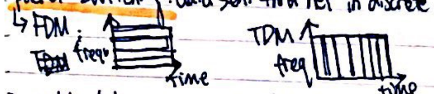
Chapter 0 Introduction

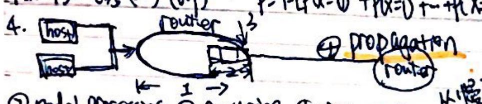
1. Bandwidth: 带宽 bits per second/Hz ~~High-used frequency~~ ~~low-used frequency~~ Data Rate: the maximum ability of a channel. Throughput: the real data received.

2. Circuit Switching: dedicated circuit per call eg. telephone net. Packet-switching: data sent thru net in discrete chunks
↳ FDM. TDM



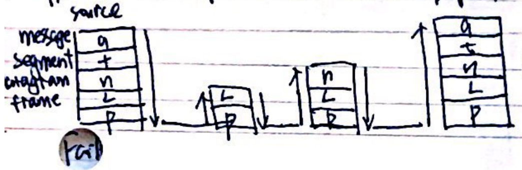
3. 1Mb/s link, each user: 100kb/s when active, 10% active
- circuit switching 10 users. total: 35 users.
- $P(x=k) = C_{35}^{k}(0.1)^k(0.9)^{35-k}$ $P = 1-[P(x=0)+P(x=1)+\dots+P(x=10)]$

4.



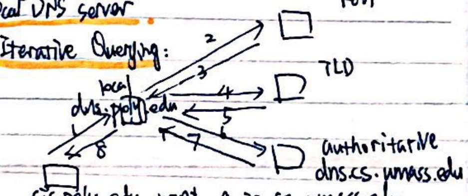
① nodal processing ② queueing ③ transmission
- transmission delay: time to send bits into link L/R
  L: packet length (bits) R: link bandwidth (bps)
- propagation delay: d/s d: length of physical link
  s: propagation speed in media 2×10^8 m/sec
- a: average packet arrival rate traffic intensity = La/R
- La/R ~ 0: small ~1: become large >1: infinite

5. application → transport → network → link → physical



4. Get: 取数据 Post: 提交数据 URL: use GET
5. total avg delay = Internet delay + access delay + LAN delay
6. HTTP: ← pull SMTP: → push
Email: SMTP: handshaking (greeting) / transfer of messages / closure; commands: ASCII text. response: status code & phrase; persistent connections; multi objects sent in multipart msg
POP3: authorization phase; transaction phase:
① list ② retr ③ dele quit stateless
"download & delete" "download-and-keep"
IMAP: keep all messages in one place, the server state. users can organize message in folders

7. Root DNS server
Top-level domain (TLD): com/org/net/uk/jp
Authoritative DNS. yahoo.com/amazon.com.
local DNS server
① Iterative Querying:



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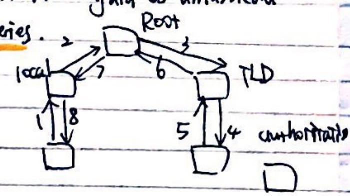
② Recursive Queries.

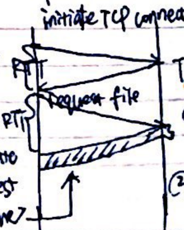


Chapter 1 Application Layer

1. TCP: connection-oriented, reliable transport, flow control, congestion control, timing, ~~minimum bandwidth guarantee~~

2. HTTP is stateless. Nonpersistent HTTP: at most one object is sent over a TCP connection
Persistent HTTP: multiple objects can be sent.
- initiates TCP connection → wait, accept, notifying
- send HTTP request ⇆ receive request, send response
- receive response ← close TCP connection.

