1.1 1G: Analog Cellular Systems, FDMA, low capacity, only Voice calls → 2G: Digital Cellular Systems, TDMA, Voice calls & SMS →
3G: CDMA2000/TD-SCDMA/WCDMA, higher speed & capacity, enable video/GPS/Location Service → 4G: LTE protocol, even higher
speed & capacity, provide all-IP-based mobile broadband solution → 5G: a complete wireless comm without limitation
1.2. cellular system: mobility management: Mobile IP, WiMax, Ad-hoc, Wireless new security, Wireless Personal Area
Network, Communication Technologies, IoT, Wireless Sensor Network, SDN.

2.1. Wireless Media deliver data by electromagnetic waves, thus is more likely to interfere with each other, however, it doesn't need physical medium, making it easier to implement and upgrade regardless of the terrain...etc.

2.2. licensed band is not for free but it guarantees the communication quality by ensuring that other operators' won't interfere the current user. Meanwhile, it also provides a long time window to develop the operator's Network, increasing operator's profit. Unlicensed band (e.g. 2.4G, 5G) one free to use, but harmful, without quality guaranteed.

2.3. 1. obstacle in the way. 2. The medium's property (e.g. dielectric constant) 3. disturbs, 4. interference from other signals

2.4 1 reflection & transmission: obstacle's size >> λ wave, occur on the surface of Earth / buildings / walls. Not the primal through transmission way. 2. Diffraction: when the path is stuck by a sharp edge, it occurs. According to Huygen's principle, each point on a spherical wave is a secondary wave front, Diffraction often takes place in shades
3. Scattering: happens when obstacle's size << λ wave AND there are many such obstacles in a unit space. This takes place on the surface of rough things or irregular objects like leaves, traffic signs, etc.

2.5. Indoor space is surrounded by walls. so reflection takes place more often. In outdoor spaces, scattering takes place more often, while diffraction is more usual in shades.

2.6 In the ideal free space: ① $Lp[dB] = 32.45 + Log\,f_c[MHz] + 20\,Log[km]$, d is the distance

② $P_r/P_t = G_t G_r (\frac{\lambda}{4\pi d})^2$. Pr is the receiver power, Pt is the transmitting power

③ $G = \eta(\frac{\pi D}{\lambda})^2$, G is antenna gains, D is the radius diameter of antenna.

④ $P_L = A + B + Log(d) + C$: $A = 69.55 + 26.16\,Log(f_c) - 13.82\,Log(h_b) - a(h_m)$. $B = 44.9 - 6.55\,Log(h_b)$, h_m/h_b is the height of mobile station & base station.

2.7. free-space model: $PL = 10\log \frac{P_t}{P_r} = -10\log[\frac{G_t G_r \lambda^2}{(4\pi)^2 d^2}]$; $P_r(d) = P_r(d_0)(\frac{d_0}{d})^2$, $t = \frac{x+y-l}{c}$

two-ray model: $PL = 40\log d - (10\log G_t + 10\log G_r + 20\log h_t + 20\log h_r)$, $P_r = P_t G_t G_r \frac{h_t^2 h_r^2}{d^4}$, $t = \frac{x+y-l}{c}$

2.8 slow fading: channel coherence time > delay requirement → amplitude & phase's variation won't be scanned
Slow-fading can be caused by shadowing (A hill / building obscures the main signal path).

2.9. $EIRM = RSL - T + T/I - C/I$

2.10. Macro-cell: 1) Okumura-Hata Model: $L_{50}(Path\,loss) = A + B\log_{10}R - C$ 2) Walfisch: $L = 42.6 + 26\log_{10} d + 20\log_{10} f$
Micro-cell: 1) Dual-Slop Model: $L = 20\,n_1 \log(r/r_b) + 20\,n_2 \log_{10} r_b + L_1$ 2) Two-ray: $\frac{1}{L} = \frac{\lambda}{4\pi}\left|\frac{e^{-jkr_1}}{r_1} + R\frac{e^{-jkr_2}}{r_2}\right|^2$

2.11. fading: rapid fluctuation of the amplitude of the radio signal caused by destructive interference between two or more versions of the transmitted signal. Called multipath. Doppler is the change of frequency for the relevant moving between sender & receiver.

