Wireless Communications and Mobile Internet Exam

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Chapter 1. Overview of Wireless Networks

1. The earliest wireless communications in human history dates back to pre-industrialized periods. People used fire, flags to transfer information. In the 1930s, telecommunications, the main technology in today's wireless communication, start to emerge. In 1931, Faraday discovered electromagnetic induction. Marconi invented radio transmission system, which started the new era for wireless communication. In 1997, the first version of wireless communication network was established.

2. (1) Cellular system (2) Mobile management (3) Mobile IP (4) Wi-Fi (5) WiMAX (6) Ad-hoc networks (7) Wireless network security (8) WPAN (9) Internet of things (10) SDN

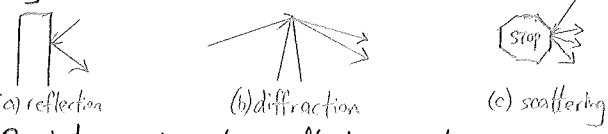
Chapter 2. Radio Propagation

1. Wireless media refers to any physical medium consisting of cables. The cables can be copper wire, twisted pair or fiber optic. Because of the material's frequency-response characteristic, the maximum transmission rate is limited. Wireless media refers to the air, and is unstable, low-bandwidth, and broadcastable.

2. Licensed bands mean that individual companies pay a licensing fee for the exclusive right to transmit on assigned channels within that band in a given geographic area. Unlicensed bands don't require permission.

3. Topology, operation frequency, and interference source.

4. Reflection happens when the size of the object is larger than the wavelength of the wave. Diffraction happens when the wave is blocked by sharp objects. Scattering happens when the object is smaller or equal than the wavelength of the wave. They are depicted below:



(a) reflection (b) diffraction (c) scattering

5. On indoor environments, reflection and scattering happen frequently, resulting in the wave being widespread. On outdoor environments, wave is more concentrated because reflection and scattering happen less. Diffraction sometimes happens.

6. Path loss is defined as $L_p = \frac{P_t}{P_r}$, $\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2$.

$\frac{P_r}{P_t} = G_t G_r \frac{h_b^2 h_m^2}{d^4}$ Thus, all those factors will affect path loss, and the reflections of their relationship is in above formulas.

7. Slow/shadow fading refers to the effects to the wave propagation due to the shadowing from obstacles. Thus in path loss, a random term X is included: $L_p = L_0 + 10\alpha \log D + X$.

8. The slow fading margin can be obtained based on the cell edge coverage probability and standard deviation of slow fading.

Edge coverage probability $= 1 - Q$ (slow fading margin)

9. For macro-cell systems, we can use the Okumura-Hata path loss model:

$$L_p(d) = \begin{cases} A + B\lg d & \text{cities} \\ A + B\lg d - C & \text{suburban areas} \\ A + B\lg d - D & \text{open areas} \end{cases}$$

For micro-cell systems, dual slope empirical model is:

$$L_p(d) = \begin{cases} 10n_1 \log_{10} d + L_1 & \text{for } d \le d_b \\ 10n_1 \log_{10}\left(\frac{d}{d_b}\right) + 10n_1 \log_{10} d + L_1 & \text{for } d > d_b \end{cases}$$

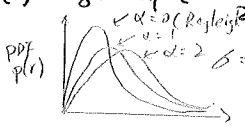
10. Multipath fading causes the receiving signal to vibrate quickly and causes fading. Doppler shift causes a shift in the frequency if the relative positions change. Thus the spetrum changes.

11. Rayleigh distribution

$$f_{ray}(r) = \frac{r}{\sigma^2} \exp\left(-\frac{r^2}{2\sigma^2}\right), \quad r \ge 0$$

Ricean distribution

$$f_{ric}(r) = \frac{r}{\sigma^2} \exp\left(\frac{-(r^2+\alpha^2)}{2\sigma^2}\right) I_0\left(\frac{\alpha r}{\sigma^2}\right), \quad r \ge 0, \alpha \ge 0$$



12. Doppler shift is cause by relative motions. The wave length can be compressed/conflated if the source/receiver is moving.

$$v(t) = \frac{Vf}{c}\cos\theta(t)$$

13. We can calculated the desired signaling strength and cell radius based on the equations for Rayleigh and Ricean fading in Problem 11.