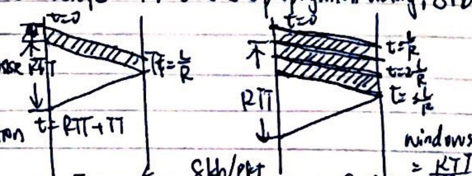
3. Round Trip Time (RTT): time to send a small pkt to travel from client to server and back
Response Time: 1 RTT to initiate TCP connection. 1 RTT for request
total = 2RTT + <file transmit time>



Chapter 2 Transport Layer

1. CW increase: ① CW = CW+1
② timeout: CW = 1+1 = 2
③ dup: CW = CW/2 + 3 + 1

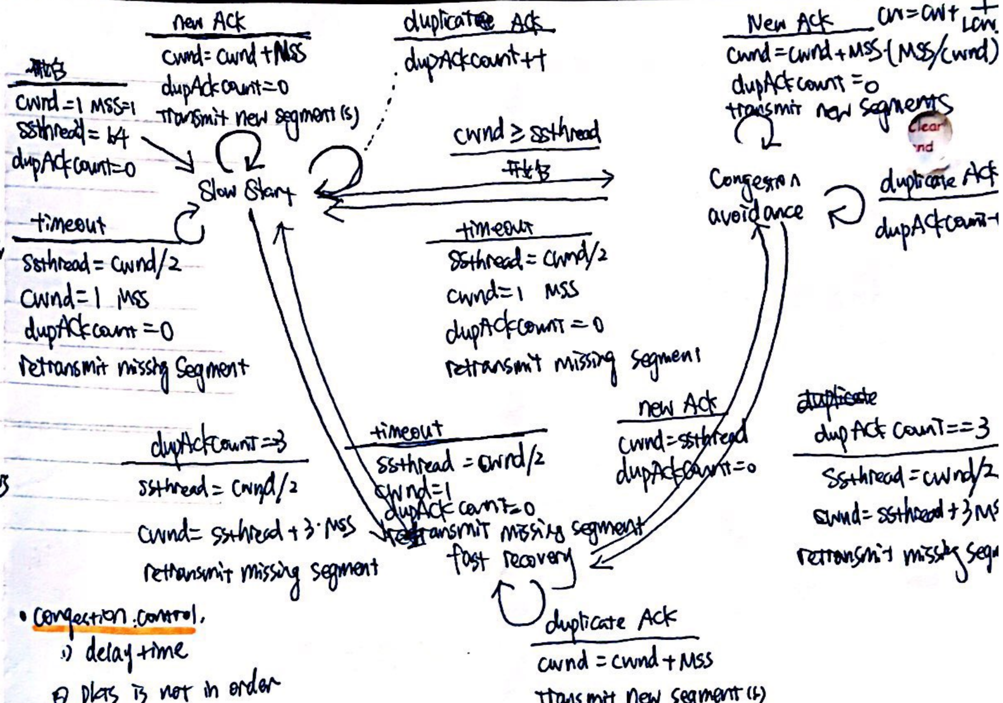
2. 1Gbps link, 15ms e-e propagation delay, 8Kb pkt



Transmit time = $\frac{L}{R} = \frac{8kb/pkt}{10^9 b/sec}$ = 8 micro

① Usender: $\frac{L/R}{RTT+L/R} = \frac{0.008}{2\times15+0.008} = 0.00027$

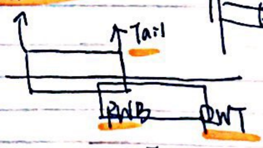
② Usender = $\frac{3L/R}{RTT+3L/R} = \frac{3\times0.008}{2\times15+0.008} = 0.0008$



- Congestion control.
  1) delay time
  2) pkts is not in order
- flow control:
  min {cw, rwnd}

3. { Go Back: Ack the last in order pkt that received; no buffer
   { selective: send Ack for px, has buffer.

