16/6/2019

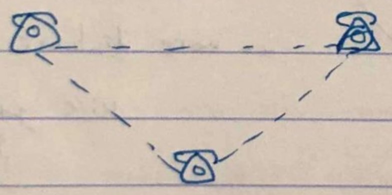
→ features of cellular communication:

- → 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 in telephone system

1) if we want point to point communication:

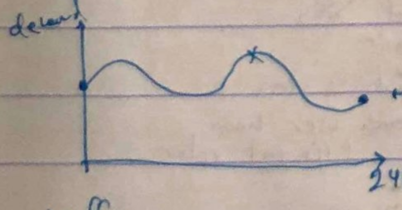


$\# \text{ of links} = \frac{N(N-1)}{2}$

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

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

→ demand : lodk fo 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

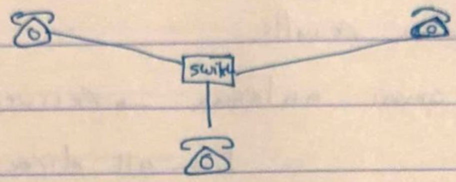
Traffic = $\frac{Q_a \bar{\lambda}}{60}$ (Er) = A

60 → per hour

(Er) → erlings

Q_a : # of active users

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

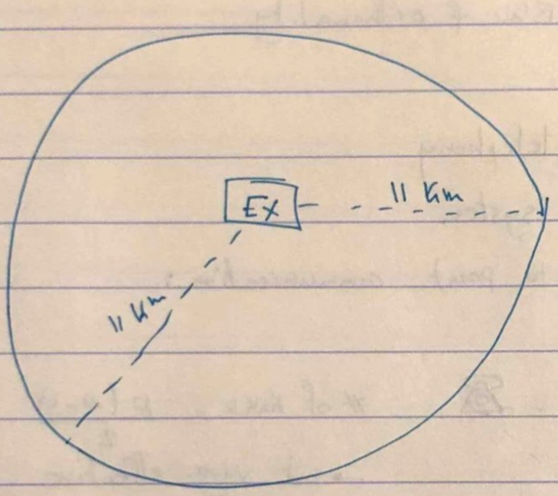


of ~~length~~ links → N

note: contries starts with (00)

Zones starts with (0)

→ phone # are orginized based on the location



→ max length of the link → 11 km

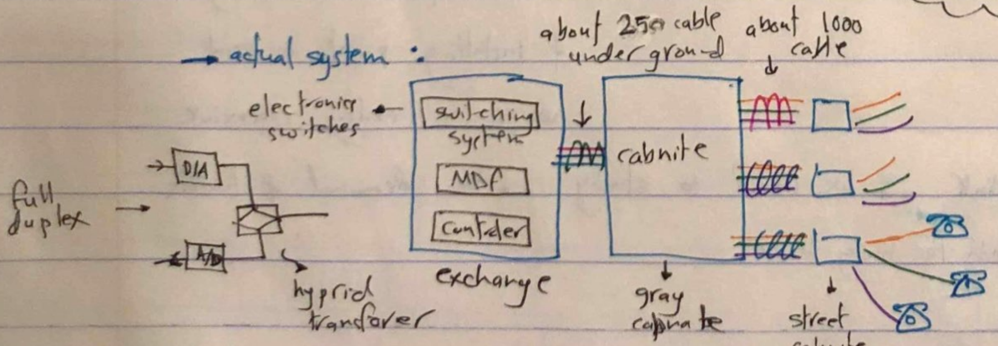
→ we use wire ~~gauth~~ gauge 22

→ more distance use thicker wire

wire ~~gauth~~ gauge 24

cat 5 → 22 cat 6 → 24

→ actual system :



about 96 users

each user have a different color

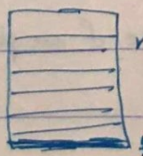
بالشارع

عل الطور

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 × 64kbps = 2Mbps
30 channels ↵ ↳ 2control
each one PCM signal
64kbps → 4kHZ × 2 × 8bit/sample = 64kbps
2BW

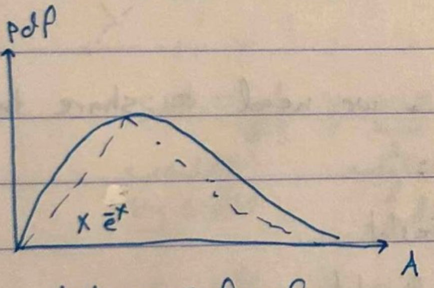
* data from Ex to Ex
is arouting process
protical → SS7 ,
now adays → IP used to control data

17/6/2019

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

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

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



← power function
← localized
← behavior → length

behavior of trafic

increase peformance
increase # of reources
Bp not important

BP given by goverment

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

→ posone
→ raylieg h

→ blocking prob → ind R.V
∫ R.V
N dimention
dropped delay
عطول الخط مشغول ← dropped
بيضل يوقف إذا الخط فضي و٢ ٢ → between ne & ~~length~~ path

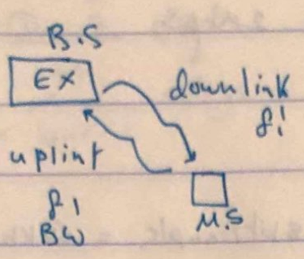
→ delayied → erlard C ⇐
→ dropped → erlard B

→ N↑ → more customers → more capacity
→ more $
higher # of resources giver 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

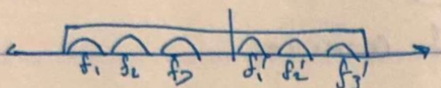
→ requires BW

→ 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 1μs)

→ 1000 channels are not enough → we need to share them

→ sharing ~~tegniques~~ tecneqies :

→ FDM → 25 KHz / 1 tieslot

→ TDM → 100 KHz / $\frac{1}{4}$ tieslot

→ hyprid → 200 kHz / $\frac{1}{8}$ tie slot ← used in cellular

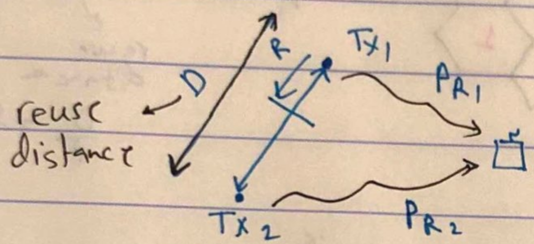
↓ because old tegniques used to use 200KHz filters

→ still we need more channels → use orthogonality

→ space → frequency → tie → code

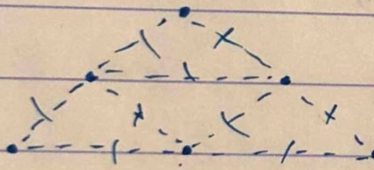
→ space orthognality → depend on : 1) reciver sensitivity (not much)
2) reciver discrimination
depend on $\underbrace{\text{modulation}}_{\text{mainly}}$ & coding & managment of system → (BER) → SNR limit

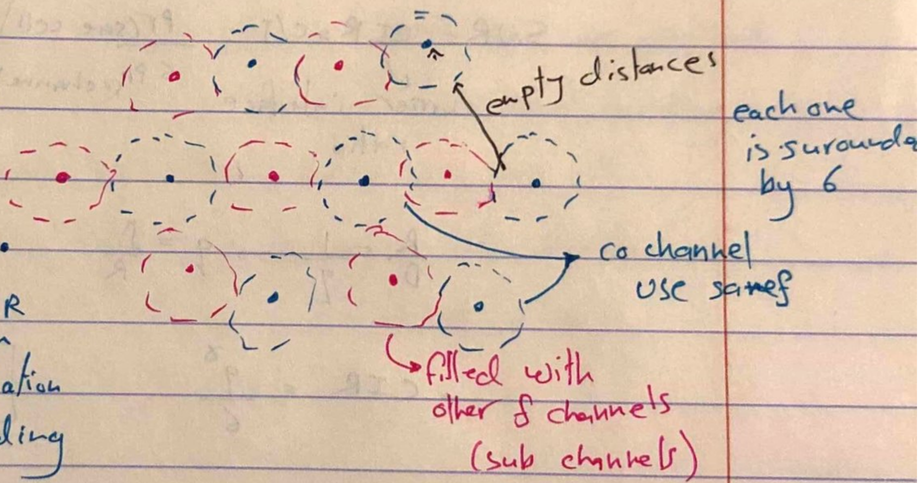
* SNR limit → after that I can reuse the f



$P_{R1} > P_{R2}$

$D \gg R$





$SNR = \frac{S}{6I} \geq SNR_{min}$

surrondded by 6cells

modulation & coding

→ number of different sub channel → K ~~Sub~~
(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 trval & error

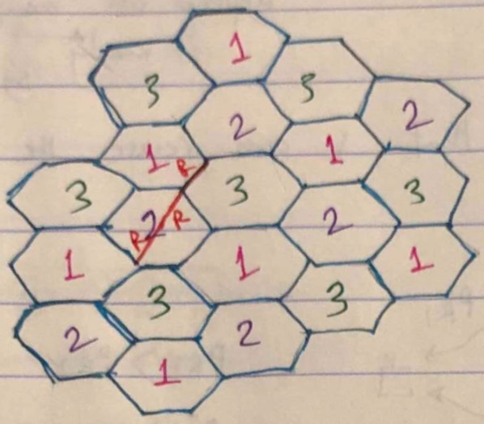
in exam use this

$N_{cell} = \frac{N_{Total}}{K}$ → 1000 chanel

K ↳ we want it to be small

→ ex: K = 3

$N_T = 90 \rightarrow N_{cell} = 30$



near end far end points → $D \approx 3R$

reuse distance

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

$SNR = CIR = C/I = \frac{Pr(\text{sae cell})}{6\,Pr(\text{co channel})} = 6\left(\frac{R}{D}\right)^{-\gamma}$

carrier interface ratio

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

$2 < \gamma < 4$ → fading coofecent → 2.73 in average in Jordan

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

$\rightarrow CIR = \frac{q^{\gamma}}{6}$

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

for $\gamma = 3$ → K = 3 → CIR = 4.9 → 6.93 dB → better solution although bad SNR → solution uree code that requires 6.93 dB

→ K = 4 → CIR = 8.4 dB

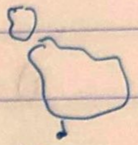
→ K = 7 → CIR = ~~15~~ 12.05 dB → best SNR but more expensive solution

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 may 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

→ $Q_T = \underbrace{100}_{area} \times \underbrace{1K}_{customer/Km^2}$ ~~cost~~ = 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 maintaining the BP

→ $N_T = 90$ cell → $N_{cell} = 30$ cell → $A_{cell} = 18.59$ ← from table
$k = 3$

→ # of cells = $\left\lceil \frac{A_{Total}}{A_{cell}} \right\rceil = 18$ cell

always take the ceil

→ cell area = $\frac{100K}{18} = 5.56 Km^2$ → $2.6 R^2$ ⇒ $R = 1.46Km$

area of ⬡

R in Km

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 bigginning 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 satalite

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

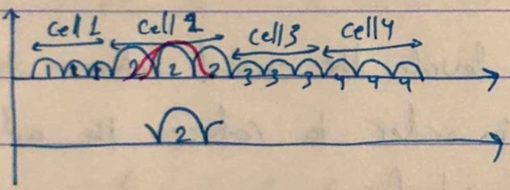
→ man made interference → may happen in some frequency

so we try to excluded from the cell near to the 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 acounter 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)