14. For Rayleigh fading,

$$LCR = \sqrt{2\pi} f_d \rho e^{-\rho^2}$$

$$AFD = \frac{e^{\rho^2} - 1}{\rho f_d \sqrt{2\pi}}$$

For Rician fading,

LCR can be calculated by $\int_0^\infty \dot{a} p_{a,\dot{a}}(R, \dot{a}) d\dot{a}$

$$AFD = \frac{1 - Q\left(\sqrt{2}R, \sqrt{\frac{2(K+1)}{\Omega}} R\right)}{LR}$$

Chapter 3 and 4 Cellular System

1. From 2G to 3G, the main technological difference is that 3G uses packet switching rather than circuit switching for data transmission. 2G used GSM, CDMA, TDMA, while 3G used W-CDMA, UMTS.

2. The larger the transmitting power is, the larger cell radius and system capacity it can support.

3. Co-channel interference can be expressed as:

$$\frac{S}{I} = \frac{R^{-k}}{2(2R-R)^{-k} + 2D^{-k} + 2(D+R)^{-k}}$$

Cluster size can use $N = i^2 + ij + j^2$

4. Base station is a radio transmitter/receiver that serves as a hub. Uplink is the communication from ground to a satellite, while downlink is from satellite to the ground. Cell is an area served by a station. Location areas are areas cell located. Mobile switching centers are primary service delivery node for GSM/CDMA.

5. The VLR is a database in a mobile communications network associated to a MSC.
The HLR is the main database of permanent subscriber information for a network. HLR is an integral component of CDMA, TDMA, GSM.

6. Location management: Search. Update. location info. Research.
Handoff management: Ensures a mobile remain connected when moving. packets and connection are routed to new location

7. Much faster transmission speed; Can communicate globally; More stable.

8. They are all used to divide resources to users. TDMA divides time, while CDMA is code division.

9. SGSN is a main component of the GPRS network, which handles all packet switched data. GGSN is responsible for the interworking between GPRS and external.
MSC is the mobile service switching center. GMSC controlls mobile terminating calls. HLR is the database for every subscriber.

10. WCDMA, CDMA2000, TD-SCDMA

11. Provide fast mobile multimedia service, use CDMA.

12. Transmission rate of 28 kbps or higher, transmission bandwidth is about 450MHz.

13. 2G: Wechat, messages
3G: Browse the internet
4G: See movies fluently

14. IntServ-Based Architecture is one possible architecture. It operates at the wireless access network and DiffServ at the core IP network.

Chapter 5. Future Technologies

1. Mobile edge computing. Mobile website, Mobile access, Ubiquitous computing.

Chapter 6. Mobility management

1. Transfer an ongoing data session or call from one channel connected the core network to another channel.

2. Intra-cell handoff is the target and source are one and the same cell and only the used channel is changed.
Inter-cell is the source and target are in different cells.

3. NCHO is network controlled, the network makes the decision. MCHO is decided by the mobile. MAHO is that the mobile provides data for the network to make decision.

4. Hard handoff is easier but slow and power consuming. Soft handoff is better, as it increases the capacity, reduces call drops.

5. It uses feedback to help hand-off, and is powerful algorithm. The feedback interval, according to the straight line model, $d = \frac{v \cdot t}{2}$, thus the interval can be calculated accordingly.

6. Straight-line model assumes each mobile moves in straight lines. While fluid flow model is used to describe the fluid level in a reservoir subject to random periods of filling and emptying.

7. In a heterogenous network and using a stochastic geometric approach, the handoff rate is

$$H(v) = \frac{2}{\pi} p_1(T^{(1)}) v.$$

8. Intra-switch: when in a given cell, MTSO finds other cell within its system to which it can transfer the call and a mobile signal becomes weak.
Inter-swith: When MTSO cannot find other cell within its system. it uses inter-swith handoff.

9. $H_{inter\text{-}cluster} = \mu_{cluster} \times \beta \times \alpha \times \lambda$

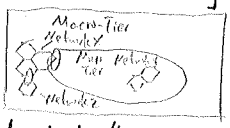
$H_{intra\text{-}cluster} = H_{total} - H_{inter\text{-}cluster} = (N \times \mu_{cell} - \mu_{cluster}) \times \beta \times \alpha \times \lambda$

10. when cells are splitted into smaller cells, the handoff rate is higher.

11. A two-tier network is a software architecture in which a presentation layer runs on a client, and data stored on a server.

12. For location update, whenever a mobile boots or shut down, or in a certain interval, it should report its location. For service delivery, cellular network search for the available access interface for called user. Caller will send a feedback to end.

13. Time based: $C^{time}_{u,av} = \frac{1}{t} = \frac{V_{max}}{l_c}$. Performs bad, but stable.
Movement-based: $C^{movement}_{u,av} = \frac{V_{av}}{k} \leq \frac{V_{max}}{k}$ Better than time, but not suitable for stable mobiles.
Distance-based: $C^{distance}_{u,av} \leq \frac{V_{av}}{l_c}$, performs better than the other two. May suffer from accuracy problem.

