16/6/2019

→ features of cellular communication :

→ Rf interface → allows mobility

→ limited power

→ health results

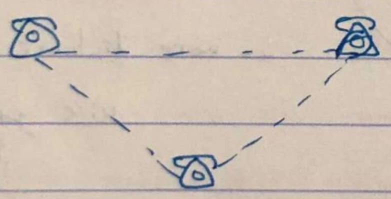
→ mobility → uses omni antenna → recives the signal from all directions

→ modulation to lower BW & orthonality

→ introduction to Traffic theory & telephony

→ resources use intelephone system

1) If we want point to point communication :

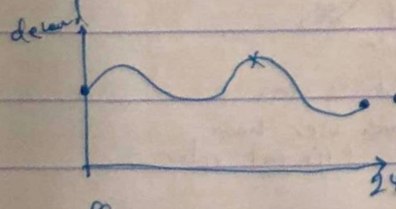


# of links = $\frac{N(N-1)}{2}$

→ not vary effective since we use the links for short period of time only & installing point to point wires is really expensive

2) sheared link → we need to study → the demand & traffic

→ demand : loads to busy hour




← start & end point for one day are not the same but for average they are the same

→ traffic :

# of users ≡ # of cars

size of one phone call ≡ length of care

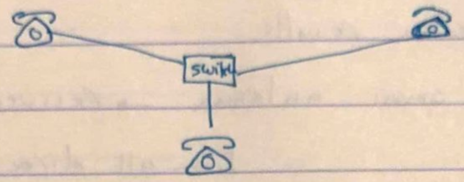
Traffic = $\frac{Q_a \bar{\lambda}}{60}$ (Er) = A

60 → per hour

(Er) → erlings

$Q_a$ : # of active users

$\bar{\lambda}$ : average phone call length (in min)

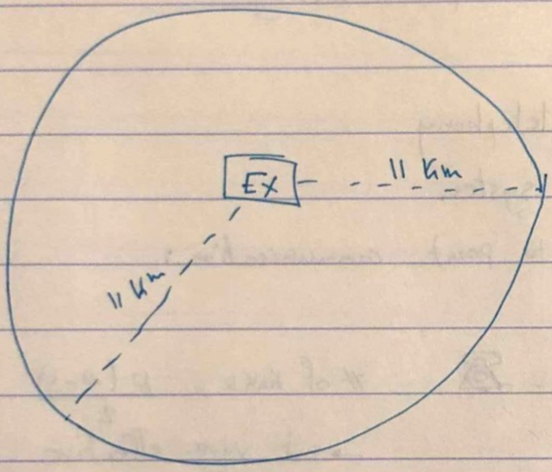



# of ~~length~~ links → N

note: contries starts with (00)

zones starts with (0)

→ phone # are orginized based on the location




→ max length of the link → 11 km

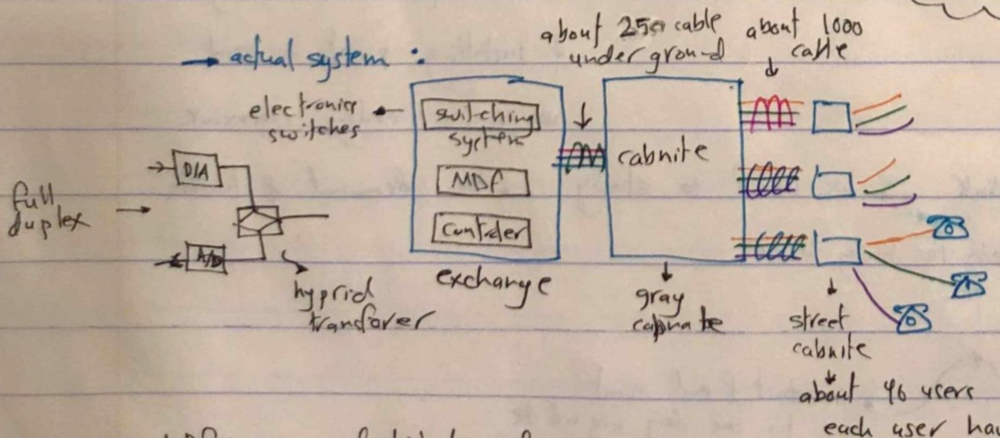
→ we use wire ~~gedth~~ gauge 24

→ more distance use thicker wire

wire ~~gedth~~ gauge 24

cat 5 → 22  cat 6 → 24

→ actual system :




MDF : main distribution frame

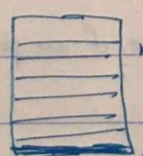
we have a fuse here

so that the system doesn't

get burned if connected to

high voltage

→ inside of EX




500 – 1000 user

→ use only 80% of them

→ memory / cpu / alarm / land card

power supple

E1 (TDM) = 32 channels × 64 kbps = 2 Mbps
30 channels, 2 control
each one PCM signal

64 kbps → 4 kHz × 2 × 8 bit/sample = 64 kbps
2BW

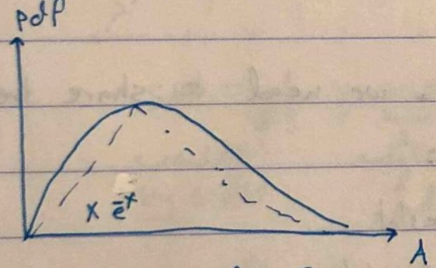
* data from Ex to Ex is a routing process
protocol → SS7
now adays → IP used to control data

17/6/2019

→ basic principle of cellular: → frequency re use
→ shared resources

$A = \frac{Q_a \bar{T}}{60}$ Er

→ in traffic theory : N resources → # of channels → limited → $↑
A Traffic
BP blocking prob → for QoS (performance user)




← power function
← localized
← behavior → length

behavior of traffic

increase peformance
increase # of resources
Bp not important

BP given by goverment

→ so many functions fit the curve → Erland → best fit
→ posone
→ raylicgh

→ blocking prob → ind R.V
∫ R.V
N dimention

dropped / delay
dropped ← كطول الخط مشغول
delay: بيضل الوقوف إذا الخط فضي ورح ٢
→ between ne & path

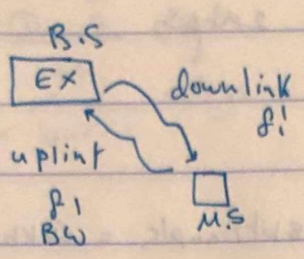
→ delayied → erland C ←
→ dropped → erland B

→ N↑ → more customers → more capacity
→ more $
→ higher # of resources gives a more effective solution
→ per costumer → less pay

shared resources minimize the cost not linearly ←

| N | BP 1% | BP 2% |
|---|---|---|
| | ↑ A | ↑ A |

wireless

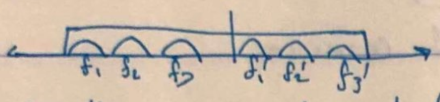



→ we have a CCC to control f

→ requires BW
→ power limitation } issues

→ full duplex → uplink f & downlink f'
(half duplex → both on f)

18/9/2019




25MHz → 1000 channel (GSM) → 25KHz/user

1000 channel not enought

GSM → uplink 890 - 915 MHz
downlink 935 - 960 MHz

→ Variable routing → duo to mobility
→ I'm alive at CCC (location update every 1ms)

→ 1000 channels are not enough → we need to share them
→ sharing ~~tequiques~~ tecneqies :
→ FDM → 25 KHZ / 1 tieslot
→ TDM → 100 KHZ / $\frac{1}{4}$ tieslot
→ hyprid → 200 KHz / $\frac{1}{8}$ tieslot ← used in cellular
↓
because old tegniques used to use
200KHz filters

→ still we need more channels → use orthognality
→ space → frequency → tie → code

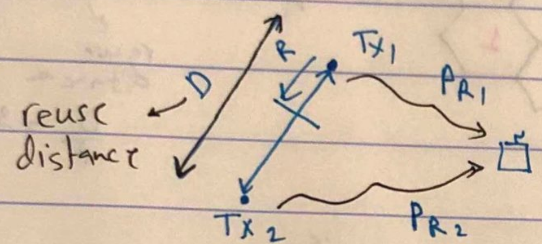
Scanned with CamScanner

→ space orthogonality → depend on: 1) reciver sensitivity (not much)

2) reciver discrimination

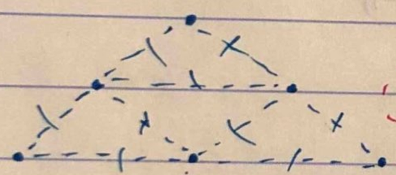
depend mainly on modulation & coding & management of system → (BER) → SNR limit

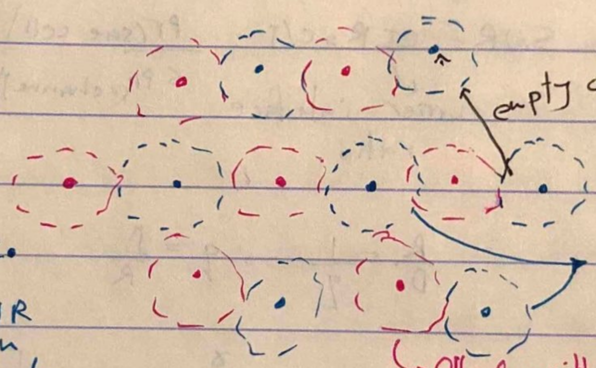
* SNR limit → after that I can reuse the f




$P_{R1} > P_{R2}$

$D \gg R$






$SNR = \frac{S}{I} \geq SNR_{min}$

I → surrounded by 6 cells

$SNR_{min}$ → modulation & coding

→ number of different sub channel → K (reuse factor)

$K = i^2 + ij + j^2$   i, j → integrated

K=1 → optimal solution (we couldn't do it till now) → 3/7 also optimal → not used / K=4 ← found by trial & error

3/7 → in exam use this

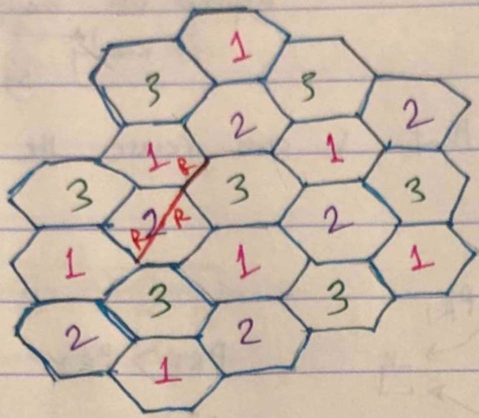
$N_{cell} = \frac{N_{Total}}{K}$

$N_{Total}$ → 1000 chanel

K → we want it to be small

→ ex: $K = 3$

$N_T = 90$ → $N_{cell} = 30$




near end
far end
points → $D \approx 3R$
↙
reuse distance

$\frac{D}{R} = 3$

$SNR = CIR = C/I = \frac{Pr(same\ cell)}{6\ Pr(co\ channel)} = \frac{(R/D)^{-\gamma}}{6}$