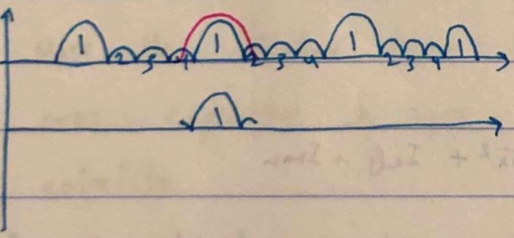
* frequency plan



* 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 arive 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

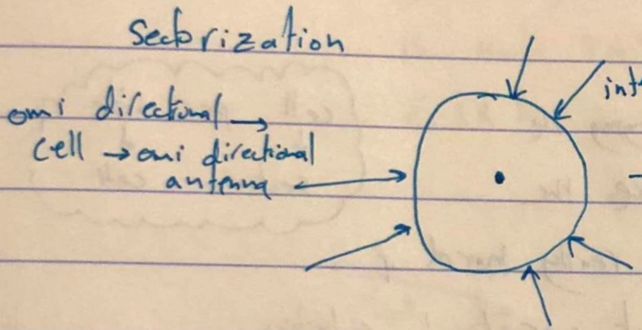
→ in cellular towers we have an alarm system connected to it to monitor the performence of the tower

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

24/6/2019

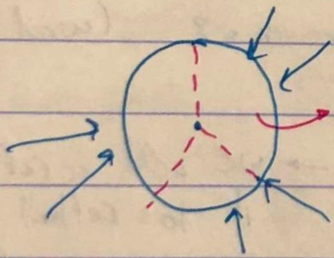
→ another method to improve the system C/I is by deviding the cell into sectors

Sectorization



→ $C/I = \frac{q^\gamma}{6}$ → 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 $C/I = \frac{q^\gamma}{\left[\frac{6}{n}\right]}$ → the least thing is one

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

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

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

operating C/I = 9.54 dB

$A_{sector} = \underset{\text{for simplisity take 23}}{23.3} = \frac{146}{2\times3}$ cell configuration $= K\times n$

$= 2\times3$

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

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

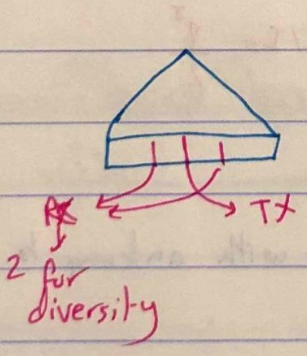
↓

better solution

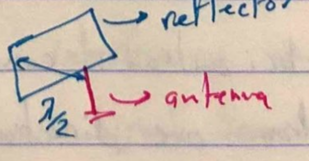
cell per site
↓ ↓
sector cell

* 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)



→ we add a reflector behind it to reflect the radiatino



↓

easy to be done for 120°

ex: solve for $n=3$

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

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

operating $C/I = 11.3\,dB$

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

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

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

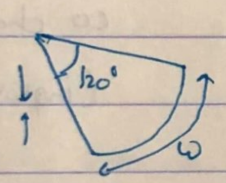
→ advantage for sectorization:

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

$G \times P$



beam width = 120° (horizontal

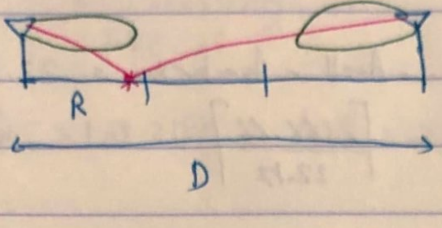
I can compress it to cover more people (rem the ballown)

↳ remember $\frac{\lambda}{2}\uparrow$ → 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 tegniqe between different users to average the performance between then → used espically when the system is fully conjested → cause more over head & failier

* harmonics can be produced if the wire is oxcided

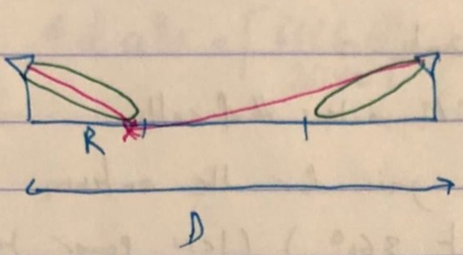
→ down telding



farend neark 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 ↑) (inprove by 2B dB)

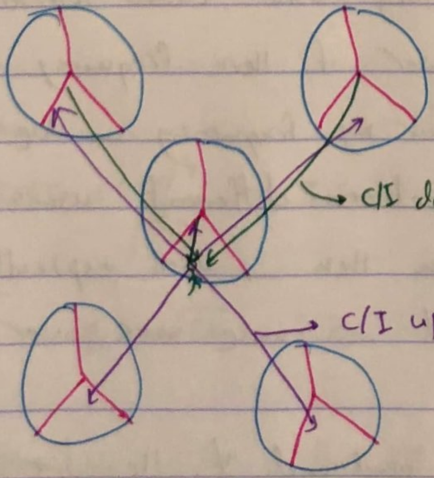
* down telding → I need about 6°

→ 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

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



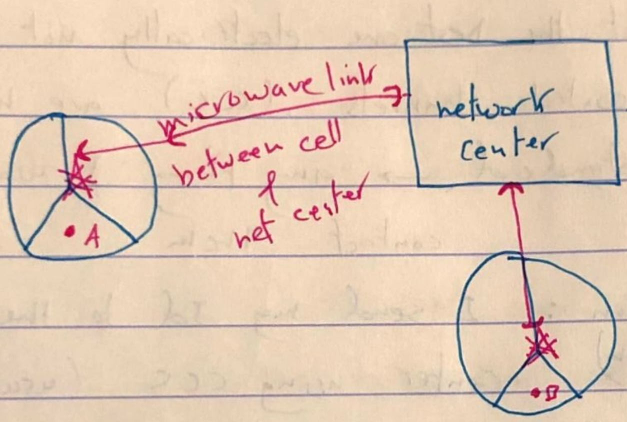
→ C/I down link (from the behind cells only)

→ C/I uplink (I radiate in all directions)

↳ we care about this more because it effect the basestation not the user only if from down fading 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 countries more)

→ it's a distributed system (more than one cpu)

1) call set up

→ first thing when I purchase a line I need to search 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 → resend

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

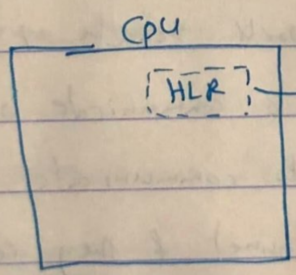
* note: I select the best one electrically not physically

* note: the control channels (CCC) are known by the standerd → any thing I want I contact them

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

→ 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 login (make a phone 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)

→ 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 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 network center using CCC → from the HLR find the location & status

*note the network center is a unix based CPU

→ distributed system

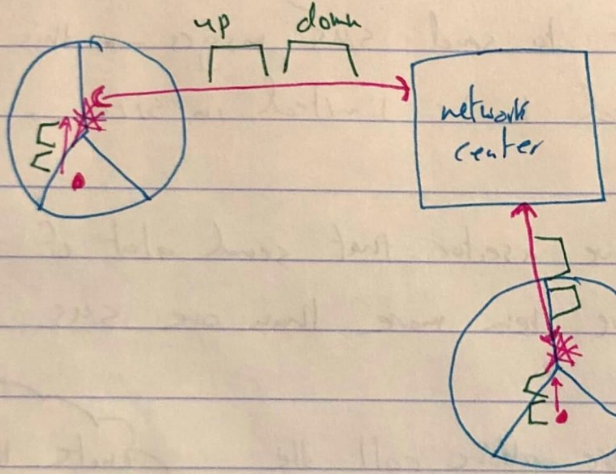
→ to use GSM chip we need to add the modem library

* 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 avalable → 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
    - ↳ of the oscilator falles to synchronize (called glitch) → call will fail

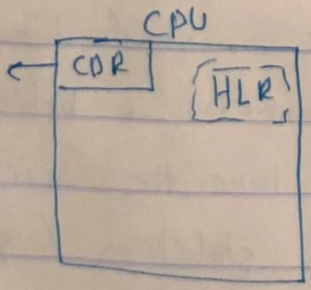


→ if any of the channels is not avalable → send all lines are busy

→ GSM → cct switching
→ symetric

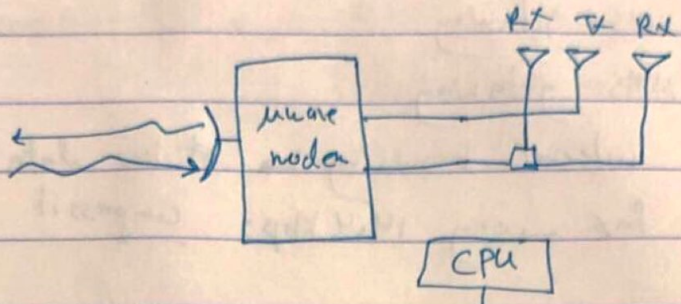
→ call release → happens when some one hang ups the phone
→ we give the channels back for other users to use them (multiple access)

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



part of it is the billing system

26/6/2019



20 channe → each one
↓
I need
20 links

TDM → 8

→ we need a controler to control the process

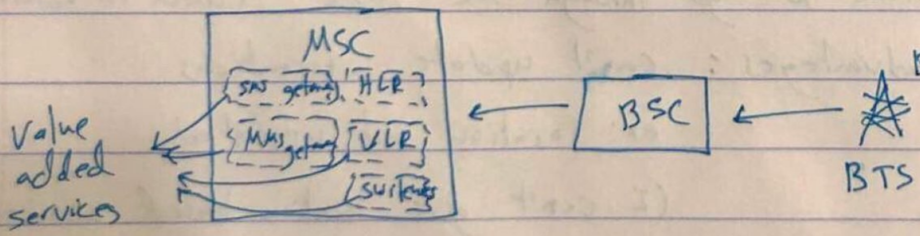
→ cordinate the channels (path) togather (each channel with what user)

→ to control this process between BS → BSC (base station controler)

→ control about ~~20~~ 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 ~~[illegible]~~ 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 $\xrightarrow{\text{compress it}}$ 9.6kbps

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

→ outside → send it through IP to the distination

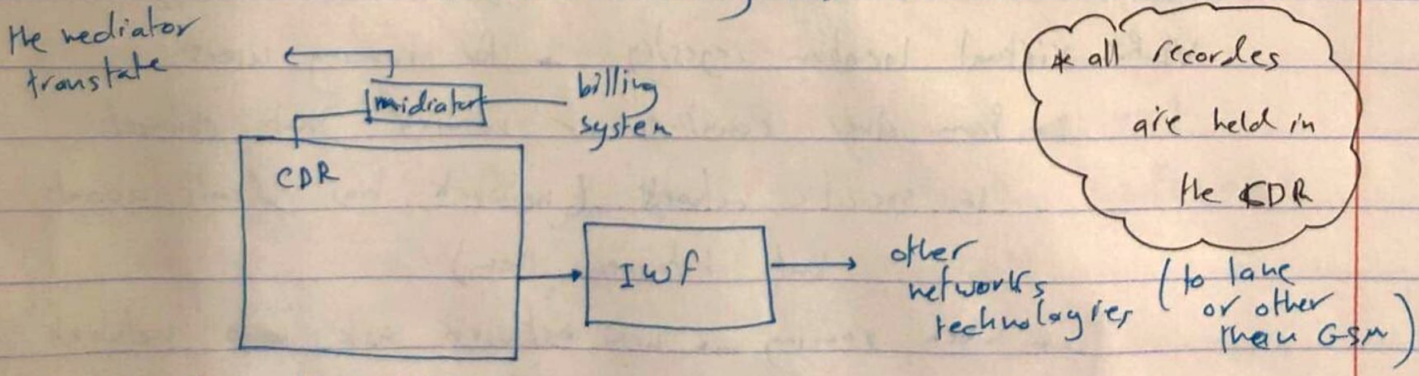
→ the system is distributed → ~~I have~~ If I want to ~~use~~ contact with user that we share the same BSC I don't have to go through the MSC (used in motorola)