14. 

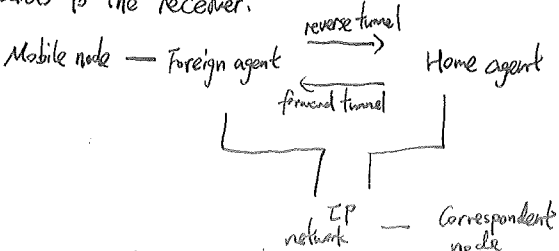
The dynamic location management scheme for next-generation multi-tier PCS systems. (1) intersystem location using BLA concept (2) intersystem paging using BLR concept (3) Location calculation.

Chapter 7 Mobile IP

1. If my IP changes when I changed position, all TCP connections will be discarded. Moreover, I might not get to quickly obtain a new IP.

2. MN: The position changes often, MN refers to "mobile node".
HA: Home agent, whose address is at home.
FA: Foreign agent, stores information about nodes visiting.
COA: Care-of address, which is associated with the network it is visiting.
CN: Correspondent node, which communicates with MN with home address.

3. MN sends to FA, FA encapsulates and tunnels packets to HA, HA forwards to the receiver.

4. 

5. The MN sends a registration request to FA to start. FA relay to HA. HA reply to FA. FA process and inform MN.

6. It allows MN to create or modify a mobility binding.

7.

IP header
ICMP Router Advertisement
Sequence number
lifetime
Care-of address
Length

8.

Type of service, Total length
Identification flags
Time to live
Source address
Dest address
checksum
reserved

9. If FA or HA that does not support reverse tunnels receiving 'T' bit set, it fails.

10. IP in IP encapsulates IP packet in another IP packet.
Generic Routing Encapsulation encapsulate a wide variety of network layer protocols inside virtual point-to-point links over IP network.
Smallest encapsulation removes redundant parts in two IPs.
In large network, I would prefer GRE, in intensive case, I would prefer smallest encapsulation. In safiest case, use IP-in-IP.

11. Start at MN's COA and ends at HA.

12. When immediate routers check for a topologically correct source address.

13. For example in the architecture in Problem 4, if the MN wants to connect. The routes might be MN → FA → HA → IP network → HA → FA → MN.

Chapter 8 IEEE 802.11 WLAN

1. PCF is the fundamental MAC technique of 802.11 based WLAN standard. PCF is a media access control technique in 802.11 based WLAN. PIFS is the time delay for which sender wait after completing backoff. SIFS is shortest interframe spacing. PIFS is one of the interframe space in 802.11 WLAN.

2. The timeline of the RTS/CTS access mechanism is shown in Page 9 in "Advances in Computer Graphics and Computer Vision". Due to limited space, I omit here

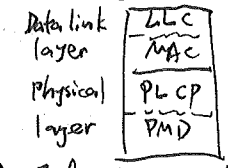
3. IEEE 802.11e is an approved amendment.
EDCA is Enhanced distributed channel access. High-priority traffic has higher chance to be sent.
HCF is hybrid coordination function, enhanced from DCF, PCF.

4. An ad-hoc mode has no control control, and can't connect infrastructure devices; while infrastructure mode is centralized, and increases security, faster.

5. Infrastructure mode, basestation connects mobiles, mobiles charges basestation providing connection into network.
Ad hoc mode: no basestations, nodes can only transmit to others within coverage, nodes organize into a network.

6. A set of data link and physical layer protocol.

7. LLC is the upper sublayer of the link layer. MAC is the bottom of link layer. PLCP is carrier sensing assessment. PMD is modulating and coding. Shown below:

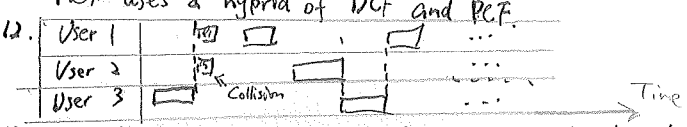


8. Infared is wavelength longer than red. It is simple circuit, portable, secure, etc., but short range, low bandwidth.
Radio has smaller wavelength. It is high speed, penetratable, but easily interfered, power consuming, etc.

9. 802.11 → 82.5MHz, 802.11a → 300MHz, 802.11b → 825MHz, 802.11g → 83.5MHz

10. After one node finished sending, other nodes compete. Higher priorities access first.

11. DCF employs a CSMA/CA with binary exponential backoff.
PCF resides in a point coordinator (AP) to coordinate.
HCF uses a hybrid of DCF and PCF.

12.