↙ carrier interface ratio

$Pr \propto r^{-\gamma}$

$2 < \gamma < 4$
↓
fading coefecent
↓
2.73 in average in Jordan

$\frac{R}{D} = \frac{1}{q}$ → $q = \frac{D}{R}$

→ $CIR = \frac{q^{\gamma}}{6}$

$q = \sqrt{3K}$ → ~~space~~ general case

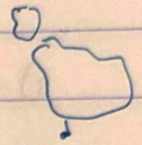
for $\gamma = 3$ → $K=3$ → $CIR = 4.5$ → 6.53dB → better solution although bad SNR → solution uses code that requires 6.53dB

→ $K=4$ → $CIR = 8.4$dB

→ $K=7$ → $CIR =$ ~~15~~ 12.05 dB → best SNR but more expensive solution

19/8/2019

→ to design a cellular system first we need to find the coverage Area → first assumption for basic cellular system: 1) uniform distributed clusters

2) flat earth → geometry effect the shape of cells → not actually ⬡ → if like this → 

ARPU → average return per person → 14$ in jordan

this cause many issues so we try to avoid it →

dis: 1) more handover ↓ leads to more overhead & maybe more blocking

EX: Area of 100Km² & we have 1K customer/Km² only 10% of them are active during busy hours & average call duration $\bar{\lambda}$ = 2min ← in jordan & BP is 1% find # of cells required if:

1) $N_T$ = 90 cell

→ $Q_T = \underbrace{100}_{area} \times \underbrace{1K}_{customer/Km^2}$ = 100K customer

→ $Q_a$ = 10K customer

→ $A_T = \frac{Q_a \bar{\lambda}}{60}$ = 333.3Er → total trafic → # of cells has to handle all the trafic while maintaning the BP

→ $N_T$ = 90 cell, K = 3 → $N_{cell}$ = 30 cell → $A_{cell}$ = 18.59 (↑ from table)

→ # of cells = $\left\lceil \frac{A_{Total}}{A_{cell}} \right\rceil$ = 18 cell (always take the ceil)

→ cell area = $\frac{100K}{18}$ = 5.56 Km² → 2.6 R² (area of ⬡; R in Km) → R = 1.46Km

2) $N_T = 150$ → $N_{cell} = 50$
$K = 3$

$A_{cell} = 34.81$ Er → # of cells = 10 cells

cell area = $\frac{100 Km^2}{10} = 10 Km^2$ → $R = 1.96$ Km

3) $N_T = 90$ →
$K = 1$

$A_{cell} = 69.05$ Er → # of cells = 5 cell → better solution & less money

cell area = $\frac{100}{5} = 20 Km^2$ → $R = 2.77$ Km

→ at the biggining of cellular we had IS95 compeating with GSM & was better than GSM but duo to the SMS that for people was a more secure solution than Username & password GSM won * IS95 used in palestine

* AGPS: used instead of GPS for cellular communication that uses the cellular tower to know the place because GPS requires to have a LOS with 3 or more salalite

23/6/2019

ex: design a system with $C/I_{min} = 8.5$ dB, $Q_a = 200K$

$BP = 1\%$, $\bar{\lambda} = 2min$, $\gamma = 3$, $N_T = 140$

→ design → # of cells

C/I operating

W

$C/I = \frac{q^\gamma}{6} = 8.5dB = 7.079$

$q = 3.49 \rightarrow q = \sqrt{3K} \rightarrow K = 4.058 \rightarrow$ highest $K = 7$

operating $C/I = \frac{q^\gamma}{6} = 12.05dB$

$A_{total} = \frac{Q_a \bar{\lambda}}{60} = 6666.667$

$N_{cell} = \frac{140}{7} = 20 \rightarrow A_{cell} = 10.97$

\# of cells $= \left\lceil \frac{A_{total}}{A_{cell}} \right\rceil = 608$ cell ← vary large # → need better solution

** frequency plan → how to devide the channel between the cell types in order to reduce the adjecent channel interference

$$C/I = \frac{C}{\Sigma I + \sigma_n^2 + I_{adj} + I_{man}}$$

→ interference : → co channel → solution by deviding into cells & other up comming solutions

→ white noise → small

→ adjecent channel → duo to imperfect filters can be solved by using ideal filter (expensive) or by frequency planning

* filters used in GSM should have roll off factor 40dB/ decate & higher

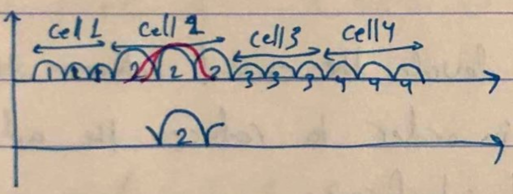
→ man made interference → may happen in sore frequency so we try to excluded from the cell near to the ~~most~~ 'man made interference, ex: noise from factories

Also another type of man made noise is going into the basement → (human behaviors)

C/I ↓ → BER ↑ → droped packet ↑ → bad service

→ in GSM we have a counter for the dropped packets when the # of droped pKts reaches a certain value it automaticly disconnect (to alert the user to change it's location)

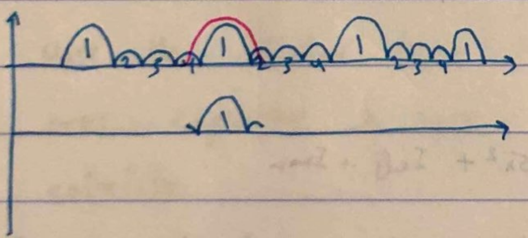
* frequency plan




* ideal filter are really expensive → for each device

→ high interference duo to adjecent channel

solution →



→ less adjecent channel interference since already the signal from the near by channel arrive attenuated

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | 140 |

← this is not the optimal way to devide the channels between the K duo to having some frequences that experement specific difficulties duo to the location so it's better to give it to another cell

* If I need to improve the service → improve the RF interface only

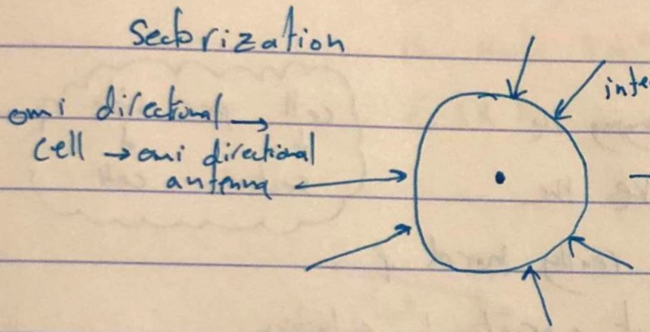
→ in cellular towers we have an alarm system connected to it to monitor the performence of the tower

ex: ~~light~~ ON/off / air conditioning / open doors / ect...

24/6/2019

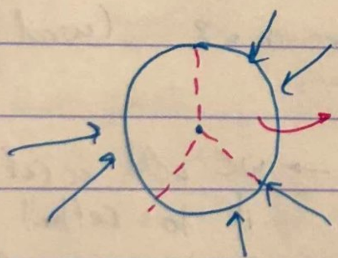
→ another method to improve the system C/I is by deviding the cell into sectors

Sectrization




→ $C/I = \frac{q^\gamma}{6}$ → we need to menimize the # of interfering signals

solution →



$C/I = \frac{q^\gamma}{2}$

sectrization : can be done with antenna to only recive / transmit from one direction

new $C/I = \frac{q^\gamma}{\lceil \frac{6}{n} \rceil}$ → the least thing is one

ex: continue previous example : assume n = 2 → # of sectors

$C/I = \frac{q^\gamma}{3} = 8.5\ dB$ → $q = 2.769$

$q = \sqrt{3K}$ → $2.56 = K$ → take $K = 3$

operating C/I = 9.54 dB

$A_{sector} = 23.3 = \frac{140}{2\times3}$ ← for simplisity take 23

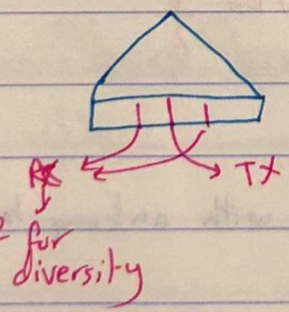
cell configuration = K x n = 2x3

$A_{sector} = 13.21 Er \rightarrow A_{cell} = 2 \times A_{sector} = 26.42 Er$

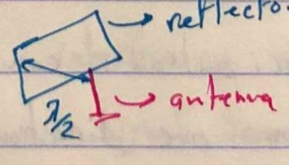
$\# \text{ of cells} = \left\lceil \frac{6666.66}{26.42} \right\rceil = 253$ cell → almost 1/3 of K=7 without sectoring → better solution

* sectoring can be done by changing the radiation pattern → to make the radiation pattern 180° is really hard & expensive so n = 2 is not a practical solution
→ most popular solution n = 3 (used in GSM)

cell per site → sector / cell




→ we add a reflector behind it to reflect the radiatino → easy to be done for 120°




ex: solve for n = 3

$$C/I = \frac{q^{\gamma}}{\lceil \frac{6}{n} \rceil} = 8.5\,dB \rightarrow q = 2.42$$

$$q = \sqrt{3K} \rightarrow K = 1.95 \rightarrow K = 3$$

operating $C/I = 11.3\,dB$

$N_{sector} = \frac{140}{3 \times 3} = 15.56 \approx 15$

$A_{sector} = 7.39$ Er → $A_{cell} = A_{sector} \times n = 22.17$ Er

\# of cells = $\left\lceil \frac{6666.66}{22.17} \right\rceil = 301$ → higher than n=2 but less than n=7 without sectoring

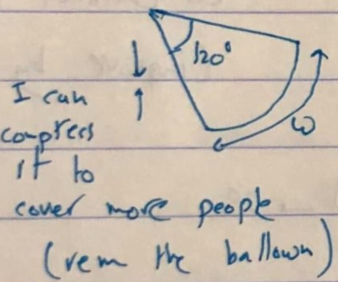
→ advantage for sectorization:

1) better C/I → less # of cells

2) higher gain for the antenna (since radiation is not 360°) (less power transmitted)

EIRP = gain x power

G x P



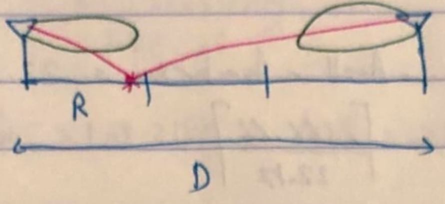

beam width = 120° (horizontal)

↳ remember $\frac{\lambda}{2}$↑ → gain in the vertical axis increases

* being close to a military station cause interference since they send real high power if there frequency is close to mine or a harmonic for my frequency → we use a frequency hopping tequniqe between different users to average the performance between them → used espically when the system is fully conjested → cause more over head & failier

* harmonics can be produced if the wire is oxcided

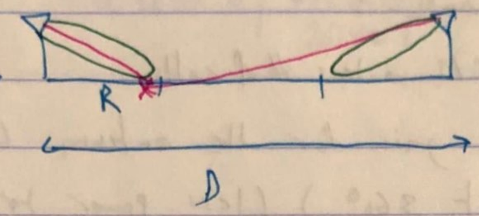
→ down telding




farend neadt end user

→ in this case experement the max inteference from the co channel & minimum signal from the channel (C/I ↓)

solution →

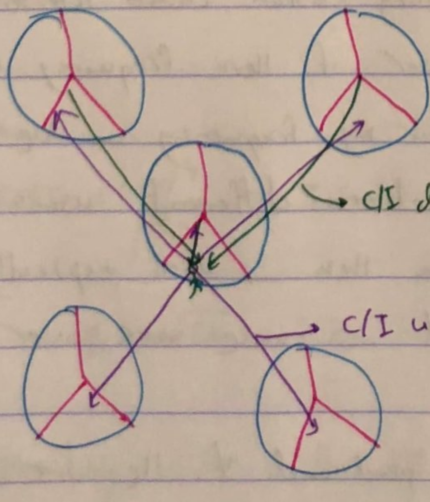



→ if we down telded the radiation I recive the ~~better~~ max from my channel & min from co channel (C/I ↑) (ingrove by 2/3 dB)

* down telding → I need about 6°
  → electric down telding (shape of wire) → ≈ 3°
  → mechanichal down telding (shift the antenna downword) → 3°

→ in real life not all the interferences are the same

$$C/I = \frac{C}{\Sigma I + G_n + I_{adj} + I_{non}}$$



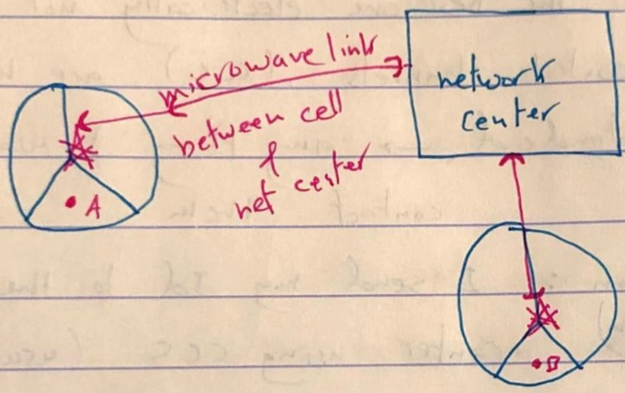
→ C/I down link (from the behind cells only)

→ C/I uplink (s radiate in all directions)
  ↳ we care about this more because it effect the basestation not the user only

if from down felding C increases by 1dB & I decreases by 1dB → C/I increases by 2dB (1dB + 1dB)

25/6/2016

→ system operations : what happens in the system to enable us to make a phone call




→ controles all operations in the network
→ one or more in the system (large contries more)
→ it's a distributed system (more than one CPU)

1) call set up

→ first thing when I purchase a line I need to srach for network (network search / handshake with network)

→ for users to communicate with the network or the network to communicate with the users they need a channel & they cordinate between them selfs to use it → called CCC (one in each cell or sector or maybe more than one in the sector)

* multiple access → simplest algorithm → sloted aloha
→ no reply for a while → re send

network search → look for CCC (wait for broadcasting)

→ each network has an Id → according to that Id I know what is My CCC

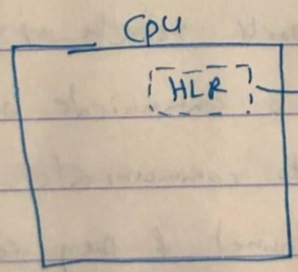
→ I will recive 7 broadcasting pkts then I select the best one of them according to the RSSI: recived signal strength indecator

* note: I select the best one electrically not physically
* note: the control channels (CCC) are known by the standerd → any thing I want I contact them

→ log in operation (authentication): I send my Id to the ~~CCC~~ net center using CCC (usually phone #)

→ my data is stored in a database called HLR: home location registery

* sim card → memory & cpu




→ hold the Id & information about user → most importantly
1) the location
2) the status
- → black: can't make call or recive
- → white: can make call & recive
- → gray: only recive

→ if I'm allowed to log in (make aphone call)
↳ reply with Ack (you are loged in)

→ idle state → I'm connected to the network but currently not ~~ex~~ using it (not making a phone call)

Scanned with CamScanner

→ one of the informations that I need to update the network center with is my address

→ location update signal → how often?
it depend on # of users in the sector
& if I'm moving fast or not
(577 ms to 3 sec)

* since the CCC have low density (often used)
we use it to send SMS msges → this is why the ~~SMS~~ used to be limited in size → only one pkt

→ if I have a sector that send alot of SMS
we give them more than one SMS

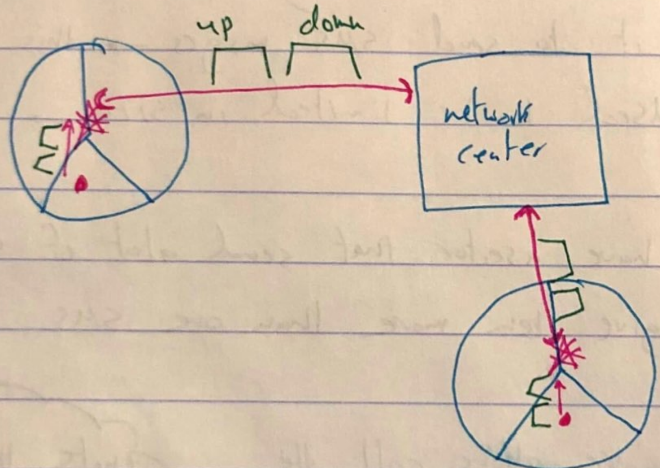
→ if I want to make phone call the first thing I have to do is send the # to the ~~MSC~~ network center using CCC → from the HLR find the location & status

*note the network center is a unix based CPU
→ distributed system
→ to use GSM chip we need to add the modem library

* status : busy or not / flight mode / turned off
can't be reached
↳ I send a msg saying I'm gonna turn off my phone

→ then if available → send him a notification
& reserve channels → before he pickes up
to be able to tune the oscilators because they take time to stabilies (quality parameter for the device)

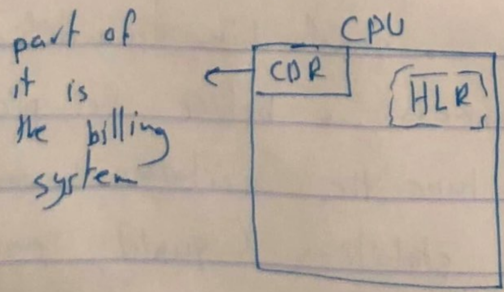
→ usually in a device we have 2 oscilators
→ one currently running
→ one getting ready → used for hand off to insure a continuouse call
↳ if the oscilator falles to synchronize (called glitch) → call will fail



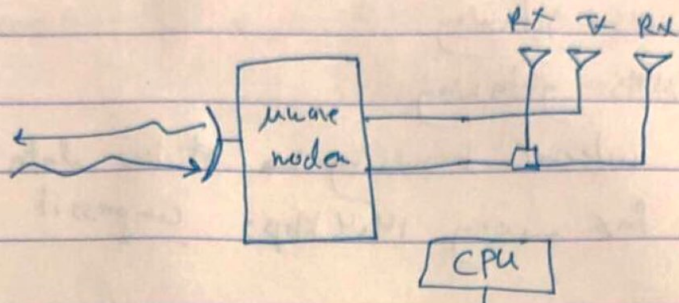

→ if any of the channels is not avalable → send all lines are busy
→ GSM → cct switching
→ symetric

→ call release → happens when some one hang ups the phone
→ we give the channels back for other users to use them (multiple access)

→ finance stuff are done in the cpu by a unit called CDR: complete data records (software)



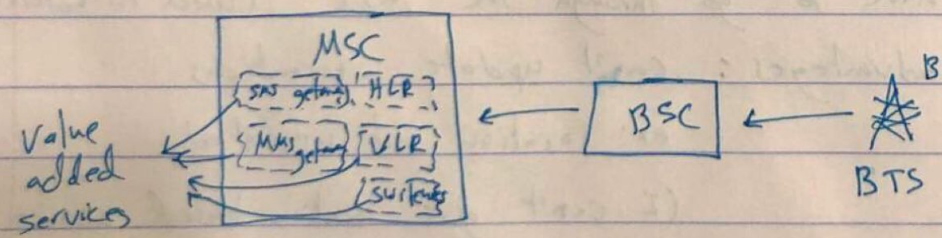
26/6/2019




20channe → each one TDM → 8
↓
I need 20 links

→ we need a controler to control the process
→ cordinate the channels (path) togather (each channel with what user)

→ to control this process between BS → BSC (base station controler)
→ control about 30 BS
→ conected to the CPUs in the BS
→ control specific operations → responsable for path reservation