2.12 Rayleigh pdf: $f(x;\sigma) = \frac{x}{\sigma^2} e^{-x^2/(2\sigma^2)}$, suppose no dominant channels & lots of reflects.
Rice pdf: $f(r) = \frac{r}{\sigma^2}\exp\left(\frac{-(r^2+s^2)}{2\sigma^2}\right) I_0\left(\frac{rs}{\sigma^2}\right)$ $r \geq 0$, $a \geq 0$,

2.13. $f = \left(\frac{c+Vr}{c+Vs}\right) f_0$. Vr is positive if receiver is moving towards source.

2.14 $dBne = -113.0 - 40.0\log_{10}(r/R)$; $R\theta = avg[r]\,10^{(dBm+113.0)/40.0}$

2.15 $LCR = \sqrt{2\pi}\, f_d\, \rho e^{-\rho^2}$, $\rho = \frac{R-threshold}{R\,rms}$; $AFD = e^{\frac{\rho^2}{\rho f_d \sqrt{2\pi}}}$.

3.1. ITU defines 3G demand → 3GPP define a mobile system fullfills the demand. CDMA from 2G established the foundations for 3G technologies

3.2. transmitting power ↑ → cell radius up ↑ capacity ↓

3.3. $S/I = q^k/N_I = (\sqrt{3N})^k/N_I$, N_I is the number of interferencing cells (6 if only consider the first layer), N is the cluster size.

3.4 base station: transceiver connecting a number of other devices to one another / wider area.
uplink: mobile station (cell phone) → base station (cell site); downlink: cell site → cell phone
location area: Service areas are created with each area considered a LA. MSC: center piece of NSS, do comm switching functions.

3.5 VLR: database that store the subscriber & its IMSI, HLR… HLR is a central database that contains details of
- mobile phone subscriber that is authorised to use GSM Ntwk.

3.6 handoff objective: transformation of user's from one cell to another to maintain strong enough signal strength.
Location management: keep track of the user's current location.

3.7 1. higher transmission rates 2. greater Ntwk capacity 3. provide multi-media service 4. Packet Switching 5. security.

3.8 ~~all~~ CAC: the practice of process of regulating traffic volume in voice communications.
2G: single-class call admission, 3G: multi-class call admission.

3.9 SGSN: keep track of the location of individual MS/UE, responsible for the delivery of packets from & to the mobile stations. GGSN converts the GPRS packet from SGSN ~~and~~ into IP format and send them out on the corresponding Net.

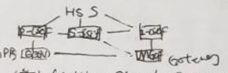
3.10 TD-SCDMA, CDMA 2000, WCDMA

3.11 1) Data rates: greater voice & data capacity, higher transmission rate at low-cost. 2) security: use UE to authenticate the Ntwk. 3) Various Multi-media Applications.

3.12 2.5G: transmission rate: 171.2 kbit/s; bandwidth: 200kHZ, Operation frequency: Up: 890-915MHZ, Down: 935-960MHZ
3G: 〃 14.7 Mbit/s; 〃: 1.25MHZ (CDMA 2000) 〃: Up: 1920-1935MHZ, Down: 2110-2125MHZ

3.13 1G: voice call → 2G: SMS → 3G: GPS, Video Call → 4G: IoT, hd video

3.14



5.1 ~~[illegible]~~ Mobile Cloud Computing; Mobile Website; Ubiquitous Computing; Mobile Access

6.1 ① power received by neighbour cells - power received by current cell > $th_{handoff}$, trigger the handoff.
② new connection generation: network must find new resources for handoff connection & perform additional routing
③ data flow control needs to maintain the delivery of the data from old path to the new one.

6.2 Inter-switch handoff: source & target are different cells
intra-switch handoff: source & target are the same cell, but different channel is used. It is useful when the current channel is interfered / fading.

6.3 MCHO: Mobile-controlled Handoff: MS monitor the signals from surrounding BSs and initiate handoff when criteria met.
NCHO: Ntwk-controlled Handoff: BS monitor the signals from MSs and initiate handoff process.
MAHO: Mobile-assisted Handoff: Ntwk asks MS to measure the signal strength & report to ntwk, ntwk decide whether handoff.

