Mobile Communication Systems

Part II- Cellular Concept

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- Cell shapes and clusters
- Frequency reuse:
  - Distance
  - Efficiency
- Cluster size
- How to find the nearest co-channel neighbours
- Channel assignment strategy:
- Channel capacity
- Transceiver

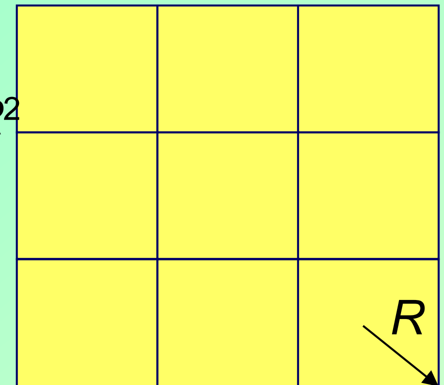
Cellular - Introduction

- Solves the problem of Spectral congestion and user capacity by means of **frequency reuse**
- Offers high capacity in a limited spectrum allocation
- Offers system level approach, using low power transmitters instead of a single not interfere with the nearest location, high power transmitter (large cell) to cover larger area
- A portion of the total channels available is allocated to each base station
- Neighbouring base stations are assigned different groups channels, in order to minimise interference

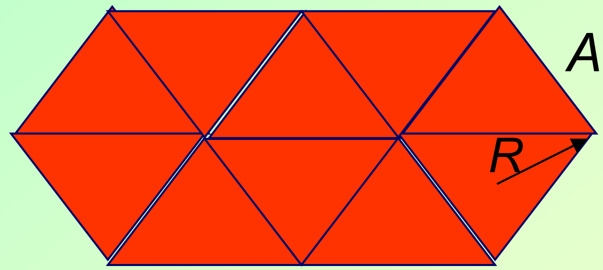
Cell Shapes

A cell is the radio coverage area for the BS

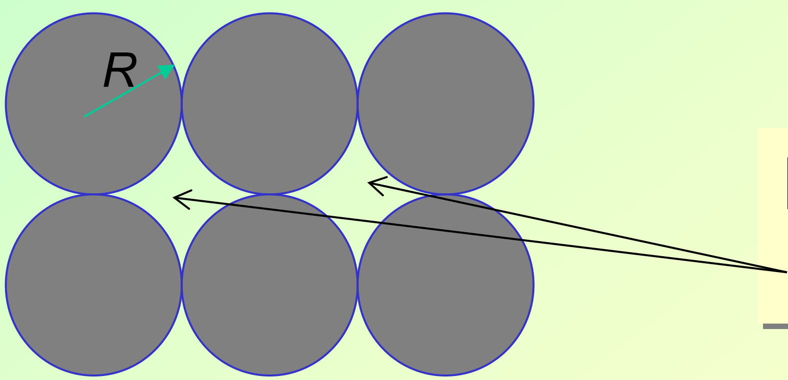
Area a = $2R^2$



Area a = $3^{3/2} R^2/16$



Not suitable, (different distance from the cell's Centre to different point in the perimeter)



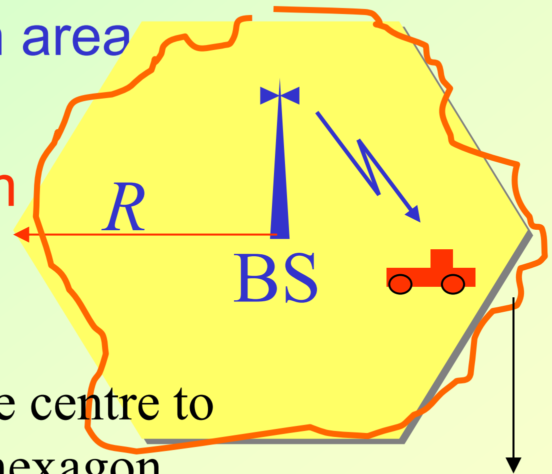
Ideal shape, but has dead zones

Cell Shapes – Hexagonal

Reasons:

- The highest-degree of regular polygons that can tile a plane .
- Approximate the circular contours of equal received signal strength when the propagation is isotropic in the horizontal plane
- Only small difference from the centre to other point in the perimeter
- Minimises the number of cells required to cover an area

Are widely used to understand and evaluate system concepts. Is the basic geographic unit of a cellular system



R : **D**istance from the centre to any vertex of the hexagon

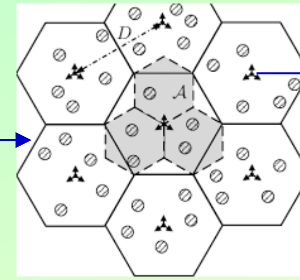
Actual cell shape

Real Cell Shape:

- System planning, terrain and other effects result in cells that are far less regular, even for elevated base station antennas
- Base stations location is strongly influenced by the practical problem of finding acceptable sites and may not follow the regular hexagonal grid

Cell Size

Wireless cells can be categorized as:



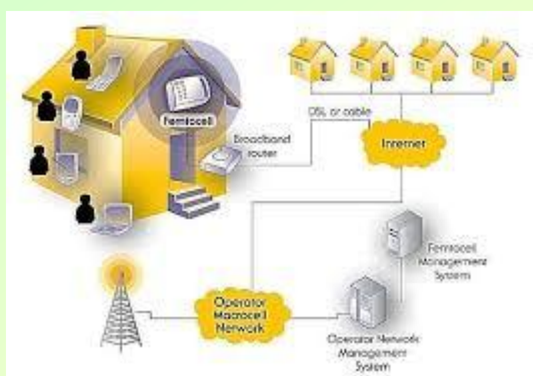
Cell Type	Typical Cell Radius	PA Power: Range & (Typical Value)
Macro	>1 km	20 W~ 160 W (40 W)
Micro	250 m ~ 1 km	2 W ~ 20 W (5 W)
Pico	100 m ~ 300 m	250 mW ~ >2 W
Femto	10 m ~ 50 m	10 mW~200 mW

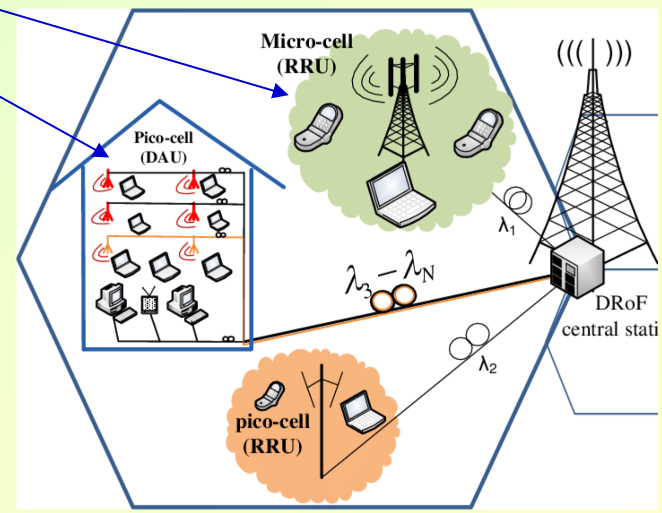
Power

Shopping centres, airports etc.