BSC control BTS
MSC control BSC

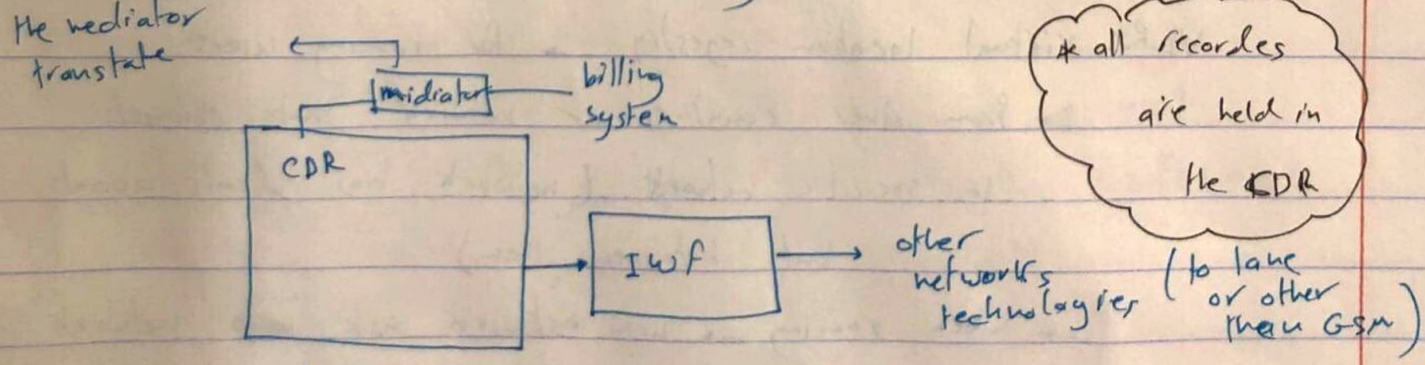
VLR: virtual location regestry → for roming users
→ from other countries or network that connect to specific network (network has deals about that between them)
→ when roming → new network ask org network for the user records from the HLR

another value added services (inside the MSR)

- → SMS getaway
- → MMS getaway
- → internet browsing → at low data rate → 9.6kbps
- → fax → org 14.4 kbps —compress it→ 9.6kbps

* SMS → on CCC → if inside the network send it through CCC to other user
→ outside → send it through IP to the distination

→ the system is distributed → ~~Ihave~~ If I want to ~~use~~ contact with user that we share the same BSC I don't have to go through the MSC (used in motorola)
→ disadvanteges : can't update informations
ex: location not updated
(I can't give location based services)
* now we relay less due to GPS



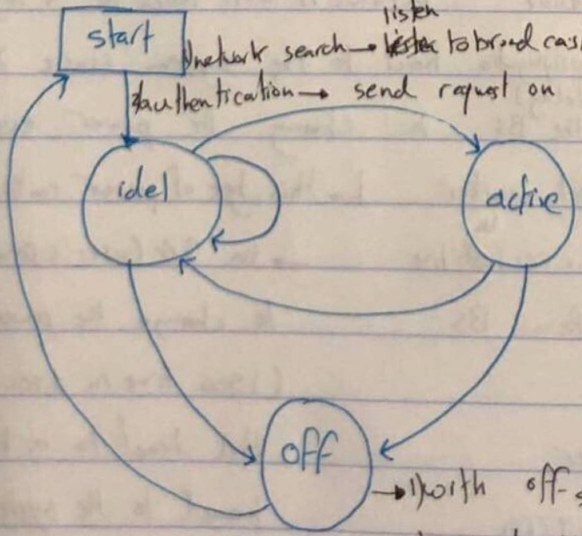

IWF : for other technologies to talk to other technologies
↓
inter working frames
GSM to IS95
→ pkt size / data rate

→ some times if I don't have a link between other countries (no E1 connection) → I can call through the internet (routing through the internet
ex: skype

call set up :
network search
authentication
→ idle state ↺
- intiate a call
- Rx
active state
- end call

* so far for voice (symetric) only works for GSM system
* 3G ↑ → data based because it's asymetric system
→ only if we have enough BW we can give up GSM & use VoIP
+ GSM is more secure than IP

30 / 6 / 2019
operations as state diagram



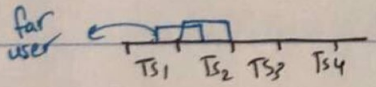

start:
1) network search → listen to broadcast
2) authentication → send request on CCC

off:
1) with off-signal → turn off your phone
2) without off signal → remove battary
go to out of signal place

what do we send during the authorization phase ?

- request to join the network
- Id of closest tower
- pass word of user name → K algorithem
  - ↳ executed in the user & BS if both gave the same result → log in
- power recived for 7 networks (mine & 6 surrounding) (RSSI)

timming advance
↓
if far away users send their pkt at time slot it will arive late due to propagation & will lead to intersymbol interference (ISIP)




→ timing advanced measure how may 550m (1μs propagation delay) the user is from the BS & they send their pkt earlier so that their pkt arive in time

ex: user 1000m away from BS send 2μs earlier

→ controled by a counter

old system → 6 bits → 33km

new system → 7 bits → 64km

power transmited (power control)

BS tell the user to increase or decrease the power recived

→ in each pkt we have one bit power control → 1 → increase, 0 → decrease

↳ save power at user

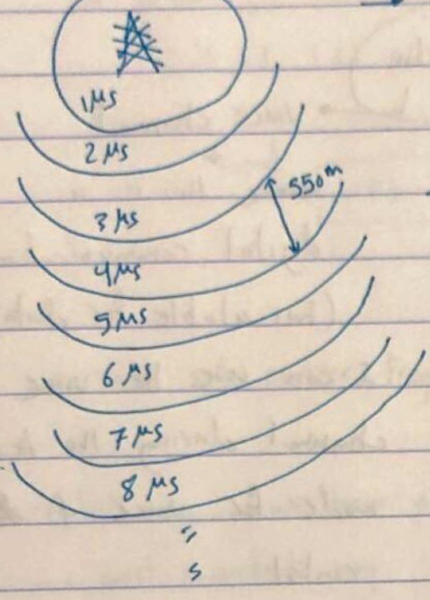
↳ less interference to other users

→ power control happens to the uplink we can't do it in the down link because it will lead to a large over head to the system since I have to chang the power every time slot

↳ this type of power control is slow

→ in 3G (uses CDMA) I need to change the power fast (1500 time in 1sec) this lead to a huge over head to the system

↳ reason why 3G failed




→ since we have a counter for the distance with limited # 8bit → GSM distance is limited by timing advanced

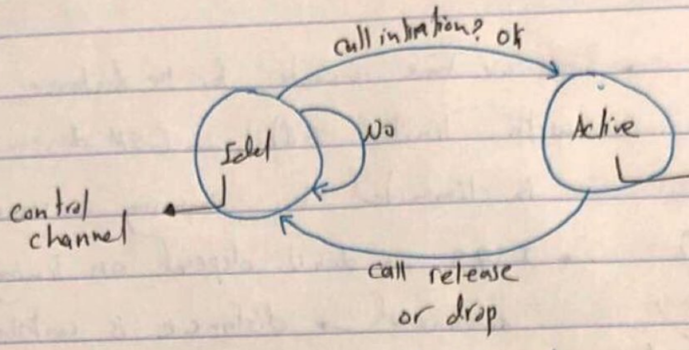
→ ISPS → don't depend on timing advanced → distance is controlled by power level

→ according to the power lever I can know:

1) my distance from BS
2) timing advanced
3) what sector I'm in

but it can't pin print the user → I need GPS system to locate the users exact location (better & chepper)

↳ networks need the exact location




physical channel vs logical channel

→ physical → modulation / fc
power transmitted / data rate

→ logical channel → pkt type → voice
→ data
→ control

understand pkt switching & cct switching

| | payload |
|---|---|

control data

→ sender & distination
pkt sequence
data type
CRC
tranning data
→ important for success full communication, since ft → faster changing channel
→ assume quazi static channel → stays the same for every pkt
→ it helps with synchronization on bit level (clk) & frame level (size)
& predect the channel state information

Voice channel
↓
since this is a digital communication (has ulable for data)
I can use the voice channel during the Active mode for voice & control

→ send control data during the scilent period
ex: SMS / location update
missed call

→ special pkt sent at the end of the call asking for order in the CCC → so that we don't do autharization All over again

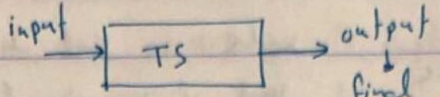
# I can use voice & control chanel but not emplied in GSM → expensive needs 2 TX

Scanned with CamScanner

example of tranning data

→ send the first 6 bits → ones

1 1 1 1 1 1 (pilot) & see the ~~input~~ output data




↓ final fading level

channel parameters → coherence time
↳ coherence BW

→ some sub carrier frequences in OFDMA

* control msg → we have about 114 msg

→ most important msg

- location update → RSSI of 7 cells
  - timing advanced
  - power control
- synchronization pkt
- value added services → SMS /MMS
- call end /release
- dupy pkt → during scilent period (to keep alive)
- QoS pkt → call drop
  - call drop reason (4 or 5 causes)
  - missed pkts
  - voice rate → depend on network conjestion
    - full 13.2 kbps
    - half 4.8 kbps
    - quarter 2.4 kbps → data rate ↓ → BER ↑ (less # of bits)
- frequency (channel) hoping → hoping sequence
  - → we need to cordinate between the users → missed synch → call drop
  - → over head (need order of synchronization)

- handover request → my ~~channel~~ cell power is less than other cell
→ right away or delayed

* hard handover → tunning oscilators
→ In GSM
→ case drop & interference

→ delayed → wait 5dB → in active mode so that I can make sure ~~that~~ of the handover & oscilators needs time for changing & I need to reserve other channels → need to be fast (hard hand over)
→ in inactive mode I don't care → just chang BS Id

* soft handover → adv of 3G
→ depend on changing the code not f
→ have some problems → synchronization, power control, dopler effect

- security algorithms → encripted data or not
→ for VIP people data is encripted from end to end

* control msg are know to the public

1/7/2019

We needed to increase the capacity of the system
→ Multiple Acess : more than one user sharing the same channel

- TDMA
- FDMA
- hyprid → TDMA & FDMA → in GSM
- devide the channel between two users
- CDMA

→ two users using the same channel (f & time slot)
→ used in GPRS (2.5G) : general packet radio service
we took advantage of the fact that we talk using the channel for 3/8 of the time & listen for 3/8 of the time (2/8 is left empty)
1) we devided the channel between 2 users where each user can use the channel during the scilent period of the other user → this increased the capacity by 1.5-2 times → more ~~spectrt~~ spectrum efficiency
* if we used a higher order (dimention) modulation we derease the BW per user
M-array → BW efficiency ↑
2) since 2 user use the same f & time slot we needed more control on the system → update from ckt switch (GSM) to pkt switch (GPRS)

* why did the system failed
→ political resons → expensive licences
→ beggining to use data for cellular & mobile phones where expensive
→ pkt switching is not as good as cct switching for voice communication
↳ 1) since pkt switch → know where to go it needs to pass through a service provider (to pay for it) → needs bigger BW to deliver data every where → it's like making a new internet → instead use the internet