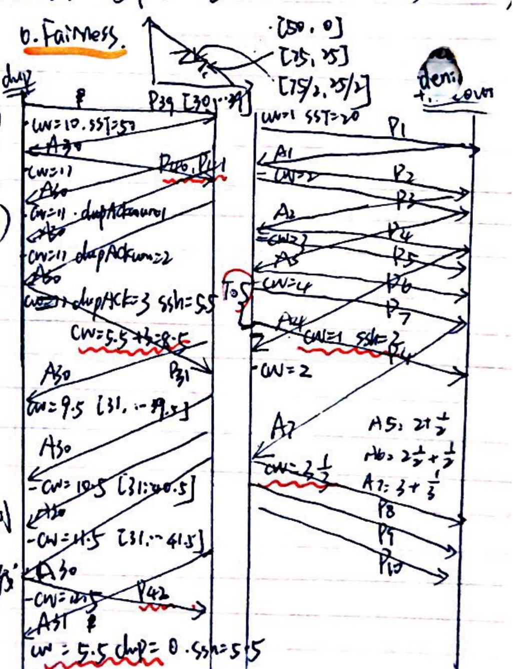
Transmit Window Base



4.
- RWB < TWB? X
- TWT 总是 > RWB? X
- RWB - TWT > 1 X
- Rx gets a pkt's seq # is less than RWB, Ack 1 (?)
  <95 不回答ACK
  >95 不知道RWB
- seq # ≥ 2 window size

5. Retransformation Time out: [Est RTT + 4 dev RTT]
Est RTT(t) = α Est RTT(t-1) + (1-α) current RTT(t)
dev RTT(t) = β dev RTT(t-1) + (1-β) current RTT(t)
= current RTT(t) - Est RTT(t)
α = 1 - 0.125 β = 1 - 0.25

6. Fairness.



Chapter 4 Network Layer

1. Network: hosts Transport: process ~~[illegible]~~
2. router: maintain connection state information
   line termination → data link processing → lookup forwarding, queuing
   ① memory ② bus ③ crossbar
3. header with TCP: 20 bytes TCP + 20 bytes IP + app header
   Fragmentation. MTU - 20 bytes
4. IP address: DHCP (Dynamic Host Configuration Protocol)
5. NAT (Network Address Translation): 138.76.29.7 + port
   local ~~address~~ network 10.0.0/24 16-bit port-number
6. ICMP (Internet Control Message Protocol): 主机 network 层间信息 e.g. error reporting, echo request/reply
7. Traceroute: nth datagram arrives to nth router.
   ① router 丢包 ② 给source发送信息 ICMP message (type 11, code 0)
8. IP address. IPv4 32-bit IPv6 ·4-byte no 分片
9. Dijkstra's Algorithm — Link state $O(n^2)$
   $D(v) = \min(D(v), D(w) + c(w,v))$
   Distance Vector Algorithm. — Bellman-Ford Equation
   $d_x(y) = \min_v \{c(x,v) + d_v(y)\}$ RIP: every 30 sec advertisement
   ① Message complexity LS: n nodes, E links $O(nE)$ msgs; DV: exchange between neighbors
   ② Speed of Convergence LS $O(n^2)$ $O(nE)$ msgs; DV: routing loops (count-to-infinity)
   ③ Robustness. LS: advertise incorrect link cost, own table; DV: advertise incorrect path cost, neighbor
   AS (autonomous systems): intra-AS, inter-AS
10. RIP — DV routing information protocol every 30 sec advertisement, up to 25 destination nets
    Link Failure: 180 sec — dead poison reverse: 16 hop
    routing table managed by app layer, advertisement in UDP
11. OSPF (Open Shortest Path First) — Link state. ① authenticated
    ② multiple same-cost paths allowed ③ hierarchical
12. Hierarchical OSPF: boundary router, backbone router
    backbone, area border routers, internal routers
    local area, backbone
13. inter: eBGP intra: iBGP prefix + attributes
    ① AS-Path ② Next-hop   msg: open, update, keepalive, notification
    inter-AS: admin wants control, policy > performance
    intra-AS: single admin, focus on performance