6.4 hard handoff: A: 1. ensure that one call uses one channel any time 2) handoff time is very short & not perceptible. 3) hardware don't need to be capable of receiving ≥2 channels. D: 1. handover fails then call must be terminated & temporarily disrupted. Soft handoff: A: 1. More reliable connection D: 1. Complex Hardware in the phone.
2) use several channels to support a single call, reduce the capacity of Ntwk.

6.5 ~~Fluid flow model: captures~~ all ~~kinds of effects that originate from time-variable~~ bit ~~rates in all kinds of~~ ntwks
I don't know…

6.6 ~~Fluid~~ Fluid flow model can derive the average rate of boundary crossing per unit time out of a given area.

6.7 Inner handoff: ongoing call mobile moves from one cellular system to another which is controlled by another MTSO, handoff happens. Intra System handoff: ongoing call mobile moves from one cellular system to adjacent cellular system controlled by same MTSO.

6.8 denote $R_{E,k}(N)$ as the inter handoff rate of k-layer clustering: $R_{E,1}(N) = (2N-1)/(3N^2-3N+1)$, N: # rings in cluster
for inter handoff $R_{P,1}(N) = \frac{2N-1}{3N^2-3N+1} \cdot \frac{2N-1}{6N} \cdot \frac{1}{1+ 1+P_m/P_R}$.

6.9 cell splitting → smaller cell → handoff rate ↑

6.10 Two-tier Architecture: based on server-client architecture, the direct communication takes place between client & server without any intermediate.

6.11 1. Mobiles detect location area codes → if different from last update, send to the ntwk the new LAC & old LAC and a location update request. 2. Service delivery.

6.13 Time-based: a mobile terminal updates in every T time units. A: simple hardware Dis: crowd the Ntwk.
Movement-based: a mobile terminal counts the number of boundary crossings. D: may fail when moving fast A: less crowd
distance-based: a mobile terminal tracks the distance (in term of RAs) it has moved since the last update. D: Ntwk noise & imprecise approximation

6.14 1) User cross a RA boundary → |forward pointer| < K → set up a pointer between two involving VLRs
|forward pointer| = K → update HLR

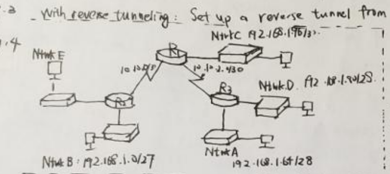
2) When a call arrives, it do search: HLR → VLR0 → ... → VLRi → cell → paging.

7.1 1) stability 2) suitable for hosting 3) convenient remote access

7.2. MN: mobile node | an internet-connected device whose location & point of attachment to Internet changes frequently
HA: Home Address, the permanent IP Addr of MN.
FA: Foreign Agent, a router serving as a mobility agent for a mobile node
COA: Charge of ~~Addr. when MN~~ switch to foreign net. this IP will be relevant to MN.
CN: Comm Node: An comm object of MN.

7.3 - With reverse tunneling: Set up a reverse tunnel from the care of address to the home agent to ensure a topologically correct address of IP packet

7.4



7.5 When the mobile node receive an agent advertisement, it registers through the foreign agent, even when the MN might be able to acquire its own co-located care-of Add. This enables sites to restrict access to mobility services. Process: 1) Request forwarding service 2) Inform home agent of current care-of Addr. 3) Renew registration 4) Deregister when return home

7.6 Because mobile IP exists within a certain period. And the registration is based on the exchange of information & status which is sensitive to the

7.7. Mobile Nodes use agent advertisements to determine their current point of attachment to the Internet or to an organization's work. An agent advertisement is an Internet Control Message Protocol router advertisement that has been extended to also carry a mobility agent.

7.8 MN sends a registration request to the prospective foreign agent to begin the registration process. The foreign agent processes the registration request and then relays it to the home agent. The home agent sends a registration reply to the foreign agent to grant or deny the request. The foreign agent processes the registration reply and then relays it to the mobile node to inform it of the disposition of its request.