Inside buildings

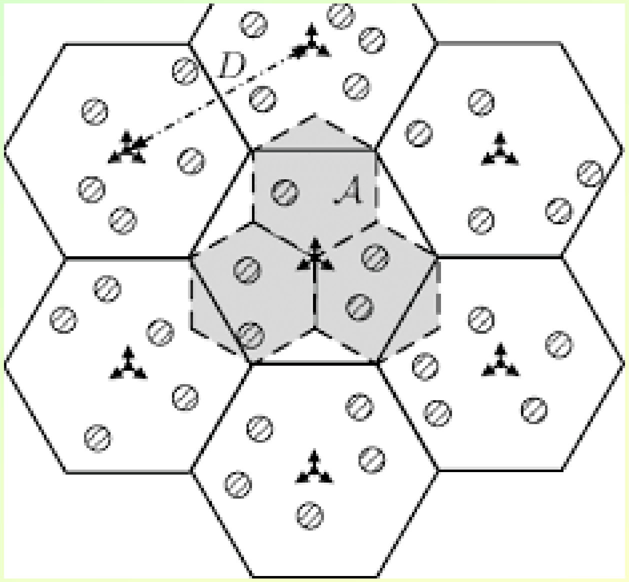
Inside rooms





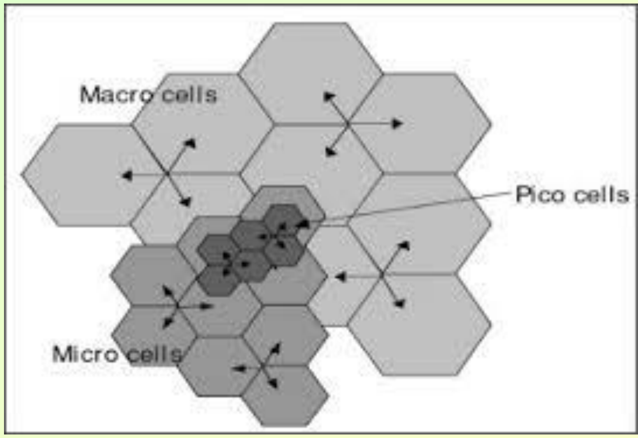
Cell Size – Macro Cells

- Cell size is quite large, typically ~ 10 km
  - 256+ users
  - Covering large areas, e.g. suburban areas
- Small number of base stations - 30-45 m height to cover a wider coverage area (e.g. 500 m or more).
- Lower capacity
- High power – 20 – 160 W (Typical 60 W)
- Poor service at the cell edge which includes a large percentage of the cell area.



Cell Size – Micro Cells

- Cell size: 1 km – [128-256 users]
  - Shopping centres, airports etc.
- Transmit power: 2-6 W
- Quality of service – Leads to improved throughput - i.e., higher capacity, which is 80-98% higher than Macro cells
- Too many base station – 15-25 m height to cover a limited area (e.g., 200 m) to provide capacity to a hot spot or coverage in a dead zone.
- Lower delays – Faster down loads
- Reduced transmit power – 2 – 20 W (Typical 5 W)
- Large number of handovers
- Require accurate power control to reduce interference



Cell Size – Pico Cells

- 4 – 100 m – Inside building [32-128 users]
- Quality of service - Leads to improved throughput - i.e., higher capacity, which is 80-98% higher than Macro cells
- Flexibility
- High number of base station - 10-15 m height to cover a limited area (e.g., 100 m) to provide capacity to a hot spot or coverage in a dead zone.
- Lowe transmit power – 23-30 dBm
- Lower delays – Faster down loads
- Better cell-edge performance, particularly for the uplink than large cells
- Higher level of handover
- Require accurate power control to reduce interference

Cell Size – Femto Cells

- Known as “Home base station”, Access point”
- First deployed in 2002
- Femto cells: 10 – 40 m – Inside rooms/building [4-8 / 16-23 users]
- Transmit power: < 23 dBm
- In-building coverage: small cells provide better outdoor-to-indoor coverage. Considering that 40% of mobile traffic originates from home and 25% from work, this can represent a significant source of revenue for network operators
- Better cell-edge performance, particularly for the uplink than large cells
- Interference is localised to within a room
- Connects to the service provider via broadband (DSL)
- Low cost

For WiFi, transmit power = 20 dBm

Compact base stations (C-BTS)