13. Unicast is to a single destination, while multicast is to a group.

14. The NAV is a virtual carrier-sensing mechanism, it is an indicator for a station on how long it must defer.

15. Qos is in 802.11, infrastructure, but not ad-hoc. 802.11 is done through coordination of AP.

16. A TSF keeps the timers for all stations in the same IBSS synchronized. All station maintains local TSF timer.

17. It is in infrastructure mode. All stations maintain local TSF timer. Timing synchronization function, timing conveyed by periodic Beacon transmissions.

18. Time divided into beacon intervals, each containing a Beacon generation window. Beacon contains a timestamp.

19. ASP is proposed to synchronize a MANET. It let the faster nodes send out beacon more often and self-correction.

20. Since mobile hosts are supported by battery power, saving power is very important.

21. Ad hoc: Use CSMA/CA, RTS, CTS, ACK, PS-Poll.
Infrastructure: Use PCF/DCF, apply PS-Poll.

22. DTIM is transmitted less frequently, and is for sending buffered broadcast packets. ATIM is transmitted in ATIM window by stations, structured the same as TIM.

23. MM offers seamless handoff when moving. Handovers are based on measurements performed by the mobile terminal and base stations.

24. IP fragmentation breaks datagrams into to smaller pieces, so packets can pass through with a smaller MTU.

25. Frame control, Duration, Address (1, 2, 3, 4), Sequence control, Qos control, HT control.

26. While transmitting, either one may not be the actual source of destination, so 4 distinct adresses are needed.

27. 802.11a is an amendment to 802.11 specifications that defined requirements for OFDM systems.

28. WEP is "Wired Equivalent Privacy". The goal is to make wireless networks as secure as wired networks.

29. 64-bit WEP uses a 40 bit key, concatenated with a 24-bit initialization vector to form the RC4 key. Its size was limited by US government, and now many are 128-bit.

30. For example, suppose some flips happened in the first 40 bit. Then, the key will have changed, and the IV no longer fits the key.

31. Two methods: Open System / Shared Key authentification
In the former, client need not provide credentials. WEP keys can be used for encrypting frames.
In Shared Key, WEP key is used in a four-step challenge-response handshake.

32. WEP/WPA: only provide confidentiality at the network level
MAC filtering: Easily spoofed, and doesn't identify a person.
Captive portals: popular, flexible, easy. But not transparent standardized.

33. Active scan occurs when client changes radio channel, broadcast a probe request and wait responses from AP on that channel. Probe requests include directed probe and broadcast probe.
Passive scan is simply changing the clients radio to the channel being scanned and waiting for a periodic beacon from AP on that channel.

34. Offined different interframe spacing. SIFS, PIFS, DIFS.

35. I will calculate the maximum throughput of 802.11g
CTS-to-self.
Fast data frame will be protected by an 802.11b CTS with preamble 192μs and 14 byte 11 Mbit/s, 203μs.
PIFS = 50μs.
TCP = PIFS + CTS + SIFS + 802.11 data = 557μs.
TCP ACK = 341μs.
Thus, throughput is 73 Mbits/s.

Chapter 9 WiMAX.

1. WiMAX is fast, remote, QoS protectable, colorful. It uses MIMO, OFDM/OFDMA etc.

2. WiMAX is based on IEEE 802.16e-2005, it improves by adding support for mobility, AAS and MIMO Tech, LDPC, QoS, etc.

3. A large number of closely spaced orthogonal sub-carrier signals are used to carry signal on several parallel data streams or channels.

Chapter 10 Ad hoc networks

1. Infrastructure is centralized on a AP, while ad hoc organizes the network by nodes.
2. Node i and j can transmit successfully if :
   (1) $d_{ij} \le R_t$, (2) $\forall k$ that $d_{kj} \le R_t$, k does not transmit
3. Nearby users will interfere. So exclusion region is used.
4. For lower bound, we should find how many hops to guarantee the transmission. For upper bound, we assume all data travels equally.

$$TH^{upper} = \frac{E[P]}{\min(4, H_r) \times T}$$

$$TH^{lower} = \frac{E[P]}{\min(H_r, 6) \times T + \max(H_r - 6, 0) \times \overline{T}^{avg}_{hop}}$$

5. Hidden terminal occur when a node is visible to AP but not to other nodes communicating with AP. Exposed terminal occur when a node is prevented from sending packets to other nodes because neighbor.

Chapter 11 Security

1. (1) Request to station (2) Reply an auth frame (3) Send auth mangement frame (4) AP decrypt and reply whether success.
2. (1) Initialization (2) Initiation (3) Negotiation (4) Authentication
3. WEP: Authentication is unidirectional, so might be fake AP.
   WAPI: Use WAI to authenticate.
   IEEE 802.11i: Increased in WLAN, strengthened abilities, and security. Proposed TKIP and CCMP.