2) if the number of users increases → real time call is not garentied

3) channel is not symetric → not sutable for real life application

4) multi application system → low security

* we needed to update the system
  → add some control hardware (servers (routers that are real smart & can handle high data rate))
  & change the BS & let BTS control

→ CDMA

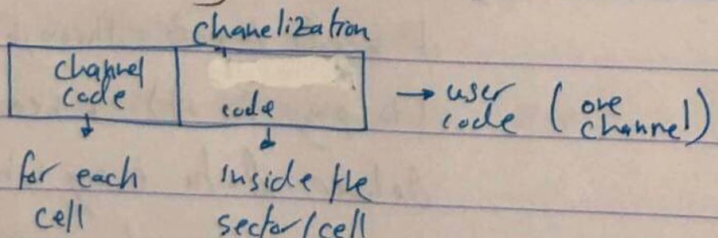
→ used in IS95 & 3G & GPS

it uses spread spectrum techneques & it uses orthogonal codes

→ # of users don't depend on BW (traffic) instead it depend on the # of codes & the MAI (multiple access interference)

since # of users don't depend on BW so IS95 BW changed from 25 MHz to 5 MHZ but still the capacity increased by 20 times

→ since users are using the same f → soft hand over



→ the # of users is controlled by C/I → MAI
(interferance not from inside the CG)

$$MAI = \frac{P_{re}\ (CG)}{(N-1)\ Power}$$

CG → code gain → $\frac{r_c}{r_b}$ → $r_c$: chip (code) rate, $r_b$: data rate

code gain ↓ expansion factor

$$(C/I)_{min} = \frac{CG}{N-1} \rightarrow N = \frac{CG}{(C/I)_{min}}$$

N ↓ # of users per cell

→ to increase the # of users → $(C/I)_{min}$ ↓

1) better modulation + channel coding → BER ↓
2) channel estimation
3) channel equilization
4) psk

→ obstacles we faced with the CDMA

→ codes should be orthogonal → we need to synchronize the codes → vary percise clk (channel for clocking)

→ emplemented in GPS

→ users distance → closer distance (highpower) effect away users (lower power)

↳ power difference between users shouldn't be more than (1–2)%. → we need fast power control (1500 persec) → high overhead & ~~cages~~ causes falier → less capacity by (18–16 time)

* still good

→ dobler effects causes fc to change fast & causesr miss synchronization

$$\Delta f = \frac{u}{c} f_c \cos\theta$$

→ expensive licence

→ MAI ↑ → capacity ↓

* IS95 → 2G → narrow band CDMA

3G wide → WCDMA

2/7/2019

→ OFDMA

same as FDMA but we use FT, we compresed the data → FDMA needs gardband while OFDMA don't

→ CDMA
- → WCDMA → stand alone technology
- ↳ UMTS → extention for GSM
  - ↳ change modulation / MA tequnique & f allocation
  - ↳ add to the system new devices
  - ↳ inside the network old & new devices (technologies) work togather
  - ↳ expensive licence
  - ↳ ex: 3Gpp
  - ↳ 3GSM won

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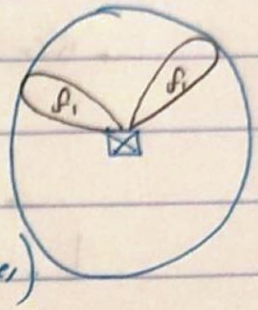
* again : to increase (C/I) ↓ → add better error correcting codes
→ 3G & above uses : tirpo code / LDPc code

→ other way to minimize interference → using smart antenna

1) spaciel filtering : inside the same cell I can reuse the same f & BW for multiple users

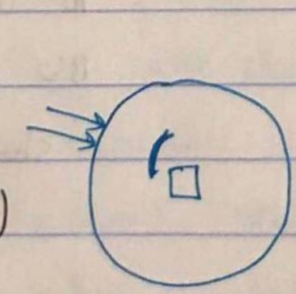



→ this is done by antennas called smart antenna / beam forier / antenna arrays)

→ the antenna creates a spical link (beam) between the user & BS → it need to know each users exact location
→ it's hard to manage during mobility (need for handout when the beams interfere (large over head)
→ not efficent when the user are centralized

* this solution works for some specific senarios since we need a spical radio (TX & RX) for each user this waste full → only add 2/3 radios in crowded areas as back up for this technology

2) interference blocking : the antenna needs to null the beam in the direction of the interference (controlable antenna)
$(C/I)_{min}$ ↓

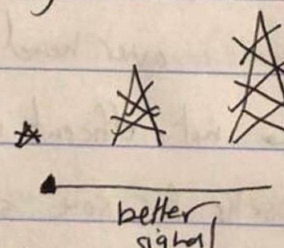


* newer technologies → every thing is adaptive / system evolutions

Gs → LTE

→ 5G → cell size ↓ → power ↓
  ↳ # of users per cell ↓

→ more like wifi cellular network
↳ uses OFDMA / CDMA technologies since we have small # of users & interference ↓
→ when # of users ↓ & the BW is the same → BW per user ↑
→ high data rate (1Gbps shares max)
→ 5G was designed to have a 3 level BS

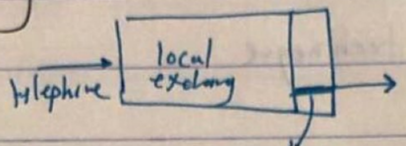



↳ the system does ~~seam~~ seamless hand over (connect to the lowest BS → higher data rate)
→ 5G used IP protocol → wasn't good when it came to voice communication → solution : reserve some BW for voice (VPN → virtual point network) & shared for data

→ VoIP → using IP

internet → [IWF] (device) → phone → phone calls as if they are done locally but it uses the internet (tellular) (ex: skype)

→ old way




* long distances → use IP
  other → racks in the local exchange

→ newer technologies uses IP to communicate
  ↳ IPV6 → added mobility features → same IP where ever I go
    ↳ VIP (virtual IP) → multiple IP for one device
      ↳ needs higher BW (resources)

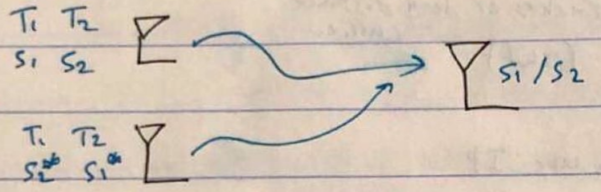
→ OFDMA / IP

→ the system is cheaper

→ resource blocks → f & BW & code & antenna → resources become like blocks
  ↳ it's very important to manage the resources so that I can get the best performance (optimization) ~~[illegible]~~
    → need coordination & management without a centralized unit → needs to be done locally but works together

→ large data needs → consentrated data storage
  ↳ to control & reachable data
  ↳ search / sort / optimization /
  distributed
  → done locally but work together

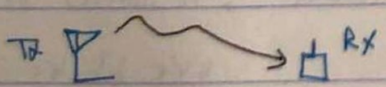
→ another smart antenna techneque
  3) space time code




→ transmition diversity (spacial diversity)
  ↳ solution for fading
  ↳ improve SNR by almost $\sqrt{2}$ times
  (more samples → noise power → avg = zero)

→ it's like CG or away to save power
* 4G → coding diversity

3/7/2019




for the Tx & Rx to be able to communicate they need to have a channel between them (not orthogonal) conditions → { $P_r \geq P_{sensitivity}$

$\frac{P_r}{I_{total}} \geq (C/I)_{min}$ → f reuse system is near orthogonal

Coverage → time
→ space

1) time → what percentage of time I can cover this area
→ relinability of the system
→ sight security
→ power system (diversity) → grid
→ battary
→ generator (desil)
→ componants life → material it's made of (good quality)
→ protection
→ heat sinks
→ scelting (protected for envirment)
→ diversity (cpu) → hot stand by
→ worm stand by
→ cold stand by

2) space → what percentage of the area my BS can cover
→ depend on the power recived

{ $P_r \geq P_{sensitivity}$
$C/I \geq (C/I)_{min}$

→ in order to find the coverage at apoint

→ this can be done using hand → car with antenna moves around the city & measure pr (systen survay) → this solution is hard & inaccurate

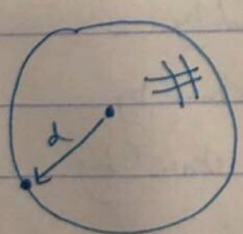
→ it can be done using software that has a GIS (geographical information system) where it has all the hights /streets /trees building then measure the Tx at each point → for this to be accurate we need a real accurate mathmatical models

link budget → pr = pt - loss + gain

$P_r = f(pt, d, \dots)$ → add elements according to the area

→ study from EM point of view

→ first model : empty space




→ omni directional antenna that radiates in all directions equally

power density at distance d ← $pd = \frac{pt}{4\pi d^2}$ → pr = Area pd

Area ↙ effectivarea of the Rx

$$A_{eff} = \frac{G \lambda^2}{4\pi}$$

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$$p_r = \frac{G\, p_d\, \lambda^2}{4\pi} = \frac{G \lambda^2}{(4\pi d)^2} \cdot p_t$$

$$P_r = \underbrace{p_t + G(dB)}_{EIRP} - \underbrace{20 \log\left(\frac{4\pi d}{\lambda}\right)}_{L_f}$$

EIRP → effective isotobic radiated power

$L_f$ → free space loss

$$L_f = 20 \log\left(\frac{4\pi d}{\lambda}\right) = 20 \log\left(\frac{4\pi}{c} d f\right)$$