→ disadvanteges : can't update informations

ex: location not updated

(I can't give location based services)

* now we relay less duo to GPS



* all recordes are held in the CDR

IWF : for other technologies to take 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

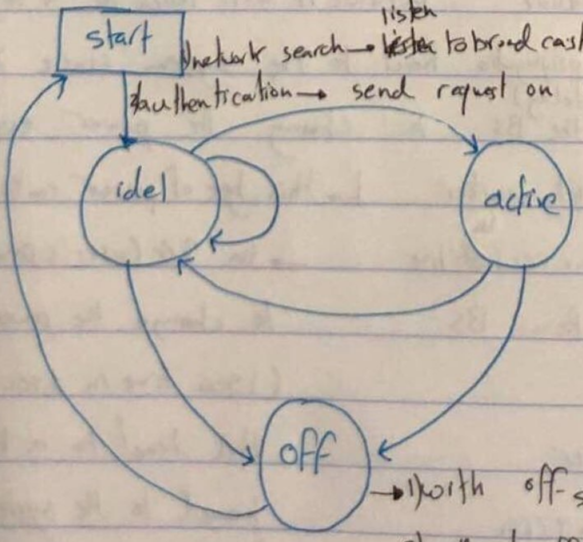
* 3G ↑ → data based because it's asymetric system

→ 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



1) network search → ~~lister~~ listen to broad cast

2) authentication → send request on CCC

→ 1) with off-signal → turn off your phone

2) without off signal → remove battary
go to out of signal place

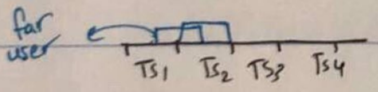
what do we send during the authorization phase ?

- request to join the network
- Id of closest tower
- pass word & user name → K algorithem
- power recived for 7 networks (mine & 6 surrounding) (RSSI)

└→ excecuted in the user & BS if both gave the same result → log in

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 → 6bits → 33km

new system → 7bits → 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

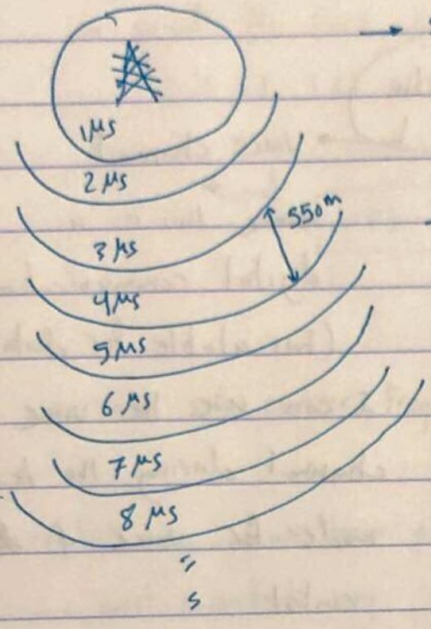
└→ less interference to other users

→ power control happens to the uplink we can't do it in the downlink 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 conter for the distance with limited # of bit → GSM distane is limmited by timming advanced

→ IS95 → don't depend on timing advanced → distance is contraled by power level

→ according to the power lever I can know:

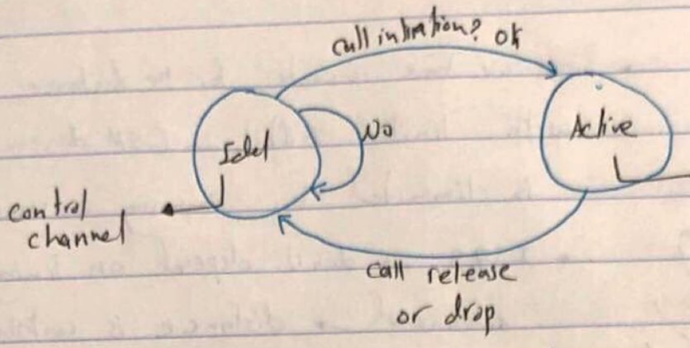
1) my distance from BS

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

	pay load

↓
control data
↳ sender & distination
pkt sequence
data type
CRC
tranning data
↳ important for success full communication → since ƒ↑ → 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 & ~~[illegible]~~ control

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

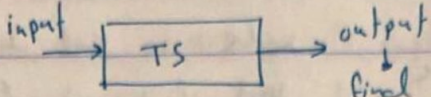
→ special pkt sent at the end of the call asking for order in the CCC → so that we don't do autharization All over again

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

example of tranning data

→ send the first 6bits → ones

111 111 (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 2.4kbps → 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

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

→ right away or delayed
→ 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 ~~spectat~~ spectrum efficiency

* if we used a higher order (dimention) modulation we derease the BW per user

M-array → BW efficency ↑

2) since 2 user use the same f & time slot we needed more control on the system → update from ct 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

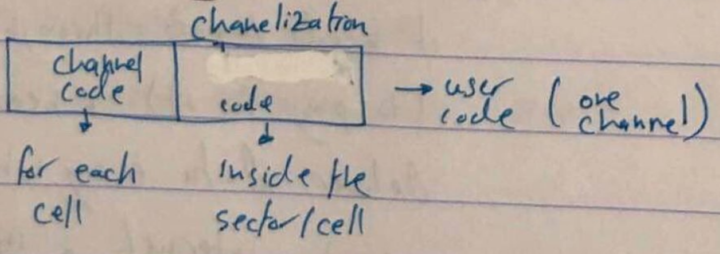
→ used in IS95 & 3G & GPS

it uses spread spectrum technegues & 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 5MHZ but still the capacity increased by 20 times

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



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

$$MAI = \frac{P_{rc}\ \boxed{CG}}{(N-1)\ P_{user}}$$

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 + ~~causes~~ causes falier → less capacity by (18-16 time)

* still good

→ dobler effects causes fc to change fast &
causes 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

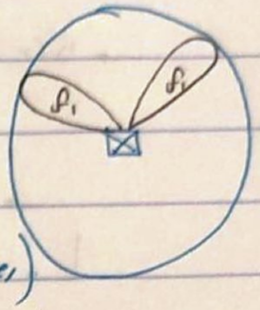
→ CDMA
- → WCDMA → stand alone technology
- → UMTS → extention for GSM
  - → change modulation / MA teqnique & f allocation
  - → add to the system new devices
  - → inside the network old & new devices (technologies) work togather
  - → expensive licence
- → ex : 3Gpp
- → GSM won

* again : to increase $(C/I)\downarrow$ → 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 former / antenna arrays)

→ the antenna creates a spical link (beam) between the user & BS → it need to know each users exact location

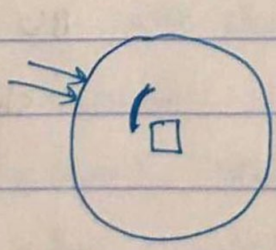
→ it's hard to manage during mobility (need for handout when the beams interfere (large over head)

→ not efficent when the user are centralized

* this solution works for some specific senarios since we need aspical ~~[illegible]~~ 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 anttena)

$(C/I)_{min}\downarrow$



*newer technologies → every thing is adaptive / system evolutions

Gs → LTE

→ 5G → cell size ↓ → power ↓

└→ # of users per cell ↓

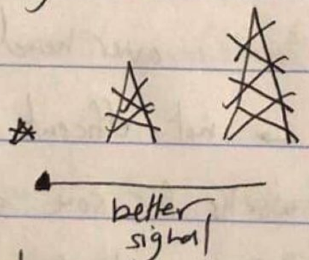
→ more like wifi cellular network

└→ 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)

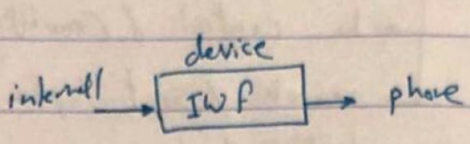
→ 5G was designed to have a 3 level BS



└→ the system does ~~seam~~ seamless hand over (connect to the lowest BS → higher data rate)

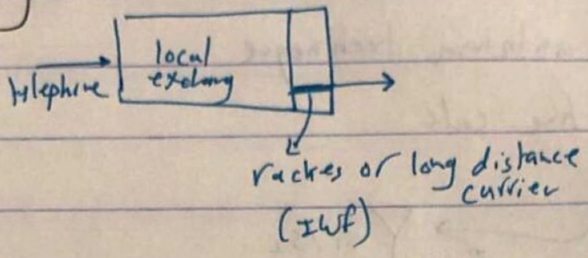
→ 5G used IP protocol → wasn't good when it came to voice communication → solution : resurve some BW for voice (VPN → virtial point network) & shared for data

→ VoIp → using Ip



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

→ old way



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

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

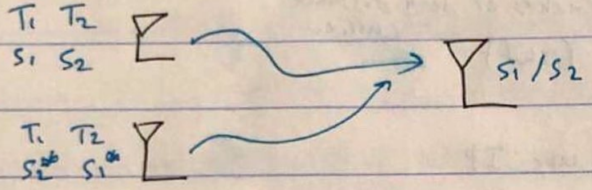
→ OFDMA / IP

→ the system is cheeper

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

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

→ another smart antenna techneque
3) space time code

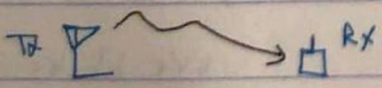


→ transmition diversity (spacial diversity)
↳ solution for fading
↳ improve SNR by almost √2 times
(more samples → noise power → avg = zero)

→ 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 → $\begin{cases} P_r \geq P_{sensitivity} \\ \frac{P_r}{I_{total}} \geq (C/I)_{min} \end{cases}$ → 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

$$\begin{cases} p_r \geq P_{sensitivity} \\ C/I \geq (C/I)_{min} \end{cases}$$

→ 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

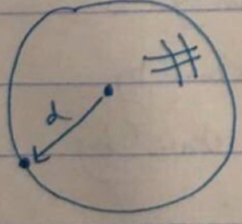
→ it can be done using software that has a GIS (geographical information systen) where it has all the hights /streets /trees building then measure the Tx at each point → for this to be accurate we need a real accurate mathmatical models

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 ← $pd = \frac{pt}{4\pi d2}$ → pr = Area pd

↙ effectivarea of the Rx

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

$$pr = \frac{G\,pd\,\lambda^2}{4\pi} = \frac{G\,\lambda^2}{(4\pi d)^2} \cdot pt$$

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

EIRP ↓ effective isotobic radiatied power

Lf free space loss

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

$$= 20 + \underset{\text{in HZ}}{20\log(f)} + \underset{\text{in m}}{20\log(d)}$$