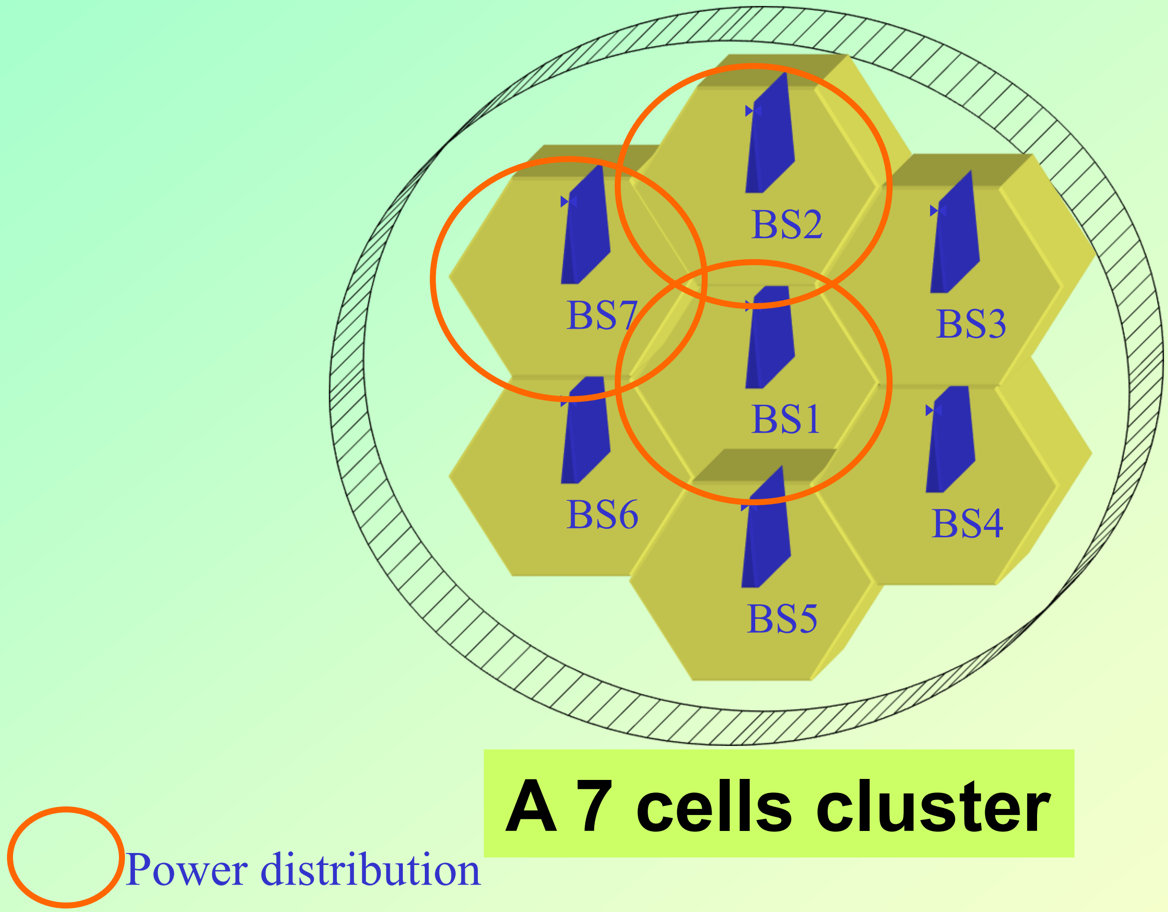
- Small size and weight (e.g., a few kilograms)
- Easy to deploy and maintain
- They come with varying output power ranging from a half-watt to a few watts
- Low gain antenna
- Fully integrated base stations that include baseband processing and radio module in one physical unit
- Used tunnels and subway stations etc.

Compact base stations (C-BTS)

- Note that the effective antenna height can significantly affect the achieved cell radius in addition to the Tx power level. An antenna installed in a location with higher or lower altitude will have more or less favorable RF propagation conditions, which will influence the size of the coverage footprint (cell radius).