7.9 ① UDP transmission fails ② connections between home agent & other nodes reach the limit, MN doesn't know the agent's Addr

7.10 1) IP-IN-IP: one IP packet encapsulated inside another. 2) minimal: An IP datagram is encapsulated with an outer minimal forward IP header. 3) GRE: goes a step further than IP-IN-IP, adding an additional header of its own between the inside & outside IP headers. GRE is performed for 1) encapsulate any layer 3 protocal 2) Add checksum.

7.11. A reverse-tunnel can ensure a topologically correct source address for the IP data packet.

7.12 I don't know

7.13 I don't know

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8.1 DCF: fundamental MAC technique of the IEEE 802.11 based WLAN standard.
PCF: a MAC technique used in IEEE 802.11 based WLANS. It resides in a point Coordinator (aka AP)
DIFS: DCF Interframe Space, DIFS = SIFS + 2 * slot time
SIFS: Short Interframe Space (SIFS)

8.2 DCF also has an optional virtual carrier sense mechanism that exchange short RTS and CTS frames between source & destination stations during the intervals between the data frame transmissions.

8.3 IEEE 802.11e: an approved amendment to the IEEE 802.11 standard that defines a set of QoS enhancement. HFC: hybrid coordination function. a methods of a channel access
EDCA: enhanced distributed channel access, set traffic priority.

8.4. infrastructure mode: STA+AP, ad-hoc: STA

8.5 infrastructure: STA: communicate with each other via AP. AP: receive & pass messages. Ad-hoc: STA: communicate with each other directly.

8.6 It defines RF transmission Standard and use CA ~~as~~ collision avoid protocol

8.7 LLC: responsible for identifying Ntwk layer protocols, encapsulating them and controls error checking and permission or transmitting data
MAC: Media Access Control: control how devices in a Ntwk gain access to a medium and permission or transmitting data
PLCP: How cells are formatted within a data stream. PMD: define the physical layer of computer Ntwk protocols.

8.8. Infrared: use IR diodes, diffuse light. A: 1) simple, cheap 2) no license needed 3) simple shielding possible.
Dis: 1) interference by sun light 2) low bandwidth
Radio: typically use the ISM (2.4GHZ). A: 1) wireless, good for mobile devices 2) coverage of larger areas. Dis: 1) limited bands. 2) channel interference.

8.9 802.11, 802.11a, 802.11b

8.10. use 2 bits to represent type (first priority), 4 bits to represent subtype, finally we get management frame > control frame > data frame.

8.11 CSMA/CA: carrier sensing is used, but nodes attempt to avoid collisions.
BEB: Space out repeated retransmissions of the same block of data
NAV: the virtual carrier sensing is a logical abstraction which limits the need for physical carrier-sensing

8.12 I don't know..

8.15 Yes. Multimedia service, Emergency Service, Group comm.

8.16 TSF: specified in IEEE 802.11 WLAN standard to fullfill timing synchronization among users.

8.17 infrastructure-based: sync by transmitting periodic beacon signal. Ad-hoc: each node maintain own timer and start transmission of beacon signal after each beacon interval

8.19 Yes. 802.11 specify a clock sync protocol but suffers from scalability problem.

8.23 ① Discovery phrase: STA leaves behind AP, SNR↓ → Mac layer scanning. ② Authentication phase: AP accept/reject the identity of STA. ③ Associate phase: STA send a re-association request to New AP.

8.25. type/subtype → function of frame. 2 bits for Version, frame-control flags

8.27 802.11a use different radio technologies & portions of the spectrum. being incompatible with each other

8.29. 40 bit key + 24 bit IV → Encryption Decryption → PRNG → ⊕ Plaintext → RC4 → cipher

8.31 open system Auth: client provide no credentials to AP.
shared key Auth: 4 step challenge-respone handshake

8.33 active: client request & listen;
passive: client listens for periodically beacons.

9.1 1) more substantial backhaul bandwidth 2) directly support triple-party service 3) economically viable to provide last-mile net access.