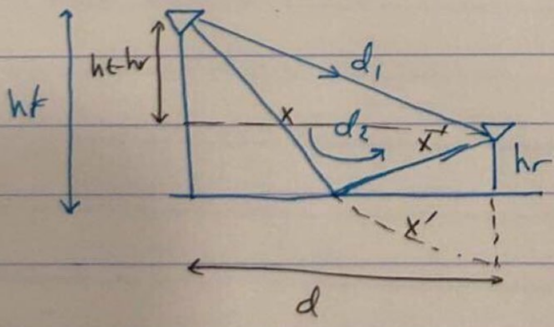
→ path loss in this case

$\boxed{\gamma = 2}$

↑

best case

→ second model : two ray model



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

$$Er = \vec{E_1} + \vec{E_2}$$

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

$$\vec{E_2} = \underset{\substack{\downarrow \\ \text{reflected from ground}}}{-E_1}e^{J\Delta}$$

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

$$d_1^2 = d^2 + (ht - hr)^2$$

$$d_2^2 = d^2 + (ht + hr)^2$$

$$d_2^2 - d_1^2 = 4hthr$$

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

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

$$\Delta = \frac{4\pi hthr}{\lambda d_1}$$

$$\vec{E}_r = \vec{E}_1 - \vec{E}_1 \left(\overset{1}{\cancel{\cos\Delta}} - j \sin\Delta \right)$$

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

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

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

$$p_r = \frac{E_t^2 G \lambda^2 4\pi (h_t h_r)^2}{\underset{\substack{\downarrow \\ \gamma = 4}}{d^4}} \quad \rightarrow \text{worst case}$$

* any other model is in between the two models

7/7/2018

freespace

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

2-ray model

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

$$= P_t + G - \left(10\log(d^4) + L_o - \left(\underbrace{20\log(h_t) + 20\log(h_r)}_{\text{hight of antenna}} \right)\right)$$

general equation :

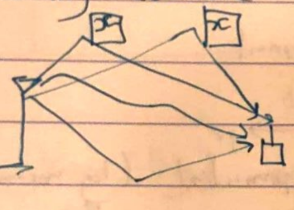
$$P_r = P_t + G - \text{loss}$$

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

$$EIRP + G_r - \text{loss}$$

$$\text{loss} = L_0 + \gamma 10 \log(d) + 20\log(f) - 20\log(h_t h_r) \qquad 2 \leq \gamma \leq 4$$

→ this actually accurate



← I don't know how many pathes I have → γ 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 differance is that it will attenuate the signal

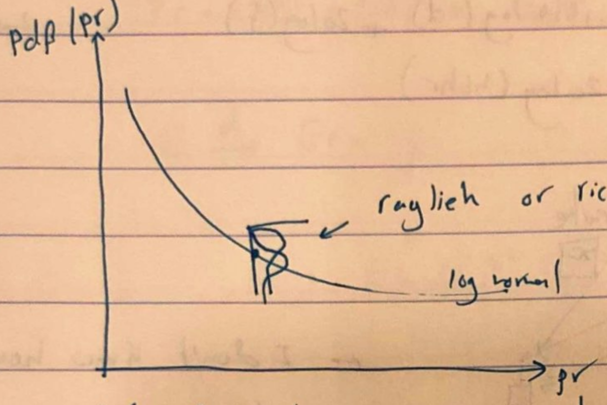
sharp edge from mathmatical model → inf # of point source started from the roof of the bulding to the infinite

→ knight edge loss

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

in actual systems the suronding objects changes from location to another & time to another → pathes change from location to a location & from time to another

↳ pr is a R.V



(complex) complicated R.V with ~~[illegible]~~ exponantial (log normal) & each point is either raylight or ricen

point ↓ has a mean

raylight ↓ no direct Los

ricen ↓ direct Los

[illegible]

$$\underset{\text{R.V}}{\uparrow P_r} = \underbrace{P_t + G}_{\text{constant}} - \underset{\text{R.V}}{\uparrow loss}$$

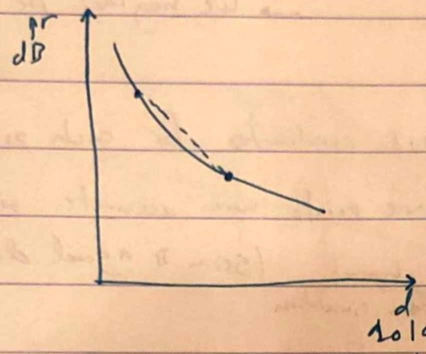
$$\underset{\substack{\downarrow \\ \text{I know the behaviour but not the exact}}}{Loss} = L_0 + \underset{\substack{\downarrow \\ \text{depend on \# of rays} \to \text{I don't know it}}}{\gamma 10 \log(d)} + 20\log(f) - \overset{\substack{\text{it's variable} \to \text{we drop it (wouldn't effect that much)} \\ \downarrow}}{20\log(h_t h_r)} + L_{knigth}$$

$$Loss = L_0 + \underbrace{\gamma 10\log(d)}_{L_{feeder}} \to \text{most Variable} + 20\log(f) \underbrace{-20\log(h_t)}_{\text{Vary small effect}} + L_{knight} +$$

→ to find γ → we do curve fitting → done as GIS layers

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

note: α: attenuation factor is important for the radio



$pr = K_0 + \gamma x$

$\frac{dpr}{dx} = \gamma$

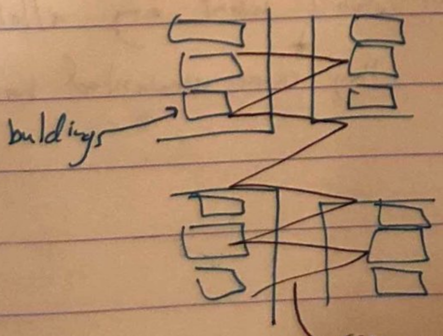
regretion (curve fitting) → the close to the actual model the less the error

- → minimum mean square
- → ~~xxx~~ leass square errors
- → total leasc square

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

→ we have around 28 models

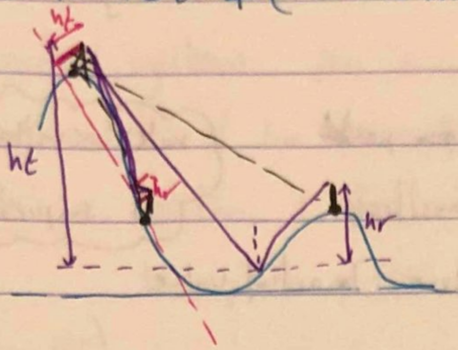
→ another phenominal



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

resonance not fading → nulling in some areas & amplification in other

$pr = Pt + Gt + (Lo + L_{knife} + 10 \gamma \log(d))$ ← ignore the hight

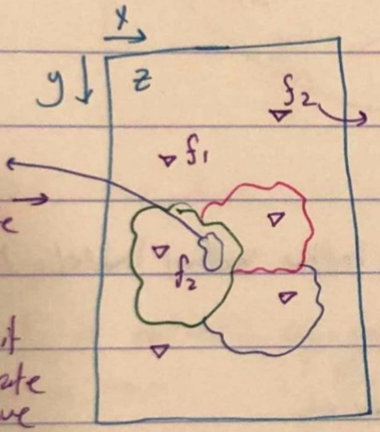


hr & ht are based on the reflected ray not the actual high of the antenna

→ we neglect the hight

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

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



f2 → we use 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 ~~the~~ 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 ~~[illegible]~~ ameba
  - └→ we don't want any attols + they cause unwanted hand off

9/7/2019

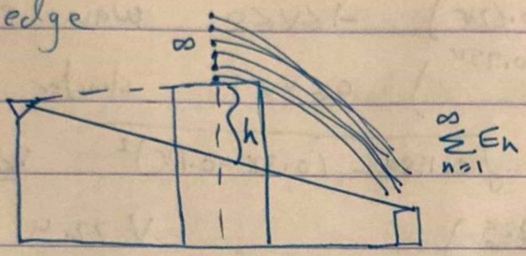
$pr = EIPR - Loss$

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

→ the signal strength is not constant → very according to the surounding environent

→ we try to find a close formila

→ Knife edge



→ the building has 2 effects :

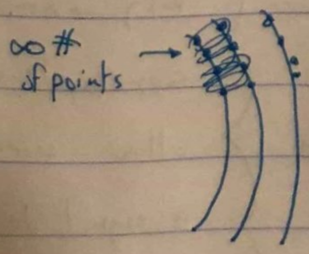
1) insertion loss → depend on the building constructor & the geometry

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

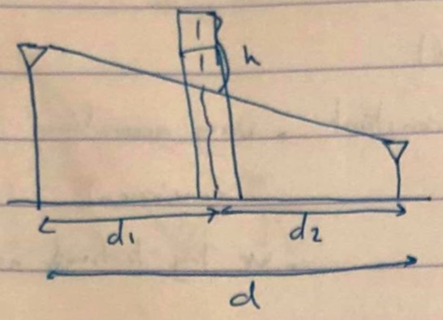
2) Knife edge (haygens principle) → each wave has a wave front (∞ number of point sources)

→ 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)



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

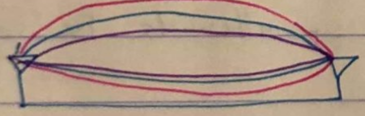
→ v ~~et~~ could be negative
↳ h is negative → the building also effect the wave even if it was shorter than the LOS

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

the answer is negative
↓
loss

→ effect of shadowing & scataring

→ Fresnel zones (also explaines the kife-edge)



∞ zones
shape of ~~B~~ an elepsoides

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

Zone number

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

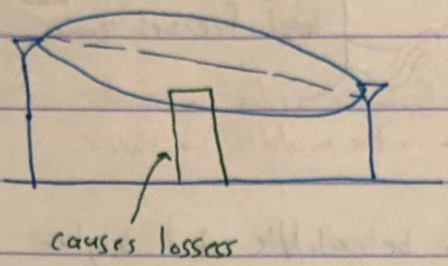
* the power from the Tx & Rx coupled in a volume not in a time
→ amount of blocage from the freznal zone → losses
→ the first Fresnal zone (n=1)
↳ delivers about 95% from the power → we care about this spically in microwave link

* 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~~ somesystems 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

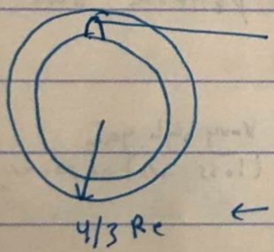
→ we don't want any obstical to lay in the first frezmal zone



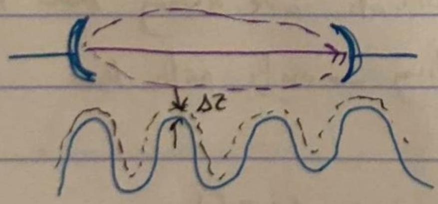
→ to design a mirowave link we find the earth profile