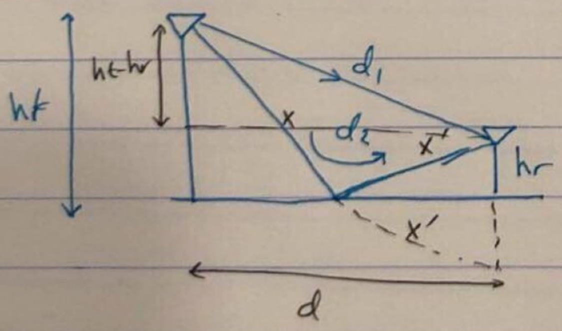
$$= k_0 + 20 \log(f) + 20 \log(d)$$

f in HZ, d in m

→ path loss in this case

$\boxed{\gamma = 2}$ ↑ best case

→ second model : two ray model




$$p_d = \frac{|E_r|^2}{\eta}$$

$$E_r = \vec{E}_1 + \vec{E}_2$$

$$= \vec{E}_1 - \vec{E}_1 e^{J\Delta}$$

$$\vec{E}_2 = -E_1 e^{J\Delta}$$

↓ reflected from ground

$$\Delta = \Delta d \frac{2\pi}{\lambda}$$

$$d_1^2 = d^2 + (h_t - h_r)^2$$

$$d_2^2 = d^2 + (h_t + h_r)^2$$

$$d_2^2 - d_1^2 = 4 h_t h_r$$

$$= (d_2 - d_1)(d_2 + d_1)$$

$$\Delta d \cdot 2 d_1 \rightarrow \frac{4 h_t h_r}{2 d_1} = \Delta d$$

$$\Delta = \frac{4\pi h_t h_r}{\lambda d_1}$$

$\vec{E}_r = \vec{E}_1 - \vec{E}_1 \left( \cos\Delta - j \sin\Delta \right)$

$E_r = \frac{4\pi h_t h_r}{\lambda d} \rightarrow P_d = \left( \frac{4\pi h_t h_r}{\lambda d} \right)^2 \times \frac{1}{\eta}$

$P_r = A_{eff} \times P_d = \frac{G \lambda^2 4\pi (h_t h_r)^2}{d^2}$

$E \xrightarrow{d} E_r = \frac{Q}{d}$

$p_r = \frac{E_t^2 G \lambda^2 4\pi (h_t h_r)^2}{d^4}$

$\downarrow$

$\gamma = 4 \rightarrow$ worst case

* any other model is in between the two models

7/7/2018

Freespace

$P_r = P_t + G_t - (20\log(\frac{4\pi}{c}) + 20\log(f) + 20\log(d))$

2-ray model

$P_r = \frac{E_t^2 G \lambda^2 4\pi h_t^2 h_r^2}{d^4}$

$= P_t + G - (10\log(d^4) + L_0 - (20\log(h_t) + 20\log(h_r)))$

hight of antenna

general equation :

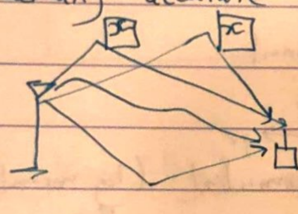
$P_r = P_t + G - loss$

$\underbrace{P_t + G_t}_{EIRP} + G_r - loss$

$EIRP + G_r - loss$

$loss = L_0 + \gamma 10 \log(d) + 20 \log(f) - 20 \log(h_t h_r)$ $2 \le \gamma \le 4$

→ this actually accurate



← I don't know how many pathes I have → $\gamma$ is R.V between (2–4)

pr is R.V

→ another phenominal → knife edge : the phenominal where the light diverce from it's path (usually happen when I have a small hole)

due to the knife edge shape sharp edges acts like a source (omi directional antenna) but the difference is that it will attenuate the signal

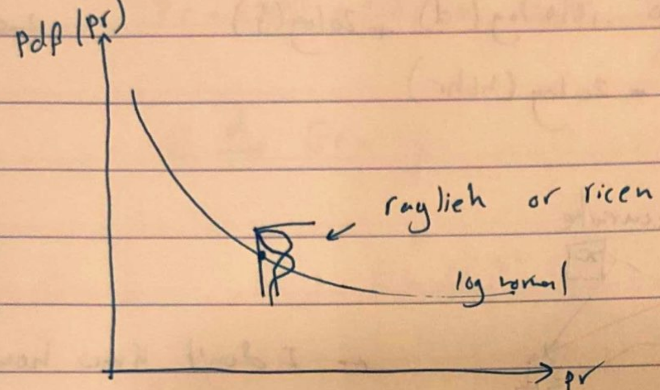
sharp edge from mathmatical model → inf # of point source started from the roof of the bulding to the infinite

→ knight edge loss

$Loss = L_0 + \gamma 10 \log(d) + 20 \log(f) - 20 \log(h_t h_r) + L_{knight}$

in actual systems the surrounding objects changes from location to another & time to another → paths change from location to a location & from time to another

↳ pr is a R.V




(complex) complicated R.V with exponential (log normal) & each point is either raylight or ricen
↓ has a mean — raylight: no direct Los; ricen: direct Los

$P_r = P_t + G - loss$

$P_r$ ↑ R.V; $P_t + G$: constant; loss ↑ R.V

$Loss = L_0 + \gamma 10 \log(d) + 20 \log(f) - 20 \log(h_t h_r) + L_{height}$

$L_0$ ↓ I know the behaviour but not the exact

$\gamma 10 \log(d)$ ↓ depend on # of rays → I don't know it

$20 \log(h_t h_r)$ ↓ it's variable → we drop it (wouldn't effect that much)

$Loss = L_0 + \gamma 10\log(d) + 20\log(f) - 20\log(h_t) + L_{knight} + L_{feeder}$

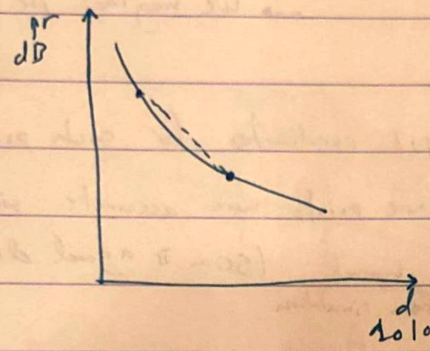
$\gamma 10\log(d)$ → most Variable

$-20\log(h_t)$ → Very small effect

→ to find $\gamma$ → we do curve fitting → done as GIS layers

→ to find $\gamma$ from the equation (only one ~~point~~ point needed) → but we take multiple point then take the avg → get closer to actual value

note: $\alpha$: attenuation factor is important for Am radio




$pr = \gamma_0 + \gamma x$

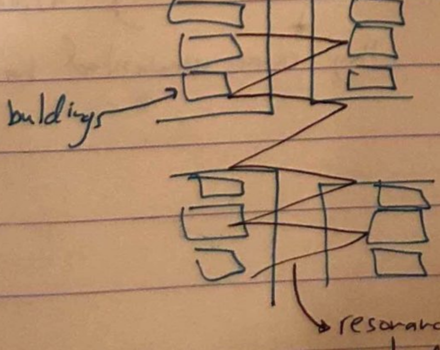
$\frac{d pr}{d x} = \gamma$

regretion (curve fitting) → the close to the actual model the less the error
- → minimum mean square
- → ~~x~~ leass square errors
- → total leasc square

→ I get impurical formela but it's based on observations

→ we have around 28 models

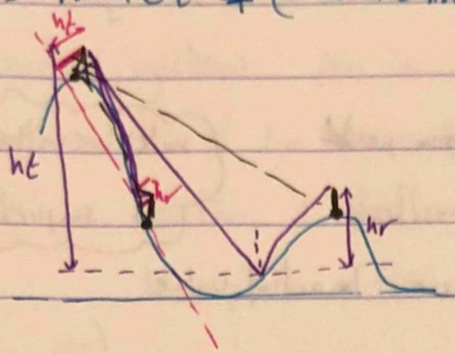
→ another phenominal




→ not vary important because it ~~spiecl~~ special case changing the rotation of the antenna can fix this

→ nulling in some areas & amplification in other hight

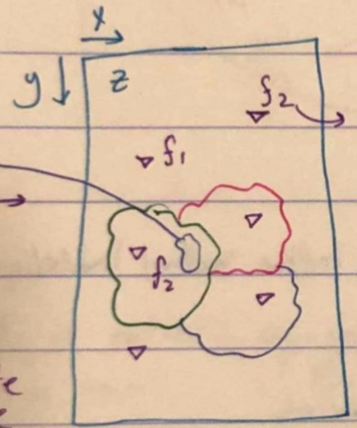
pr = Pt + Gt + ( Lo + Lknife + 10 γ log(d) ) ← ignore the




hr & ht are based on the reflected ray not the actual high of the antenna

→ we neglect the hight

→ in simulations → take x, y, z cordinates for each point




→ more points more accurate simulation (50m is a good distance)

→ we give channel f from simulation

atols
soft ware →
→ Very accurate for closer distances then make it less accurate as we move away from Tx
↓
faster simulation

← do super position for each Tx then according to that devide the areas to the closes Tx & also calculate the C/I

Tx1 → pr(x, y)

Tx2 → pr(x, y)

" "

Txn → pr(x, y)

From this I get
→ power received
→ interference level
→ cell shape → looks like ameba
  ↳ we don't want any atols
  they cause unwanted hand off

9/7/2019

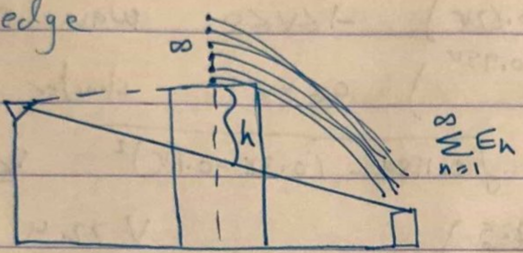
$pr = EIPR - Loss$

$loss = L_0 + 10\gamma \log(d)$

→ the signal strength is not constant → very according to the surronding envirment

→ we try to find a close formila

→ Knifke edge




→ the building has 2 effects :

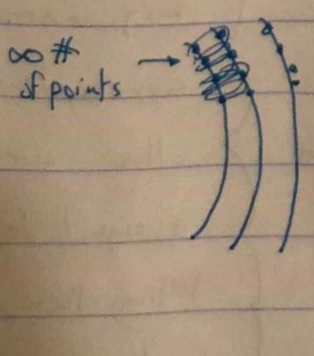
1) insertion loss → depend on the building constructor & the geometry

→ if the building is made of steel & concrete → altenuate the signal hard

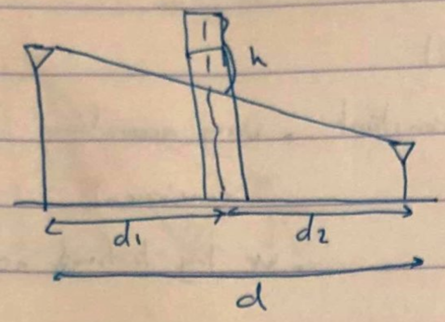
2) Knife edge (haygens princple) → each wave has a wave front (∞ number of point sources)

→ the distance between each 2 → $\lambda/2$

→ duo to this phenominal we get a signal behind the building but we get with less power