9.3 use N orthogonal sub carrier so that info can be demodulared by FFT. $V(t)=\sum_{k=0}^{N} X_k e^{j2\pi kt/T}, (0\le t<T)$

10.1 infrastructure comm through AP while Ad hoc comm direct between devices. Ad-hoc use WEP/no security. infrastructure have more security options

10.3 a zone established to prohibit specific activities in specific areas

10.5. A hidden terminal is the fact that A is transmitting to B so B can't hear C. Exposed terminal is the fact that C is not listence of C enter the backoff periods and C is not permitted to talk

12.1 low-energy + more reliable + more secure + faster

12.3 transponder: programmed with unique info
transceiver: pass tag info to the outside
antenna: attached to the reader, reader-interface layer

13.1 WSN can be star Ntwk → multi-hop mesh Ntwk, using routing finding

13.3. Area Monitor, Health care, Water quality measure

13.5 IFE, in cabin, medium Data rate, 3-5m Range.
SHM, out cabin, Low " . 50m range

13.7 solar cells

14.2 High transfer rate, low power consumption, immunity to external interference.

14.4. it detects available channels and change parameters to use the best one.

15.1 allow Ntwk programatically changeable

15.3 SDMN. SD-WAN, SD-LAN

15.4 centralized ntwk provising + cloud + lower operation cost

16.2 Waymo, Apollo, Tesla. Waymo: Google's self-drive car project.

17.1 SIMO: single in single out | MIMO: multi-in-multi-out

19.3 I don't kn..

20.1. security lies in "transaction block chain"

8.13. multicast service makes use of a single rate out of the various rates included in the BSS.

8.14 because it contains the time that the station has already the medium will require to transmitt its frame, the information is used by other stations to set NAV value.

8.18 Because PLCP frame structure of a PPDU provides for asynchronous transfer of PSDUs between stations,

8.22. DTIM: the content of TIM IE will give info about broadcast traffic buffered in AP. ATIM: message-type used to notify peers of pending data transfers in an ad-hoc wireless Ntwk

8.24 because of bandwidth limitation.

8.26. When data is transmitting to a receiving device, either one of these device may not be the actual source/destination of the L2 traffic. So this can create situations where you need four distinct addresses.

8.28. goal of wep: provide data confidentially

8.30 WEP2 extend both IV & key values to 128 bits but is still deficient

8.32 WEP2. D: deficient A: compatible for most routers
, Mac filter D: can be fooled, inconvenient
captive portal A: help protect against hackers D: can be spoofed

8.34 use 3 bit Priority Code Point.

8.35 $\Theta(W\sqrt{An})$, A is the total area, n is number of nodes, W is the transmission rate between 2 nodes.

9.2. 802.16 Physical layer contain TCL & PMD. can adaptively handle burst data blocks & dynamically change modulation method & transmit power.

10.2 receiver: i) should be within range r of transmitter T
ii) outside $(1+\Delta)r'$ of any other T'.
tranciever: i) should be within r of receiver r. ii) outside $(1+\Delta)r$ of any other...

10.4 according to area constraint, we get upperbound, and we can use a specific placement to get to the bound, so we get $\Theta(W\sqrt{An})$

11.1 To 8.27

11.2. initiation (send EAP-Request) + Negotiation + Authentication

11.3 WPA2 (IEEE 802.11i) is the best. WPA is a remedy for WEP, but still deficient.

12.2 Inquiry: know nothing about each other. Paging: know address
Connection: two connected

12.4 AIDC: Automatic Identification & Data Capture.

12.5 Asset tracking, ID badging, Personnel tracking.

13.2 Controller: control other components / process data.
tranceiver: give pattern allocation. External Mem
Power source, Sensors.

13.4 significant manpower, depend on skilled developers

13.6 I don't kn...

14.1. NFC, QR code, BLE

14.3. BLE doesn't need to exchange much data as Bluetooth

14.5 feature: frequency band, data bandwidth, transmission distance
App: health care, military.

15.2 1) decouple of controller & data plane 2) logical centered control 3) exposure of abstract ntwk resources.

16.1 camera, pressure, gyroscope, microphone..

19.2 $Y(t)=\int H_c(t,f)X(f)e^{2\pi ift}df+n$

19.4 WIFI. 3G. 4G: MIMO is an essential element of 4G-LTE & WiMax

20.2 3 distinctive squares at the corners + A small square near the 4th corner + small dots through out the QR Code