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

→ actually the waves bend from the horizen

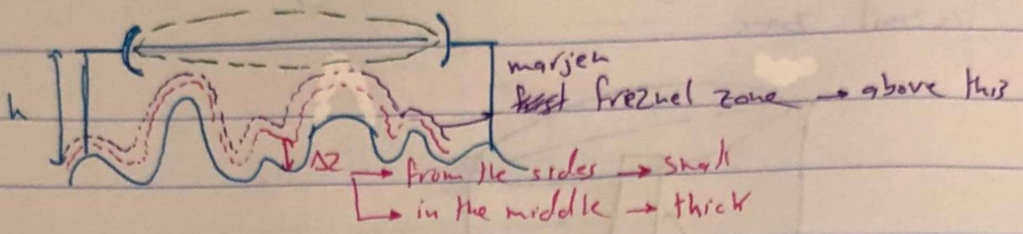


← corrected earth profile → the hights is different from actual hights

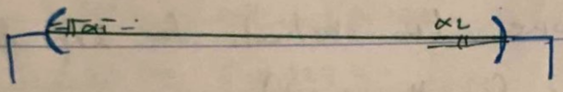


1) fix the earth profile ΔZ
2) make sure that the horizental line between the Rx & Tx & the first frizmal Zone is away from any obsticals
3) if it's not away → rize one of the antennas or both
   - ↳ we want them to be almost the same high → less expensive system (extra distance = double the size)

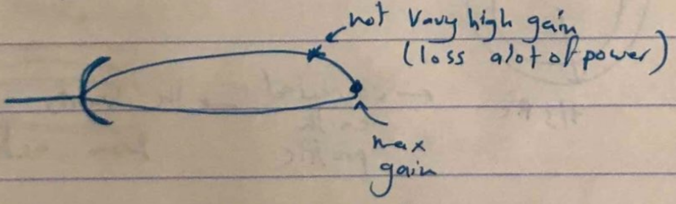
10/7/2019 → microwave links



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



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



* perfect alinement & obstirals are away from the frezuel zone → no fading → only path loss

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

* the problem we face in microwave ~~[illegible]~~ 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 (use full)

→ show & fog doesn't cause path sprate (forking)

→ ~~[illegible]~~

→ the same phenomenon happens to the satalite communication in the ionosphere → dusting or ducting

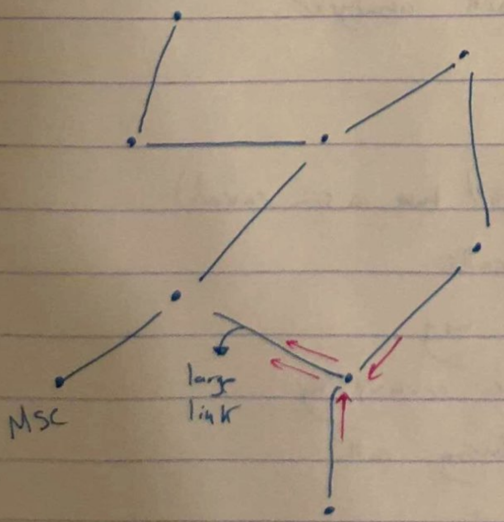
→ this problem causes diflection to the signal → may not alice with the antenna 100%

↳ 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 point to point)



* self healing system → need diversity (re routing)

→ we need the least cost of self healing

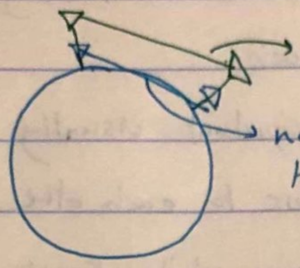
* if it's hard to make a micro wave link

→ use UHF link → but not standard

dis: less BW

→ max distance between 2 antennas :

1) reciver sensitivity } → take the least one
2) earth curvature



→ fix it by rising the antenna

→ no Los duo to earth curvature

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

→ GSM → -110dBm } sensitivity
4G → -150 / -170 dBm

* 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: emergancy 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

18/7/2019

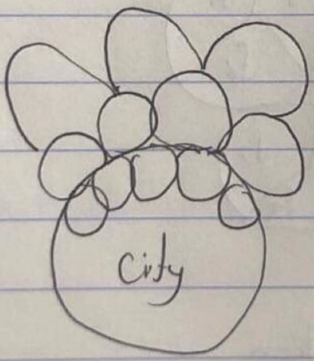
→ types of BS → roof top → inside the city
→ green field → in open areas & sometimes inside the city
→ very expensive

→ type of cells

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

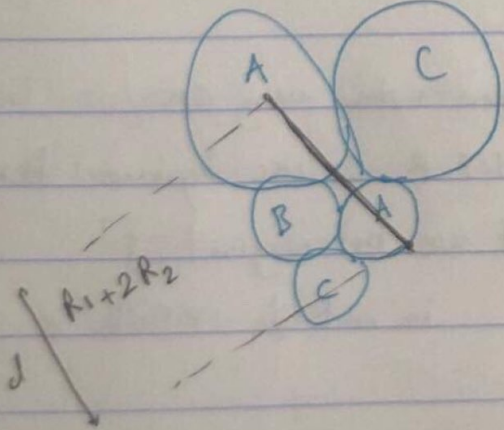
→ coverage cell
↳ area of the cell is controlled by eaither the timing advanced or the earth curvature
↳ usually outside the city (low density A areas)

→ so the areas of the cell is not the same everwhere → 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

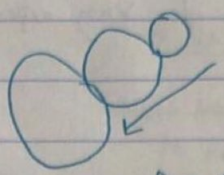
for the small cell
$D = 3R_2$
↳ $d > D$ ✓
better C/I

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)

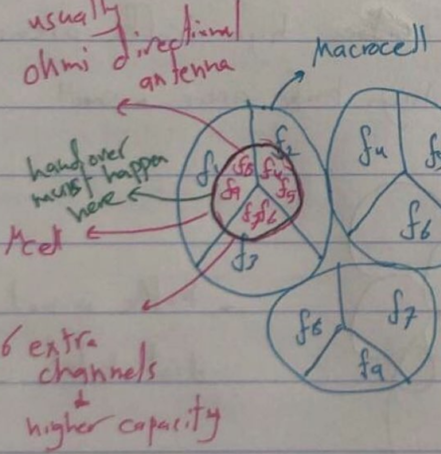
1) gradual change in the cells size



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

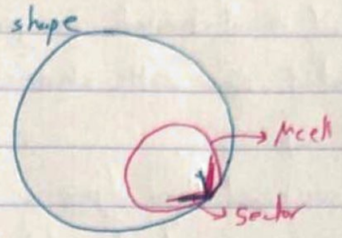
$R\mu = 0.61 R$

in new systems using GPS

→ if the user timing advanced < 0.467 R → use frequances from the µcell group other than that use the orrginal f

→ 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



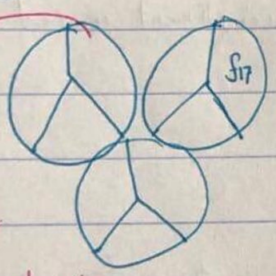
→ in this case users may interfere with surrounding ~~channels~~ cells → we use power control

→ 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

→ this doesn't happen in all cells

→ hard to manage the system (overhead to the system) ex: handover

→ we need extra radios in the station

→ channel assignment → frequency plan

→ fixed channel assignment (frequently 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 compliment in real life
except for μcell

15/7/2019

→ any development that happens in the system either by solving
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 8users by TDM → recived BW 200kHz

→ effectively 25KHz
↓
we care about this
↑
→ actual speed # throughput
↑
recived correct data

part of QoS ←
↑
part of it is the BER

→ we care about it for the
applications

→ 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 one place 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)

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

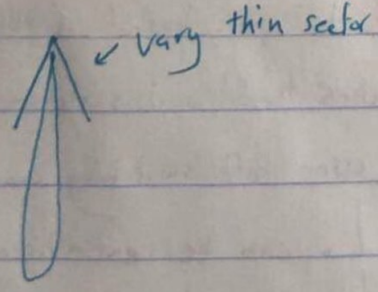
→ why we care about QoS → we don't want coustomers to stop using the application

- → 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



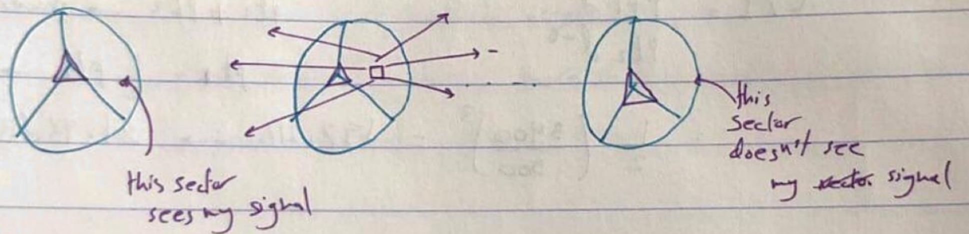
3) glitches → causes :1) noise at power line system (lightning) that reaches the BS & causes reset (brown out)

2) oscillators miss synchronize

3) pkt delayed (control pkts to BSS 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 down link


this sector sees my signal

this sector doesn't see my ~~sector~~ signal

→ also ~~the~~ 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 down link

→ 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

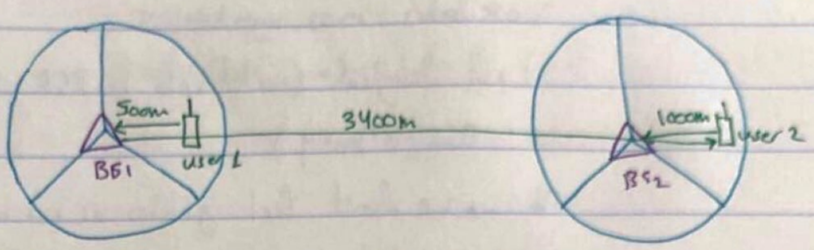
→ speed is throughput not data rate

→ 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)

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

find C/I at user 2

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

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

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

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

→ All BS transmit the same power except for the micro cells & cells that have geometrical obsticals (في 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 (A 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 → dmin → to keep it the same I need to increase the C → higher I to other cells
→ dmin ↓ → 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 of between data rate & distance → in GSM it was between power transmitted by user & distance

→ multiple access tequnices :

TDMA / FDMA / hyprid / CDMA / OFDMA

→ CDMA : spread spectrum tequnice → more effected by fading
- code is different not modulation type
- interference limited system
- tolirate noise ↑ ↓ cap ↑
  - better modulation
  - 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

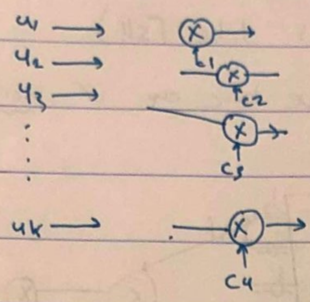
$$BW = \frac{R_b}{m} + \overset{\uparrow}{\alpha}$$

larger than the effictive duo to the cyclic prefex

- narrowband → fading happens to some subcarriers → through them

28/7/2019

→ CDMA → I can modulate each user signal in spread signal code



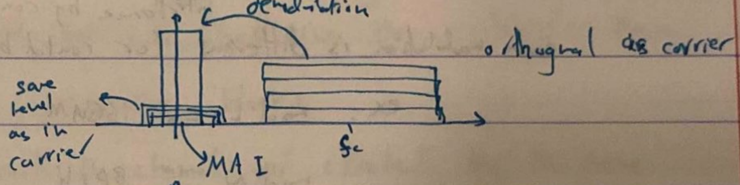
$+\Phi = \sum_{i=1}^{k} C_i$

@ Rx $u_j = \langle c_j , \Phi \rangle$

$= U_j + MAI$

↳ not 100% orthogonal

↳ demodulation



$\sum_{k \neq j}^{R} \langle c_k , \Phi \rangle$

$SNR = \frac{P_u}{(N-1) \cdot \frac{P_u}{CG}} = \frac{CG}{N-1}$ → this tecqnice is noise limited not power / distance limited