→ Knife edge model (huygen principle)




$$v = h\sqrt{\frac{2(d_1+d_2)}{\lambda d_1 d_2}}$$

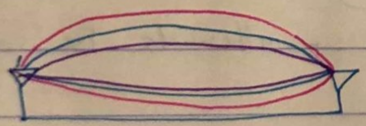
→ v could be negative
↳ h is negative → the building also effect the wave even if it was shorter than the LOS

$$L_{knife} = \begin{cases} 20\log\left(\frac{1}{2} - 0.62v\right) & -1 \le v \le 0 \\ 20\log\left(\frac{1}{2} e^{-0.95v}\right) & 0 \le v \le 1 \\ 20\log\left(0.4 - \sqrt{0.1184 - (0.38 - 0.1v)^2}\right) & 1 \le v \le 2.4 \\ 20\log\left(\frac{0.225}{v}\right) & v > 2.4 \end{cases}$$

↙ the answer is negative → loss

→ effect of shadowing & scatering

→ Fresnel zones (also explaines the knife-edge)



∞ zones
shape of an elepsoides

$$r_n = \sqrt{\frac{n \lambda d_1 d_2}{d_1 + d_2}}$$

n → zone number

→ d1 & d2 → obstical distance from the Tx & from the Rx
→ max r at the middle

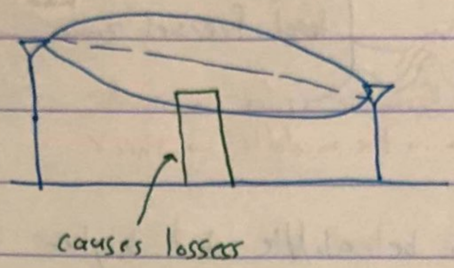
* the power from the Tx & Rx coupled in a volume not in a line
→ amount of blocage from the freznal zone → losses
→ the first Fresnal zone (n=1)
↳ delivers about 95% from the power → we care about this spically in microwave link

* power in the phone is measured by the AGC (automatic gain control) → a DC control voltage change according to the recived signal (RSSI)

→ in the location update msg → ~~send the~~ some systems can allow user to send a signal to the BS telling them about the location that had a problem with coverage

using the GPS → sent to OMCR (operational & maintenance center research)

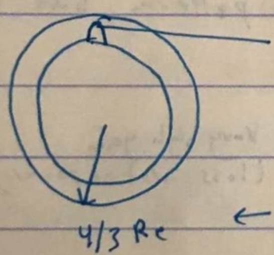
→ we don't want any obstical to lay in the first frezmal zone



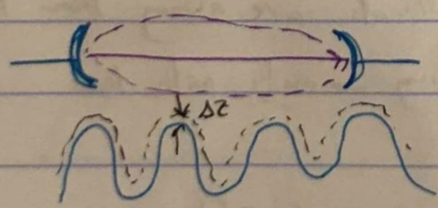

→ to design a mirowave link we find the earth profile

→ earth profile → let the obstical away from the first frezmal Zone (no obsticals for 1rn from the left & 1rn from the right)

→ actually the waves bend from the horizen




← corrected earth profile → the hights is different from actual hights



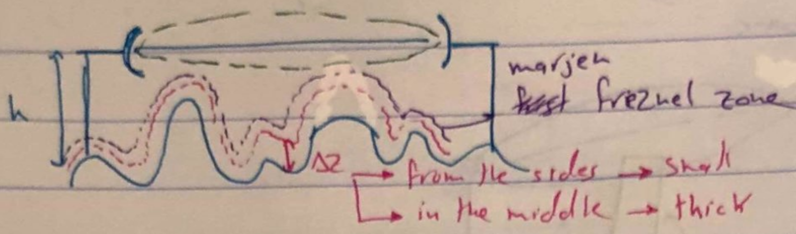

1) fix the earth profile ΔZ

2) make sure that the horizental line between the Rt & Tt & the first frizhel zone is away from any obsticals

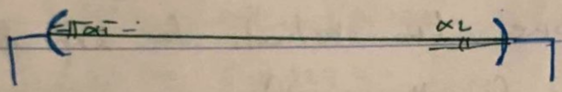
3) if it's not away → rize one of the antennas or both

↳ we want them to be almost the same high → less expensive system (extra distance = double the size)

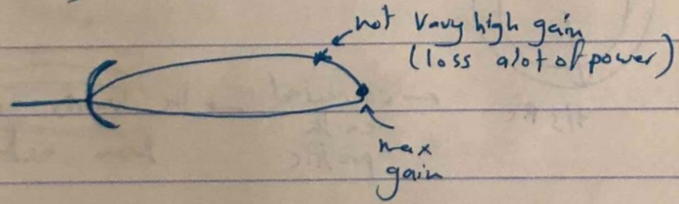
10/7/2019 → micro wave links




→ we chose the high to be alittle bit higher than the marjen frezual zone → less expensive antenna




→ we should make the antenna alire → dish is a high gain antenna → radiation pattern like a pincele shape (vary narrow beam)




* perfect alinement & obsticals are away from the freznel zone → no fading → only path loss

$$Pr = Pt + G - 20\log\left(\frac{2\pi d}{\lambda}\right)$$

* the problem we face in microwave ~~links~~ links
→ dust & rain → they cause the path to sperate → multipath → losse power or fading
→ in the antenna we have a record of how much power I've recived (usefull)
→ snow & fog doesn't cause path sprate (forking)
→ ~~2 days~~

→ the save phenomenon happens to the satellite communication in the ionosphere → dusting or ducting

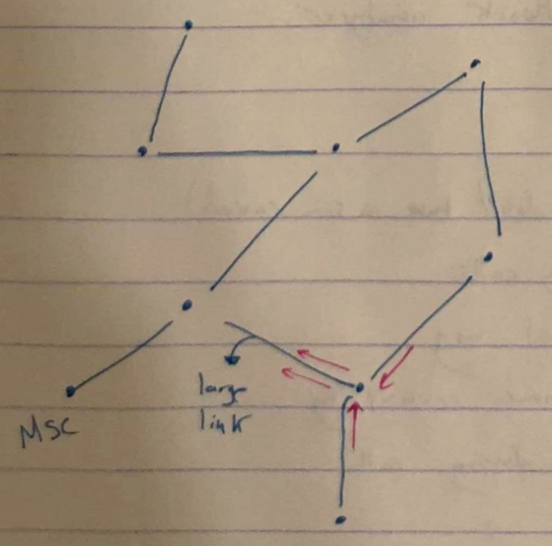
→ this problem causes diflection to the signal → may not aline with the antenna 100%

↳ if the link is important usually we put 2 reciving anttenas close to each othe

↳ or only one antenna while keeping it ali ned (we can know if they are not a lined by an alarm)

0 rain drope causes the signal polarization duo to it's shape

→ how to connect sites to the MSC → using microwave links we connect this as a network (not print to point)



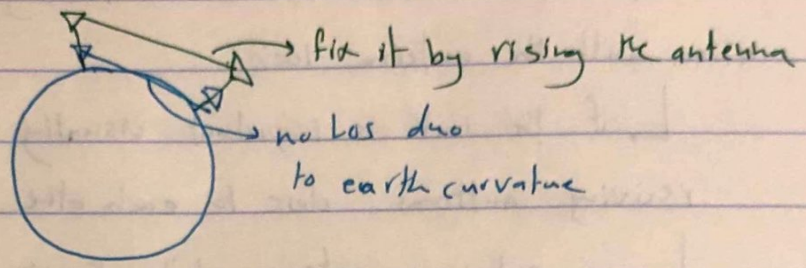

* self healing system → need diversity (re routing)
→ we need the least cost of self healing

* if it's hard to make a micro wave link
→ use UHF link → but not standard
dis: less BW

→ max distance between 2 antennas :

1) reciver sensitivity
2) earth curvature

} → take the least one




$$d_{max} = \sqrt{17 h_t} + \sqrt{17 h_r}$$

→ GSM → −110 dBm
4G → −150 / −170 dBm

} sensitivity

* LAC: location acess code → tower id

→ how I read power in GSM → only my channel
→ to know about health → all the channels
→ in 4G → I need network analyser

→ levels of control pkts

L3 → basic msg (I don't have a sim card)
ex: emergany calls

L2 → internal control msg
ex: if I have scrampling

L1 → call setup / during call

* note: i don't get "all lines are busy" for the microwave links in the cellular system → the opizate for telephony

Scanned with CamScanner

1$/7/2019

→ types of BS → roof top → inside the city
└→ green field → in open areas & sometimes inside the city
└→ very expensive

→ type of cells

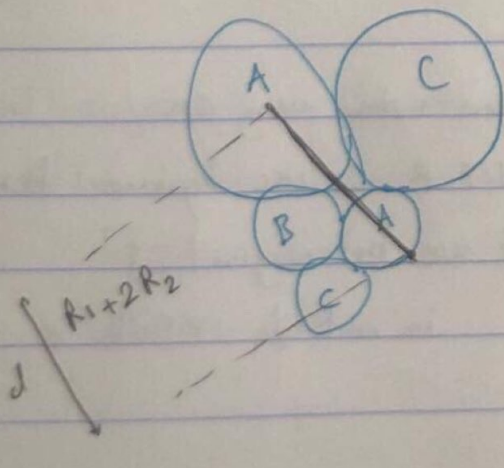
→ capacity cell
└→ for high trafic areas → controlled by
$A = Q_a \bar{\lambda}$
(# of users) └→ economical case

→ coverage cell
└→ area of the cell is controlled by either the timing advanced or the earth curvature
└→ usually outside the city (low density A areas)

→ so the areas of the cell is not the same everywhere → outside the high traffic areas → large
→ inside the high trafic areas → small


→ traffic is not normally distributed

→ effect of different size cells on C/I

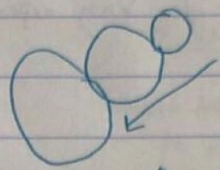



→ reuse distance

for the small cell
$D = 3R_2$
└→ $d > D$ ✓
better C/I

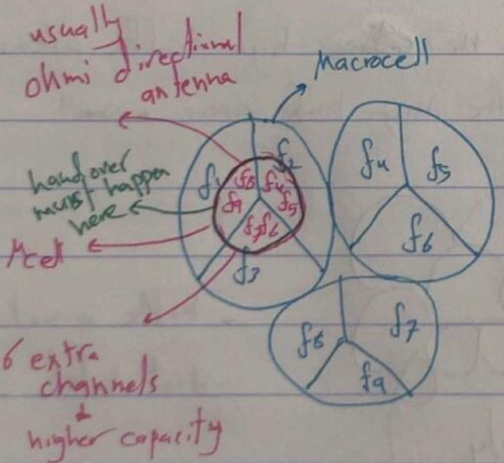
for the large cell
$D = 3R_1$
└→ $d < D$ ✗
worst C/I

