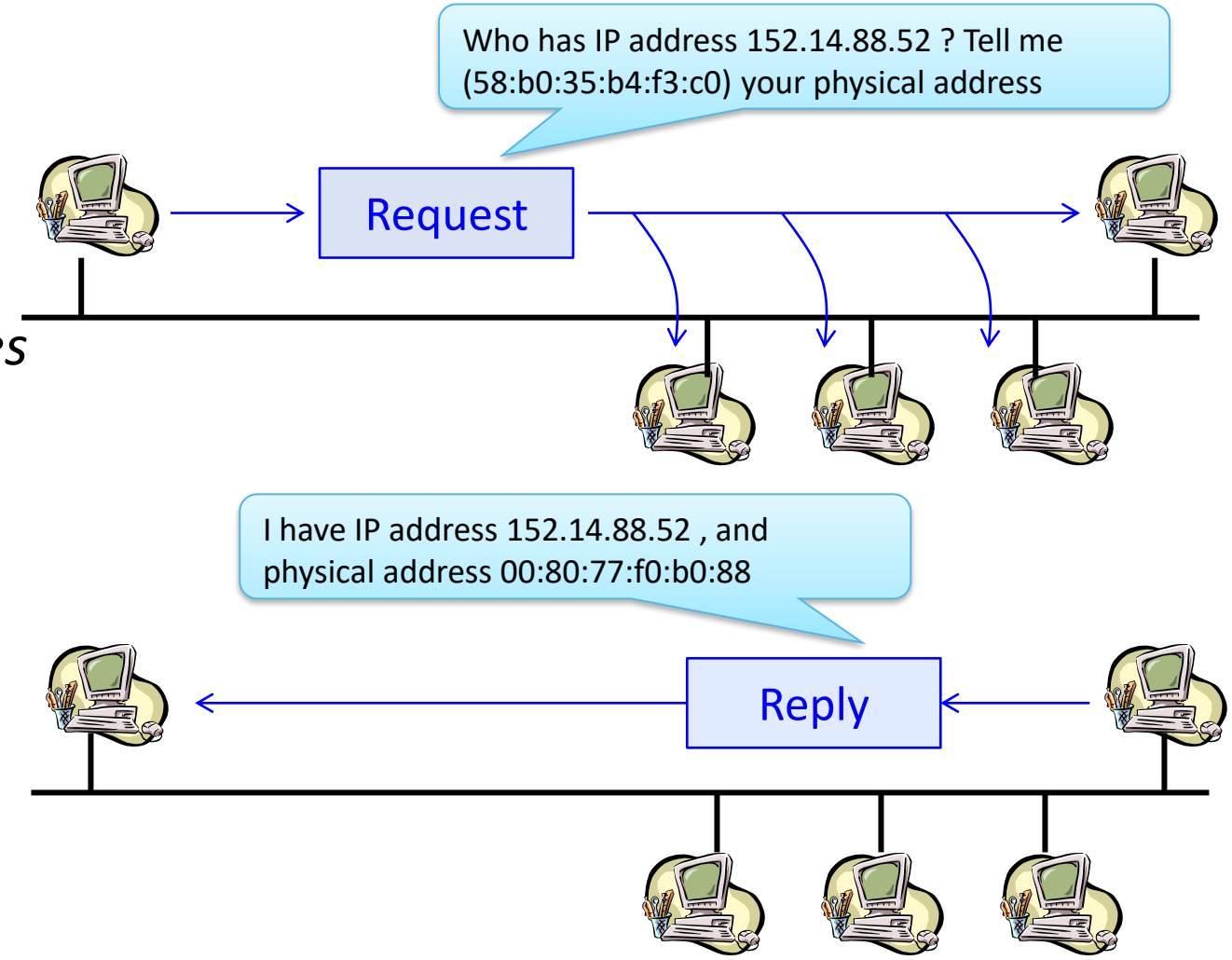
(a) Position of ICMP in the network layer



(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*



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*
  - *congestion avoidance: AIMD*

How cwnd changes?

- ***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*

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.* e.g. router, switch
- ***Note***
  - *default mode of a NIC: Broadcast + Direct*