↳ under 2 controles :

$S.S\ GC = \frac{W_c}{W_m} = \frac{r_c}{r_b}$

Key to success [1) power control (fast)
2) synchronization

→ main thing for the system failier → doupler shift

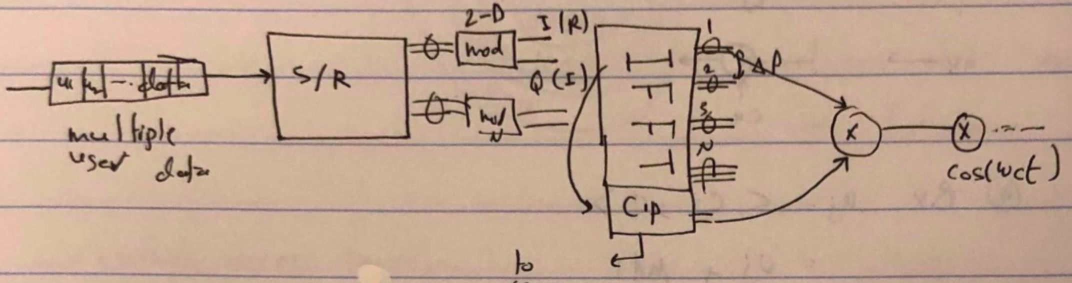
↳ in 3G at the beggining it didnot use mobility after that ~~so~~ it moved to only low speeds → data rates dropes as we move fast

→ one of the solutions for dopler shift was to add gard band → but it didn't work for CDMA → due to the large BW (remember wide band more effected by fading than narrow band)

→ solution → equilization → done by RAKE Rx

→ OFDMA → squesize the subcarriers into small BW while maintaining the orthogonality (looks like FSK)

→ inside each channel we have one or more users



to remove the multiple access interference by converting circular convilution into linear convelution

each modulation is different (or could be the same)

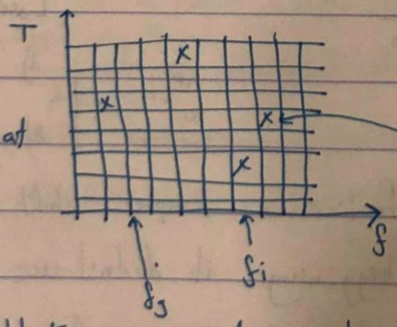
ex: mod 1 → 16QAM

mod N → BPSK

→ BW on demand → each user uses different BW according to his demand → this ~~should~~ could depend on the distance

↳ data rate not symetric for all users

resource block → Δf at same fc & same time



resource block (R.B) → ex if each block has 2Mbps & I want 4Mbps → take 2RB

→ resource block mangement → to solve the deepfading

(resource mangments) → we can manage the resource block to manage the channel condition

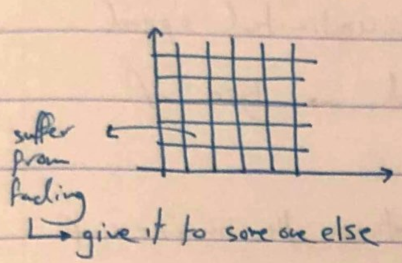
↳ we need to make obtimization → real hard & complex

↳ usually no cloe formula

↓

this is why we have

→ we have 2 degress of divirsity for fading → time of frequency



→ if the timeslot per resource block is too small
→ overhead since I need more resource blocks to get the same data

→ what controles the width depend on the coherent time
→ in now aday technologies it's fixed (about 20msec)
→ it's better be adaptive is the obtimal way → hard to emplement
↳ we might devide them into small pices then devides them into bigger resource blocks

* coherent time : the time that the channel get effected by the same fading

* coherent ~~fre~~ BW : the BW that all f get effected by the same fading

→ diversity gain → the amount of gain I gain by ~~ma~~ resources managment vs if I don't do resource managment → If I ~~[illegible]~~ give the channels that get effected by suver fading ~~to u~~ to the user I loss my data so instead give them another resource block

* the main difference between the G's is the way to solve the problems in more optimal way in order to get the max throughput
→ for data communication we focuse more on the ~~[illegible]~~ throughput "amount off correct data I recive"
→ capacity depend on the throughput
ex : BS ~~[illegible]~~ capable of producing 100Mbps → devided around users (shared)

→ number of R.B for a user is limited by the policy

↳ we have something called free time → unlimited speed for every one during a certain period → type of publicity

→ OTA: over the air programming → connect between the business & technology → send this code to this user

22/7/2019

Q II find the system capacity for a CDMA system with $CG = 128$ & $(C/I)_{min} = 3.5\,dB$

solution:

$$(C/I)_{min} = 10^{0.35} = \frac{CG}{N-1} \rightarrow 10^{0.35} = \frac{128}{N-1}$$

$$N = 58.3 \rightarrow \boxed{N = 58}$$

→ practical issues:

$\frac{C}{I}$ → our goal is to increase it

C → coverage cell → ~~small~~ large area C↑

capacity cell → small area C↓

→ we want to reduce the over all power consumption for the system

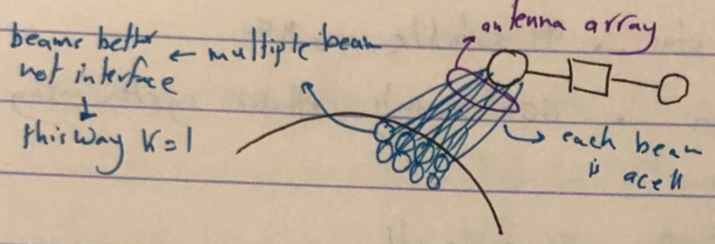
I → we manly focuse on decreasing I → sectorizing

→ telding

→ telting → we generally focuse on making the power recived by the BS is Max ~~with~~ while minimizing the interference

↳ this can be done by the radiation pattern for the antenna → we want the antenna to spot the cell

→ the best way to achive this is by putting the antenna on top → satalight



→ this introduced the idea of cellular system over the satalight

→ iridum → motorola

global stat → qualcomm   * this system failed

Thuraya

* Iridum → to cover the earth we need 77 satalite
  - ↳ we use only 66 one
  - ↳ LEO → 7-10 thoughens km
  - ↳ 1 rev per 6 hours

→ coupler low → $T^2 \propto R^2$

if we have to bodies one large & the other is tiny the tiny body rotates around the large object in a constan period that is proportional to the radiace this depend on the initial speed

~~[illegible]~~ → ~~&~~ speed of rotation ↑ → R↓

↳ 42,000 km → geo → 1 revolution per day

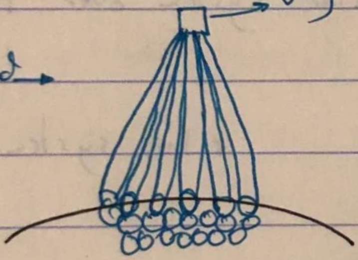
* LEO / MEO / GEO

→ my location is fixed & the cell is moving → makes seamless handover

→ it was designed to use CDMA → we have getaways on earth to the satalite to send the control data

global star → 44 satalite → MEO
thuraya → GEO → only cellular system using satalite

→ same solution but for a BS on earth



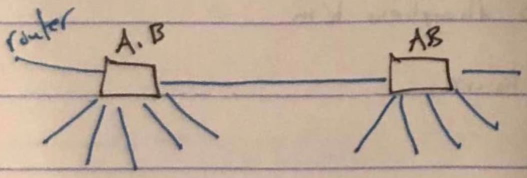
→ vary expensive → we need a large # of BS & antennas

large overhead →

→ not implemented yet

Capacity = capacityold × # of beams

→ to increase the coverage area → add access point ~~access~~
↓
BS multiple point can connect to it
↓
to cover more add another access point → connect parallel → conect as one user to the org A.B

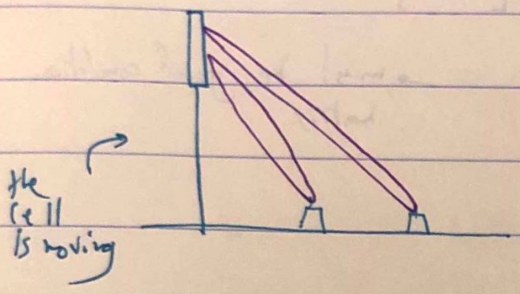


server → radias → hold the password to all users → seamless handover
↳ same as the concept of 5G

* the 2 A.B must see each other wired or wireless

23/7/2019

→ smart antenna



→ the path for reciption is the same as transmision → like a tunnel (Isolated channel)

↳ done by changing the radiation pattern

↳ pencle shape

→ each beam is a channel independent

→ point to point communication → makes the facling less effected

↳ $\gamma \downarrow \rightarrow q^{\gamma \downarrow} \rightarrow C/I \downarrow \rightarrow$ bad

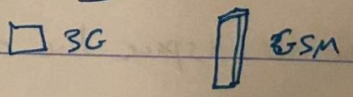
but since $I\downarrow$ we get again overall

→ problem with this system → the beams should follow the user & if two user crossed each other → change f (overlap in space domain)

→ new antennas → 8X8 array (planner array)

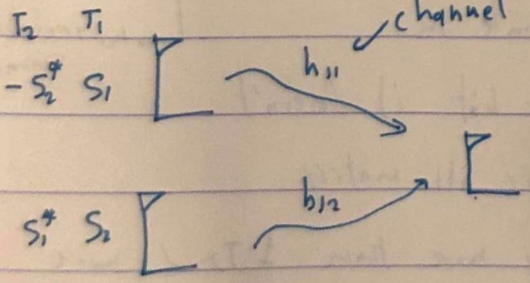
↳ 3G & above

↳ not implemented widly



→ space time coding → not actually a code
(STC)

channel attenuation factor



$r_1 = h_{11} S_1 + S_2 h_{12}$ ← time one

$r_2 = -h_{11} S_2^* + h_{12} S_1^*$ ← time 2

$r_2^* = -S_1 h_{11}^* + S_1 h_{12}^*$

$$\begin{bmatrix} r_1 \\ -r_1^* \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ -h_{12}^* & h_{11}^* \end{bmatrix} \begin{bmatrix} S_1 \\ S_2 \end{bmatrix}$$

$$\begin{bmatrix} S_1 \\ S_2 \end{bmatrix} = H^{-1} \begin{bmatrix} r_1 \\ -r_2^* \end{bmatrix}$$

→ must be good condition matrix

H^{-1} → channel matrix

H^{-1} should exist to be able to get back S_1 & S_2

→ det should not be zero

$\Delta h = |h_{11}|^2 + |h_{12}|^2$ ← always ≠ zero → full rank matrix

- → space & time code
- → if we created any cooperation under the condition of making Δh always ≠ zero
  - → this is the code

→ this is a space time diversity → we get a diversity gain

→ fading ↓

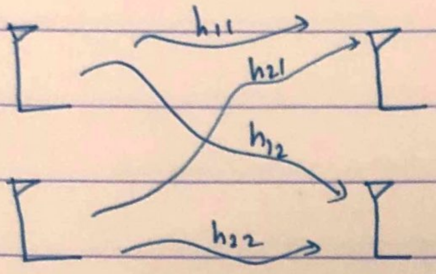
h_{11} & h_{12} → we find them by → channel estimation