CSMA/CD

have pkt → listen to channel → is channel idle → ~~pick rand 时R~~
is channel idle ↓Y → pick rand 时R → countdown to 0
keep listening to channel → is channel busy —N→ is countdown 0 —Y→ transmit & keep listening
is channel busy ↓Y → freeze to countdown
transmit & keep listening ↓ is transmitted signal = sensed signal —Y→ is it complete ↓Y wait for Ack
is transmitted signal = sensed signal ↓N
is it complete —N→ transmit & keep listening
exponential backoff: $\{0, 1, 2, \ldots, 2^{m-1}\}$ K · 512 bit time

Chapter 5 Link Layer

connectionless, unreliable

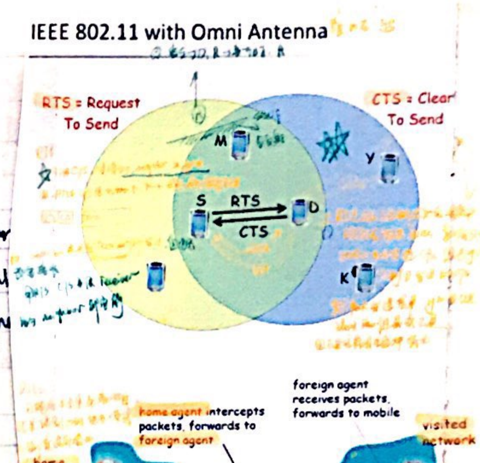
1. transferring datagram from one host/router to another MAC addresses ~~ip address~~
2. ① flow control ② error detection & correction
   ③ half-duplex and full-duplex
3. parity checking. ① single bit parity ② two dimensional bit parity
4. MAC Protocols. ① channel partitioning ② random ③ taking turns: polling: invite, token passing
   (TDMA: time, FDMA: frequency)
   Access ↳ Slotted ALOHA. prob p $Np(1-p)^{N-1}$ → 37%
   ALOHA, 没有时间片, 整体 performance 更差 $p(1-p)^{2(N-1)}$
   CSMA: listen before transmit (carrier sense multiple access)
   CSMA/CD (collision detection) Ethernet
   CSMA/CA. 802.11 wifi
5. CD: carrier sensing. adapter doesn't transmit if it senses that some other adapter is transmitting
   Collision detection: abort transmit 如果发现冲突就不在发
6. MAC addresses. 48 bits
   broadcast address: FF-FF-FF-FF-FF-FF
7. ARP (address resolution protocol) <IP, MAC, TTL>
   (A)-(R)-(B) MAC: A→R ⇒ R⇒B
   IP: A→B ⇒ A⇒B
8. hub: 把所有的连接在一起
   Switch: plug-and-play. Self-learning forwarding
   broadcast reply

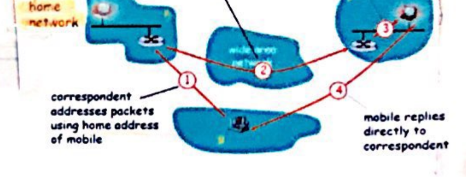
	hub	switch	router
traffic isolation	X	✓	✓
plug & play	✓	✓	X 要configure
optimal routing	X	~~X~~	✓
cut through	✓	✓	X have to decode

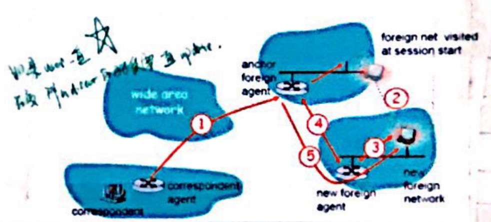
router: routing table, routing algorithm, ip, network
Switch: switch table, filtering, learning algorithm, MAC.