→ small cells effect the large cells C/I
↳ to solve this problem (or at least make it smaller)
1) gradual change in the cells size



2) frequency hoping for the surounding cells (espically during congestion)
3) a little bit of down telding

→ μcell : a solution used to solve the problem of high traffic for a short duration → it's not efficent to buy extra channels for a short period use




→ I can use the surounding f in the microcell as long as we keep D/R exceptable (check out image from e-learning)

pt from μcell is less than Pt from org cell

→ worst case solution

$Pt_\mu = \frac{1}{5} Pt$ ← $R\mu = 0.467 R$ → C/I ↓ → 8.5dB

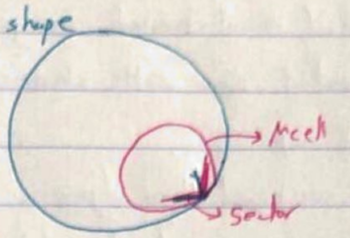
→ avg case

$R\mu = 0.61 R$

→ if the user timing advanced < 0.467 R → use frequances from the μcell group other than that use the orrginal f (in new systems using GPS)

→ GSM design 8.5dB in real life 7.5dB is exceptable

→ μcell doesn't have to be in the center & it doesn't have to be a circular shape



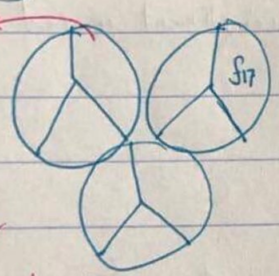

→ in this case users may interfere with surrounding channels cells → we use power control

→ we can also use it for indoor systems that are crowded
ex: hospitals / malls

→ we also have picocells & nano cells (bigger)

→ channel borrowing

all channel are used in this sector
↓
we borrow channels from near by cells that are not being used




→ this is a complex thing since we will borrow cells that might be used in the surrounding users

→ if the org cell want's it's channel back I have to give it to them

→ hard to manage the system (over head to the system) ex: handover

→ we need extra radios in the station

→ this doesn't happen in all cells

→ channel assignment → frequency plan

→ fixed channel assignment (frequency plan)
↓
better be adaptive

→ dynamic channel assignment
→ first in first out
→ all ~~data~~ channel are devided according to the need
→ causes over head & expensive when it comes to radio

→ hyprid channel assignment
→ we have fixed # of channels assigned
to the channel of other cells channels
being back up
→ causes less overhead than dynamic channel assignent
→ waste for resources (radio stations)
→ used in some senarios

→ cell breathing → Also can be used if we are going to a congested cell

→ all of the above are hard to complinent in real life except for μcell

15/7/2019

→ any development that happens in the system either by soluing the problems in certain region or by changing the technology to make the system better

ex: GSM technology is developed from the talky walky device that has hardware for 200KHZ → gsm devided the 200KHZ between 8 users by TDM → recived BW 200KHz
→ effectively 25KHz
↓
we care about this
↑
→ actual speed ≠ throughput
↑
recived correct data
→ we care about it for the applications

part of QoS ←
↑
part of it is the BER

→ practicall issues → 1) Qos :

→ end to end signal quality
- → voice
- → image
- → data

→ we have differend protocoles each one is used for a certain service

→ ftp → transfer data from oneplace to another

→ http → for browsing the internet → formated text (html) / → data itself (image video text)

→ rtp → real time protocol
- → broadcasting (phone calles
- → if we missed one pkt drop it (order is important)
- → almost real time → internet is query service

→ each one of these applications is treated differently

→ Qos changes according to the application

→ what is manly different in the different protocoles is the size of header & payload → real time app : header is small (higher throughput)

→ the internet is a practical network : I can add any protocol I want

→ UDP : not Ack     TCP : ACK

→ GPRs → more system capacity but it's not a real time application since it's pkt based (pkts need processing)

GSM → uses traditional switching (at BS) → hardware switch

GPRs → uses soft switching → at routers
- → can be centralised or distributed (like the internet)
  - → gateways
- → must have processing delay (not good for voice communication)

Scanned with CamScanner

→ For a good service of voice → delay should be less than 20 msec
↳ if we want to study the service performance → during congestion time

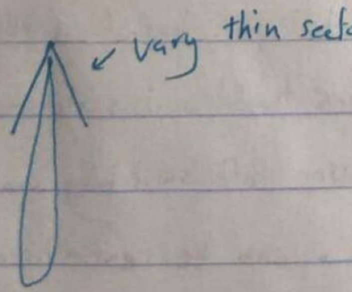
→ why we care about QoS → we don't want costumers to stop using the application

→ data losses → data node → Ack → retransmit
→ Not Ack → dropping
} in both cases we loss throughput QoS ↓

↳ causes of data lossess → C/I
→ handover
→ glitches

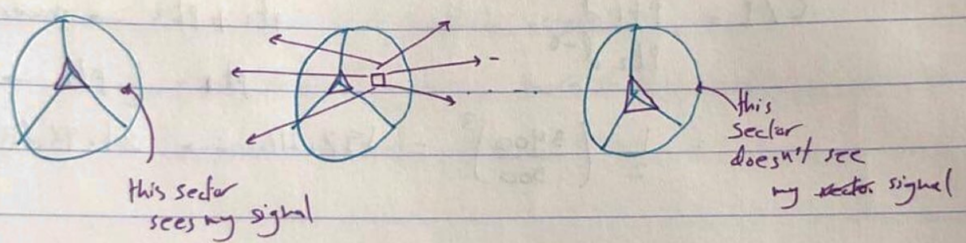
1) C/I → depend on coverage & the current interference

2) handover failier → causes: going into conjested cell
miss synchronization
→ solutions : 1) study the cell location (derease handliver rate)
2) changing the cells shape: ex. at high ways make the cells more like a triangelar shape



3) glitches → causes : 1) noise at power line system (lightning) that reaches the BS & causes reset (brown out)
2) oscillators miss synchronize
3) pkt delayed (control pkts to BSC when the BSC is busy)
→ we don't feel glitches as much as we feel the other types

→ remember that C/I uplink is not the same as C/I downlink




→ also maybe in the cell that interfere with me there isn't any user using same channel as me

→ we have uplink QoS for uplink & QoS for downlink
→ we have a standard voice at my device & at BS
we compare between them to calculate the mean square error

4) quing size → small → alot of droping

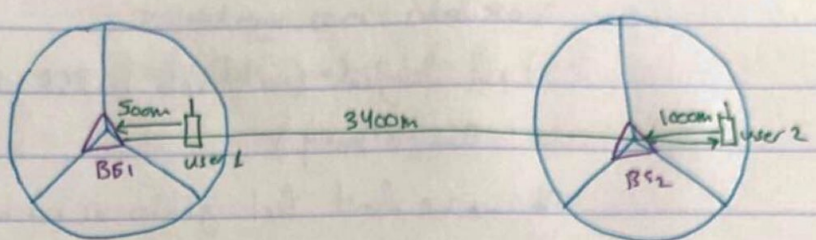
→ speed is throughput not data rate

→ multiple access

16/7/2019

ex:

→ co channels




find C/I at BS

$C \propto pt_1 = pt_1 d^{-\gamma}$ → only take the effect of distance since

$I \propto pt_2 = pt_2 d^{-\gamma}$ everything ~~else~~ else cancles

$$C/I = \frac{pt_1 d^{-\gamma}}{pt_2 d^{-\gamma}}$$

$pt_1 \neq pt_2$ → power control

$pt_1 = \frac{1}{2} pt_2$ → not the real case but assume it's half (actually it's a cubic relation)

$$= \frac{1}{2}\left(\frac{3400}{500}\right)^3 = 157.216 \rightarrow 21.96\,dB$$

find C/I at user 2

$C = pt_{BS2} \cdot d^{-\gamma}$ → $pt_{BS2} = pt_{BS1}$ → no power control for BS

$I = pt_{BS1} \cdot d^{-\gamma}$

$$C/I = \left(\frac{3400}{1000}\right)^3 = 39.304 \rightarrow 15.944\,dB$$

$$(C/I)_{uplink} > (C/I)_{downlink}$$

→ All BS transmit the same power except for the micro cells & cells that have geometrical obsticals (فيّ وادي)

→ uplink 890 – 915 MHz → between the uplink & the downlink
downlink 935 – 960 MHz 45 MHz

→ high f for downlink & lower f for uplink
↳ due to the antenna size → at Rx I want more gain that's why I use high f (↑ aperture)
↳ in BS I have more attenuation but I can increase the power at BS

→ multiple access
↳ why do we care about multiple access?
↳ less # of BW per user → more # of channels → cell size ↑
→ less expensive system

→ to decreas BW per user → 1) data compresion (less data rate → less BW)
↳ in condition I maintain the same quality
2) increase the constllation size (modulation order) → spectral efficency ↑
↳ (data rate ↑ → BW ↓)

→ constllation size
BPSK → 16QAM → $d_{min}$ → to keep it the same I need to increase the C → higher I to other cells
→ $d_{min}$ ↓ → C ↓ → I can do that as long I maintain a sutable C/I
↳ BER ↑ → I intentionaly increas error on the expense of having higher data rate

→ in all system above 3.5G

(3.5G → WiMAX)

adaptive modulation


trade off between data rate & distance → in GSM it was between power transmitted by user & distance

→ multiple access tequniques :

TDMA / FDMA / hyprid / CDMA / oFDMA

→ CDMA : spread spectrum tequniqe → more effected by fading

- ↳ code is different not modulation type
- ↳ interference limited system
- ↳ tolirate noise ↑ → better modulation
  - cap ↑
  - ↳ ECC → BER ↑ → $(C/I)_{min}$ → cap ↑
- ↳ Terbo code & LDPC code
  - ↳ hard to implement in hardware & processing power & memory → good channel quality → convelutional code
    - ↳ worst → Terbo
    - ↳ worst → higher codes
    - ↳ worst → no connection (disconnect)
- ↳ about 20 times more capacity

(wideband more effected than narrowband for fading)

→ oFDMA : multicarrier modulation → every subcarrier for a user & modulation type → to compress them & make them orthogonal use FFT & IFFT → total BW ≈ efficent BW

$$BW = \frac{R_b}{m} + \alpha$$

↑ larger than the effictive duo to the cyclic prefex

↳ narrowband → fading happens to some subcarriers → through them