→ must be good condition matrix

→ eigon values close to each other so that if I miss estimate the channel parameter a little bit it doesn't effect much → unlike ill matrix

* null fading → zero
→ no recived signal

→ space time code can be done by having more than 1 Tx & more Than 1 Rx → but more than 1 Rx at user phone is hard duo to the size



MIMO system

most popular → MISO

HD → 30 frame per sec

the timeslots width depend on the application

ex: voice less than 20 msec

→ ~~sta~~ we give higher priority for ~~RTA~~ real time applications

skype → broadcasting → data

* bluetooth → no final version

wifi → IEEE 802.8

MPEG → photoes / videos compresion

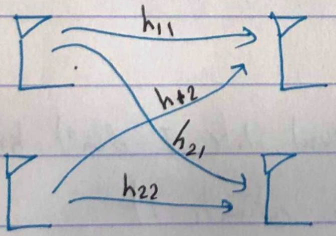
MP2 ← TV broadcasting ← more resolution

MP4 ← mobile

28/7/2019

→ space diversity (space multiplexing) → used to over come the effect of fading

→ MIMO system



$Y_1 = h_{11} X_1 + h_{12} X_2$

$X_2 = h_{21} X_1 + h_{22} X_2$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

↗ attenuation factors of the channel

└→ real

└→ complex → 2D modulation (sin & cos)

→ with noise

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} h_1 \\ h_2 \end{bmatrix}$$

└→ I want the matrix to be full rank matrix

$\bar{X} = h^{-1} \bar{y}$

↙ if I can get the inverse I can recover the org signal

$y \rightarrow$ without noise

$\bar{y} \rightarrow$ with noise

→ to recove the X better → minimize the error

$|X - \bar{X}|^2 \rightarrow$ minimum

$$|h^{-1}y - h^{-1}\bar{y}| = |h^{-1} \underbrace{(y - \bar{y})}_{h}| = |h^{-1} n| \downarrow$$

← we want it to be minimum

$|h^{-1} \sigma|$

→ I know nothing about the noise

└→ I need to estimate it

→ if I don't know the channel matrix

$|h^{-1}y - \bar{h}^{-1}\bar{y}| \rightarrow$ in real life I don't know it.

I do estimate it

└→

→ if I don't have equal # of Tx & Rx → I don't get square matrix

→ inverse for not square matrix

└→ psedo inversy

$$h^{-1} = (h^T h)^{-1} h^T$$

$$[\ \ ][\ \ ] \to [\ \ \ ]_{3\times3} \to [\ \ ]_{3\times3}[\ \ ]_{3\times5} = [\ \ ]_{3\times5}$$

* if I have 5x3 matrix I need 3 ind rows to get the inverse

→ minumum varince estimate (MVE)

→ best linear unbayared estimate (BLUE)

→ music → multiple signal classification

* ways to optimize linear system

→ the better the algorithm the faster the results

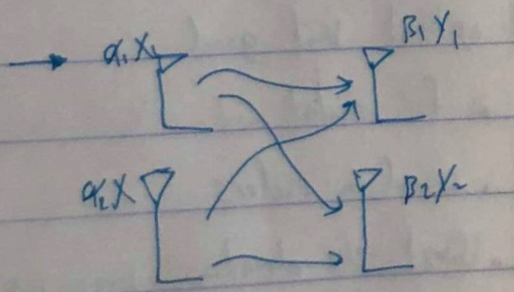
* a way to judge the better estimation tequnique is by finding the BER (end to end)

→ or by looking at the condition number of the estimated h matrix → rank : how independent the rows are

$$\text{rank} = \frac{\lambda_{max}}{\lambda_{min}}$$

→ if the matrix is not full rank → antennas are close to each other → we have mutual couples (local feed)

→ we should sperate this so that they become independent

→ 

$$\to \begin{bmatrix} y_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} \alpha_1 h_{11} & \alpha_2 h_{12} \\ \alpha_1 h_{21} & \alpha_2 h_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \left(\underbrace{\begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix} \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}^T}_{\text{new } \bar{h}} \right) \begin{bmatrix} x_1 \\ X_2 \end{bmatrix}$$

→

$$\begin{bmatrix} \beta_1 & 0 \\ 0 & \beta_2 \end{bmatrix} \begin{bmatrix} y_1 \\ X_2 \end{bmatrix} = \underbrace{\begin{bmatrix} P_1 & 0 \\ 0 & \beta_2 \end{bmatrix}}_{\text{pre processing}} \left(\underbrace{\begin{bmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{bmatrix}}_{\text{post processing}} \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix}^T \right) \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$$

→ pre processing & post processing effect on the channel matrix
& don't effect the data
↳ helps us to condition the channel matrix (better rank)

ex: post processing → equalization
pre proccessing → coding & pre equalization
↳ I can do that at BS
↳ so that the users don't do it

* we did a model for communication system

→ channel is known for Tx → pre processing (less processing)
channel is known for Rx → post processing
known for both → post & pre

* blind tequniques → gussing & it work → popular techniques

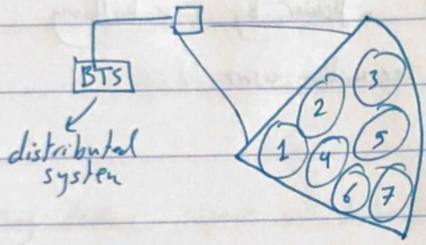
→ eterative → better estimation → not optimal but good
↳ ex: calmen filter → for control
↳ used in radars
↳ first 3/4 eterations gives us 90% of true result

29/7/2019

→ for smart antenna having 7 independent main lobs, how much capacity capacity enhancement we can get?

→ theoritically → 700%.

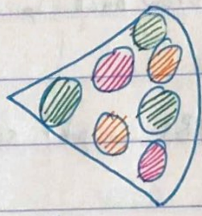
↳ but not actually true since they are not perfectly independent



→ they have coupling between them espically at the edges

↳ solution → devide the channels between the lobs

↓



* we need more equipments of smart antennas

Capacity → 1 → $3 \times \frac{1}{3}$

2 → $2 \times \frac{1}{3}$

3 → $2 \times \frac{1}{3}$

233.3% → capacity inhancement

→ we try to look for orthoganality → space / time / frequency

→ this add another things → handover → I can do it using the antenna

↳ distributed system

↳ requre to change the GSM standard

↳ over head to the system

handover outside → network

handover inside → BS

→ hard to implement duo to the buldings in between

* this solution is implemented in some cells → it's like having multiple micro cells

Scanned with CamScanner

→ different generations :

- → 1G → technology not ready (not digital) → same as miletary → walky talky
  - → FM with BW → 200KHz
  - * AMPS : advanced mobile phone service
    - ↳ anlog mobile
    - ↳ used cars as BS → same as military
    - ↳ pt → 80 - 100W → power by car baltery
    - ↳ in first 2 years 200 milion users

→ 2G → IS95 / GSM

- → GSM about 95% of global market
- → main drawback → cct switching → real lie application

→ 2.5G → GPRS → pkt switching → capacity ↑

- → failed → not symetric
- ↳ used for data

→ 3G → CDMA → fixed duo to dopler shift

- ↳ ofDMA → first generation WiMAX
  - ↳ good for data
  - ↳ not for mobility → no serial processing techiqus yet

→ 900-100 MHZ
↓
2.4 GHZ
↓
5 GHZ

↓ BW ↑ but harder to estimate & small cellss

→ 4G → solved that by gardband & higher center frequency & higher BW

- ↳ used ofDMA more stable

→ we added to the network → systems & robots & smart things

→ I can spy on the data in the air → less ~~sequre~~ security
- If I connected to the network I can sniff the data
- protocoles should be more advanced
  - most popular → IP → IPV6 → solved the mobility & higher # of addressess

5G → devided large sector into smaller & replaced smart antenna with routers
smaller cells → can use IP to communicate

→ my device suport all techniques → wifi sae technology as 5G but different speeds

* data is prioritiesd → rtp /http/ smtp /mqtt
  - small pkts → oriented with IoT
  - no ~~small~~ overhead → RTT is small
  - each group is a topic → msg that arives to the topic → transmit it to all users → no need for distination address → rtt↓
  - suport life streaming but with low resolution

* the higher resolution I need → human eye resolution
  → 417 pixel per inch

* i need more resolution for zooming only

→ data compresion → less data rate → less BW → # of chanels ↑

→ higher capacity & less # of cells

→ data compression
- → lossless → we don't loss any bit → zip (file compestion)
- → lossy → we ~~don~~ tolerate some loss
  - → jif / mpk → less roslution

less in quality Vs smaller BW

→ row data

→ audio

→ video

30/7/2019

→ data compresion → reduce the size of data under the condition of keeping most of the data

→ lossless usually for row data (binary)

→ executable files → ~~alread~~ already compresed

→ the comand is already compesed

→ programing
- → fast code
- → compact

→ for modulation → BW = $\frac{rb}{m}(1+\alpha)$

m ← constelation size (parallesize)

→ to decrease the BW → reduce rb
- → compesion
- → highe M

→ I can change the modulation type → adaptive modulation

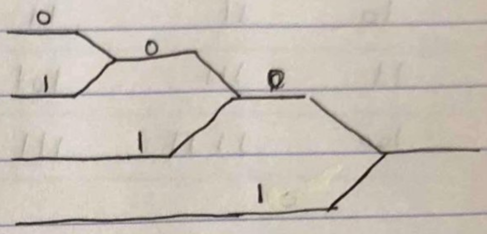
* remember the relation between the capacity & cell ~~#~~ number is not linear → small increase in capacity much smaller # of cells

→ lossless compression :

1) halfman code → optimal code

↳ each representation for the symble according to their propability

ex : a	0.1	a	0.1
b	0.2	→ b	0.2
c	0.4	d	0.3
d	0.3	c	0.4



→ a 000

b 001 → prefix code

d 01 ↳ self fuctioated → I can recover it

c 1

ex: data = cc b c a b d cc

11 0011 000 001 01 11

↳ recome it → c c b c a b d cc

2) LZ algorithem

0 11 10 11 0 100 11 11 0 111 11 0 1 0111

I	data	out
0	0	00 ---..
1	01	01
10	1	101
11	10	100
100	11	101
101	010	10
110	011	11
111	110	1000
1000	111	1001
1001	1101	1111
1010	0111	1101

→ bits in the index ↑ → Zeros to the left

↳ to become word length

→ the higher the data the better the compression ex : $\underbrace{0}\,\underbrace{1\,1\,1}\,\underbrace{1\,1\,1}\,\underbrace{1\,1\,1\,1}$

I	data	out
0	0	000
[illegible]	1	11
10	11	11
11	111	101
100	1111	111

* used in windows & web browser

* more corelated data → more compression
↳ ex : images

→ compression ration → $\frac{\text{out}}{\text{input}}$

* at the RX → I don't transmit the table I regenerates it

→ usually in the compresed files we add a header
- → code type (version)
- → blockes → reset after a certain data
- → CRC → for error detection