Chapter 12 Bluetooth and RFID

1. (1) Lower Power Consumption (2) Lower cost (3) Lower delay (4) Larger range
2. Standby. Connection. further divided into: Page, Page Scan, Inquiry, Inquiry Scan.
3. (1) RFID tag (2) RFID Tag reader (3) Application software system
4. Microprocessor tech., Antenna design, encapsulation, Tag application, collision avoiding.
5. Transport card, Identity card, Animal tracking.

Chapter 13 Wireless sensor networks

1. WSN is built of nodes in different topologies. Sensor network is the components, BS organizes them, monitoring station monitors them.
2. Power module provide power. Sensor obtain environmental and equipment status. Microcontroller process sensor data. Wireless transceiver transfer data.
3. (1) It can be placed in houses to improve energy-efficient performance (2) It can monitor online transmission lines.
4. (1) Sensor network broadcast status. (2) Organize in certain topo. (3) Compute suitable paths
5. (1) The range is short, so several hops are often needed. (2) data rate is usually small.
6. (1) Transmission rate (2) delivery reliability (3) network lifetime. If transmission rate increase, reliability will be lower and lifetime shorter. vice versa.
7. It can harvest external energy such as MEM technology based methods. Also can use solar energy.

Chapter 14 Internet of Things

1. Software defined radio, Radio Frequecy identification. Ultra-wide band wireless communication
2. High security, processing gain, transfer rate, system capacity. Accurate positioning. Low cost.
3. Bluetooth Low Energy is based on Bluetooth, and simplifies Bluetooth.
4. A CR monitors its own performance and the radio's outputs. Then determine environment, conditions, etc. and adjust settings to deliver the required quality of service subject to those constraints.
5. High speed, short distance, personal, time changing. It can be used in health monitoring, navigation, entertainments.

Chapter 15 Software-Defined Networking

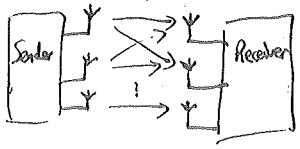
1. SDN architectures decouple network control and forwarding functions, enabling network control to become directly programmable and the underlying infrastructure to be abstracted from applications and network services.
2. SDN has three central working principles: (1) Forward mechanism based on flow (2) Routing mechanism based on centralized control (3) Program mechanism for applications
3. (1) Open computing project by Facebook aimed at providing better switches (2) Protocol Oblivious Forwarding proposed by Huawei (3) OpenDaylight
4. Non-SDN only implicitly and indirectly describe their network requirements, do not express a way to expreess the full range of user requirements, and do not expose information and network state to applications. But SDN has complete control of datapaths, subject to limit of capacities. This allow networks to run with complex and precise policies with greater utilization and service guarantees.

Chapter 16, 17, 18 Intelligent Robots, Cars and Quadrotors

1. Baotary, Sensors, Effectors, Control systems, Camera, Microphone, Network devices, Navigation systems, etc.
2. (1) Leap-Frog Path Design (2) Scalable Smoothing and Mapping (3) Simultaneous Localization and Mapping (SLAM). In SLAM, robot is thrown into a new environment, and it can automatically construct maps regarding the environment.

Chapter 19 MIMO

1. MIMO is technique for sending and receiving more than one signal simultaneously by exploiting multipath propagation. SISO has only one sender and receiver, one input and one output.
2. $N_T \times N_R$ routes intotal, $\vec{y} = \vec{H}\vec{x} + \vec{n}$, if we use $\vec{x}$ for sending signal, $\vec{y}$ for receiving, $\vec{H} = \begin{bmatrix} h_{11} & \cdots & h_{1N_T} \\ \vdots & & \\ h_{N_R 1} & \cdots & h_{N_R N_T} \end{bmatrix}$



3. Space diversity transmit same data over different route to strengthen. Space multiplexing divides flow into different low-speed flow sent from different routes.
4. (1) Incaporate with OFDM/OFDMA, to get MIMO-OFDMA. (2) Mobile radio telephone standards. (3) Non-wireless communication systems. One example is the home networking standard, which defines a powerful communications system that transmit multiple signal over AC wiring.

Chapter 21 and 22 Bitcoin and Graphic Code

1. (1) The stability of value. (2) The security of accounts (3) The safety in transactions. One would need over 50% computing to modify transaction (4) Very private. We cannot know the person's identity.
2. It consists of black squares arraged in a square grid on a white background, processed using Reed-Solomon error correction.