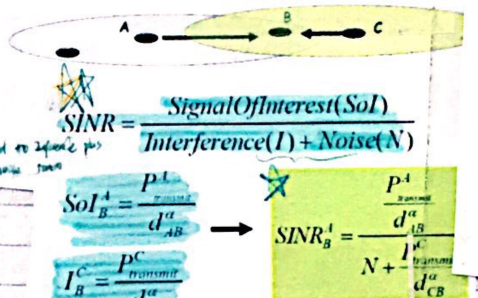
Chapter 6 Wireless

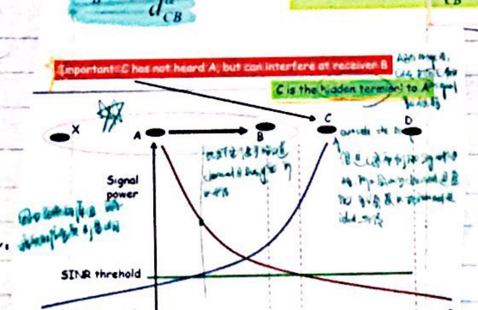
1. wireless host, base station, wireless link, infra...
   infrastructure mode: 通过 base station 与 wired network 相连 handoff: 节点从一个基站切换 Ad hoc mode: 没有基站, 节点之间...
2. wireless link: ① decreased signal strength ② interference from other sources ③ multipath propagation
3. CDMA code1 [1,1,1,1] a_1 (value) ⇒ [a_1, a_1, a_1, a_1] ⇒ signal
   code2 [1,-1,1,-1] a_2 ⇒ [$a_2, -a_2, a_2, -a_2$] ⇒ signal
   (chipping sequence)
   $S_1 + S_2 = k \cdot [a_1+a_2, a_1-a_2, a_1+a_2, a_1-a_2]$
   $\frac{1}{4} RS_1 = \frac{1}{4}[a_1+a_2, \ldots][\ldots] = a_1$ decoding.
   $\frac{1}{4} RS_2 = \frac{1}{4}[\ldots][\ldots] = a_2$
   code 每... $\frac{\sum_{m=1}^{M} Z_{i,m} \cdot C_m}{M}$
   TDMA/FDMA
4. SINR: SINR threshold, Sensitivity threshold

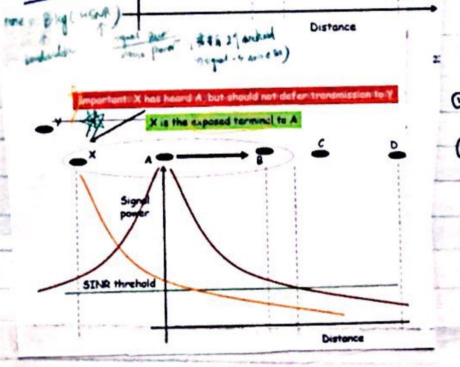












5. mobility: home network, home agent, permanent address
   visited network, care-of-address, foreign agent
   indirect: triangle routing
6. GSM

Chapter 8 Security

eavesdrop, intercept, insert, impersonation: fake src, hijacking, denial of service

1. Cryptography: symmetric (DES), public
   $K_B^-(K_B^+(m)) = m = K_B^+(K_B^-(m))$ ① large num p, q (1024 bits)
   ② $n = pq$, $z = (p-1)(q-1)$ ③ e (< n) 和 z 互质 ④ $ed \bmod z = 1$
   ⑤ public: (n, e) private: (n, d) ⑥ encrypt: $c = m^e \% n$
   ⑦ decrypt: $m = c^d \% n \Rightarrow m = (m^e \% n)^d \bmod n$
   $x^y \% n = x^{(y \% (p-1)(q-1))} \% n$
2. authentication   MD5; SHA-1
3. message integrity: ① hash ② digital signature =
   signed message digest (用 private key 加密)
   ($m \to H(m)$) → private key → $K_B^-(H(m))$ signed
   ③ $m \to H(m)$ → public $K_B^+(K_B^-(H(m)))$ → is equal? verifies
4. key distribution & certification $K_{A-KDC}(R1, K_{B-KDC}(A, R1))$
   ① Symmetric KDC → $K_{B-KDC}(A, R1)$
   ② public: CA public key → K_B^+ → CA private key
   Bob's identifying information