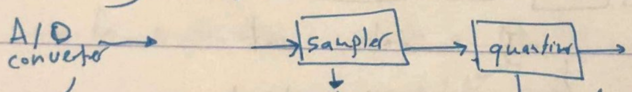
→ compresion ration → $\frac{\text{out}}{\text{input}}$

* at the RX → I don't transmit the table I regenerates it

→ usually in the compresed files we add a header
  - → code type (version)
  - → blockes → reset after a certain data
  - → CRC → for error detection

4/8/2019

→ lossy compression

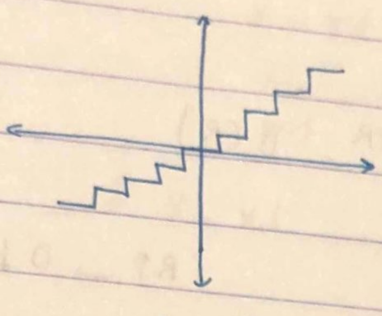


A/D converter → from continous time, continous amp → discreate time, Discreate amp

sampler → sample every period depending on nakros rate

quantizer → devide the amplitude into quantizes from Continuous amplitude → discreate amp
  - → finit # of posible output
    - → encoded in binary

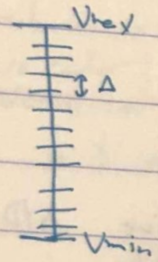
ex: BCD / BCO



← # of steps → M steps → better be a power of 2

$M = 2^m$ ↳ bits

→ data rate (bit/sec) = m bits X fsample
↓
rate (normalized data rate)
↓
R

→ 

2^m steps → $\Delta = \frac{V_{max} - V_{min}}{2^m}$ ← uniform quantization

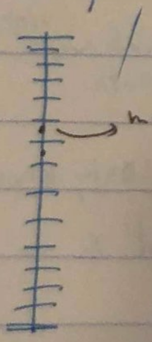
* we also have a non-uniform quaintization

→ since most signal are around the Avg

→ we add A low & M low amplifier to limit the ~~peak~~ transmited power

* most ~~popular~~ optimal non-unifor quantization is the entropy → data with high entropy → step size large

→ mean square error

→ 

mid interval quantization (the best)

we also have start & end qantization

→ MSE = $E\{(X - X_0)^2\} = \frac{\Delta^2}{12}$ 6x → data power

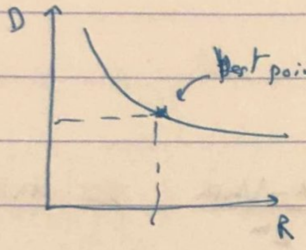
→ pdf = $\frac{1}{\Delta}$

→ distortion (normalized mse) $= \dfrac{\Delta^2}{\sigma_x^2 \cdot 12}$

$$= \frac{(V_{max} - V_{min})^2}{\sigma_x^2 \times 12} \cdot 2^{-2R} = D(R)$$

$$= \underbrace{\frac{V_{pp}^2}{12\,\sigma_x^2}}_{\text{constant}} \cdot 2^{-2R}$$

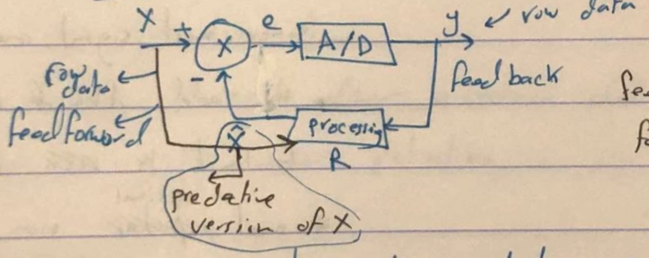
R↑ → D↓



best point to operate → D↓ & data rate ↓

↳ the best way to determine this → adaptive A/D

→



feedback is not enough for predection

block diagram for any lossy A/D converter

↳ better predcation → better data

→ correlated data → better predection ↓ req low data to represent the signal

→ not correlated → need more data

→ feed back & feed forword

→ feed back → have some information about X → only knows y

→ feed forward → better : has more information about X

$$X \approx y + \hat{X}$$

not exact due to quantization

$\hat{e}$

↳ actual $X = e + \hat{X}$

$X = X_d + X_r$

deterministic part → pure random (X_r)

→ if $X = X_d$ → $y = X$ → best we can do

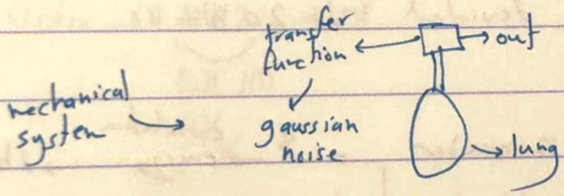
* all designing for A/D is to find the best predection for $\hat{X}$

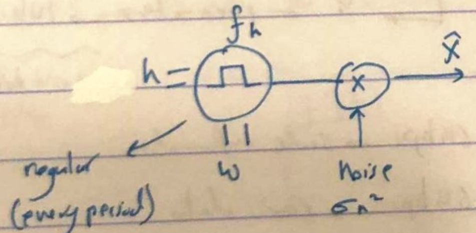
→ two main ways for A/D

→ used in GSM : RPE – STP → regular pulse excited short term prediction
(Vo coder)
(Voice coder)

troll quality

* if studied the way the human talk → for voice not audio





* not mathmaticly proved but it works

→ the first part of the model (regular pulse excited)

→ we have 4 parameters
↳ if I know the parameter → I can know $\hat{X}$
↳ this is aparametric model

→ Voice is not always in the same rithem → changes
every 20ms → 4 new parameters
4 parameters every 20 ms → every 160 sample

→ second part of the model (short term prediction)

→ prediction from the previous short term → 8 samples

| | | | | | | | → next sample is a function of the 8 samples before

* long term prediction
↳ longer # of samples

→ restart the process every 20ms

$\hat{X}_2 = f(\vec{X})$

function of the 8 samples → energy functions

→ 8 samples into corellation matrix

$\vec{X} = f(E_1, E_2, \cdots E_8)$

$C_{XX} = E[X X^T]$ ← coverance matrix

→ 160 sample is devided into 20 blocks

→ every 20ms I have 12 number → 8 → correlation → 8 bits
↳ 4 ← parameters → 10 bits

$\overbrace{}$ 104 bits

→ every sec → 3.6kbps → side information
9.6kbps → raw data

we need to add extra data ← this is compressed ← 13.2 Kbps → data rate for GSM system

25KHZ

↳ it uses minimum shift Keying & gausian filter → modulation type

6/8/2019

→ data compression

quality for voice → represented by distortion factor

→ Voice

→ data → only loss less comprision

→ video

* Voice & video → contain more data → requier high BW

* for Gsm → 9.6 Kbps is max data rate → any application above that we need to convert it & then re convert it at Rx side

→ compresion tegniques

Voice → MP3

Video → $\underbrace{MP2}$, 4, 6

full HD

4K

20K

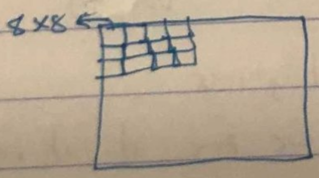
MP2 → for high definision inage

→ 27.5 Mbps → livestream

→ 6 Mbps

→ MP → devide the pictures into blocks → 8 X 8 → 64 pixel → X3 colors

started in JPEG



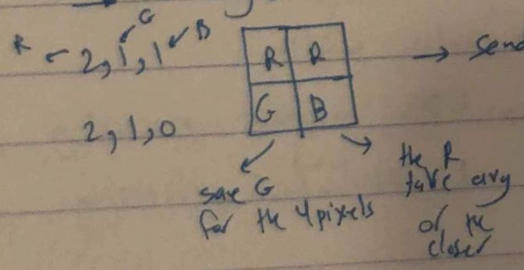
full HD 720 – 1080 pixel

1080 – 1920 pixel

each pixel → R G B I

→ intensity to correct for the color

→ the way I transmit

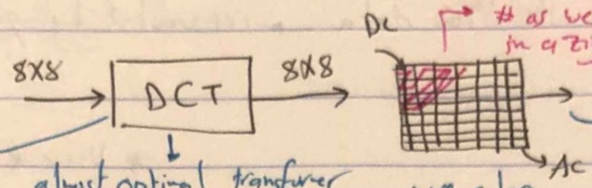


→ send one color for each pixel

→ since in the photoes are corelated so the colors are the same next to each other

→ the sharp edges require higher # of pixels

→ JPEG → devide a picture 8X8



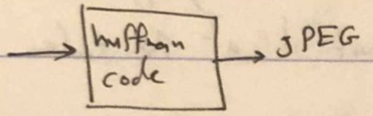
more important # as we move in a zigzag way

from time to f domain

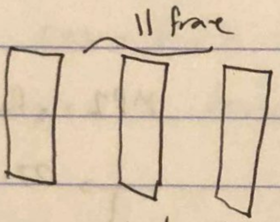
almost optimal transfarer for pictures
↓
LK transfarer the optimal for all signals

more colors change → higher f

→ if we don't have much details
↳ first 10 numbers are not zero & the others are zeros
↓
from 64 value to 10 values
↓
more details take more data



→ MP → video → # of photos after each other (frames)



30frame /sec

→ since the frames move high (highly correlated data)
↳ take the corellation between them & sent only the difference data (motion vector)

→ I take 3 frames → start → full
→ biggining → half full
→ end

* MP4 → for small pictures → most smart phones

* if the data rate is low when we zoe it it repets the same color for multiple pixels → solution for that to do blending between the pixels (trick for the aye)
→ done by convolution for a certain width
↳ this need high processing → GPU: graphical processing unit
↳ distributed processing

→ how data is sent

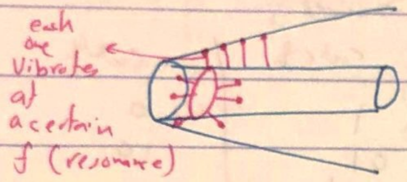
L1 control
CRC ← L2 protection
L3 audio → MP3
L4 vedio

* they are sent as pkts
→ each Layer need different processing

→ real player → for audio

→ look at the ear model

* codex (coder & decoder)
in the same ship

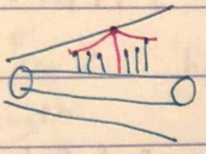


same f × different f → 22.5M sample
1500 15K

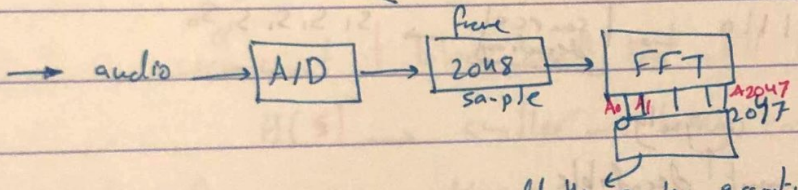
↑
\# of samples for each f

↓
for each ~~ear~~ ear
↓
24M sample

→ if one f is high → shut down the closer ones → sycho accostic model



200 – 15KHz



(A_i, i) ← index, ← amplitude

add the sycho accostic model to each one & subtract the covered ones

→ maybe we get only 50

(A_i, i)

16bit ↙ ↘ 11 bit

→ why sent more data if I'm not gonna hear it

→ used by real player
then moved to MP3 & all other technologies

→ MP3 still have different data rate (we have control data)

* Camera take the photo using a sensor (CMOS or CCD)

* bias filter