Cell Cluster

- A cluster is a group of cells
- No channels are reused within a cluster



A 7 cells cluster

Cell	Frequency (MHz)
1	900
2	900.3
3	900.6
4	900.9
5	901.2
6	9001.5
7	9001.8

Frequency Reuse - Concept

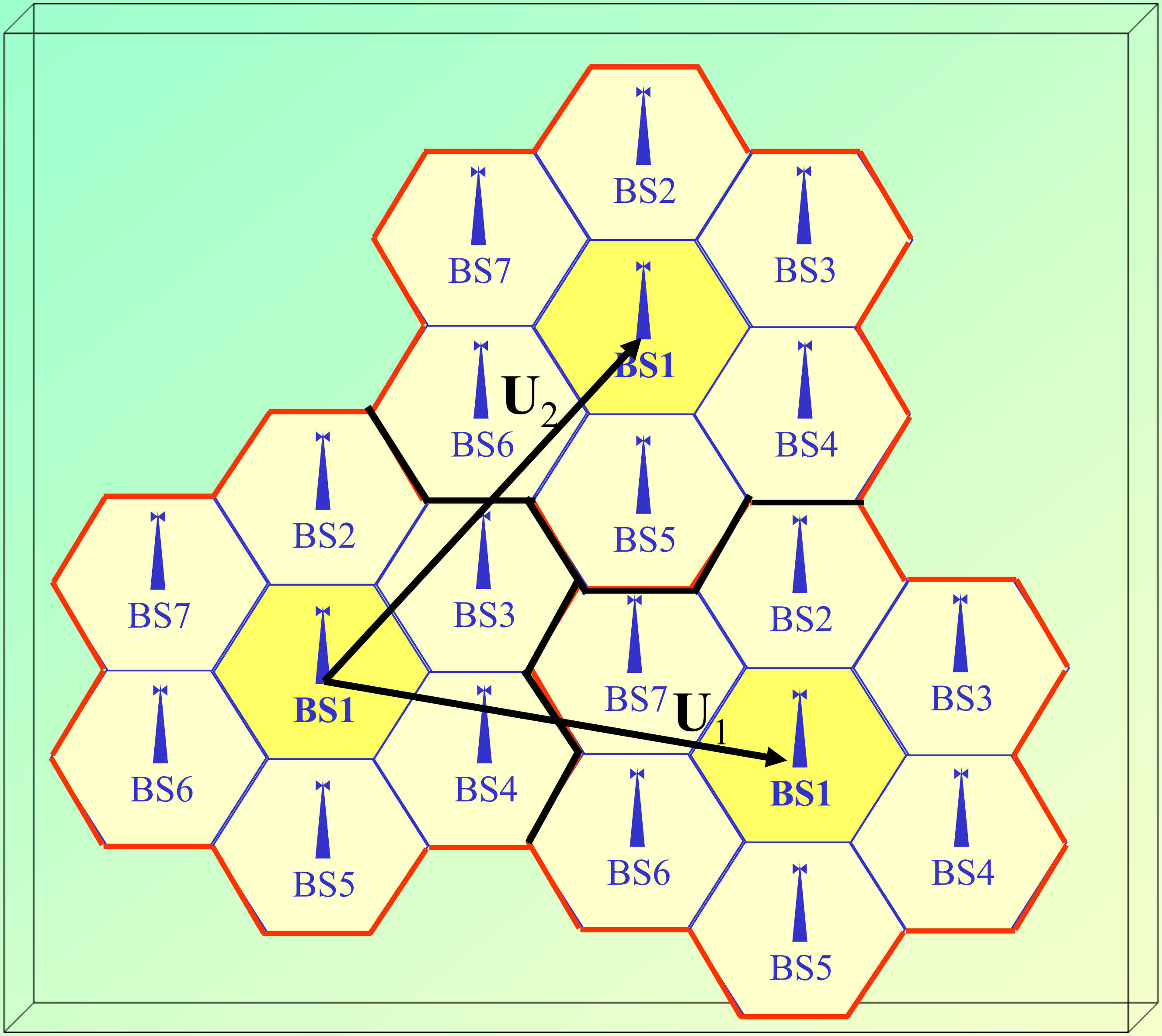
- Adjacent cells - assigned different frequencies to avoid interference or crosstalk

- 10 to 50 frequencies assigned to each cell

- Cell coverage area - called the footprint and is limited by a boundary, so the same group of channels can be used in cells that are far enough apart

- Transmit at power levels sufficiently low in order not interfere with the nearest location at which the same channel is ***reused***.

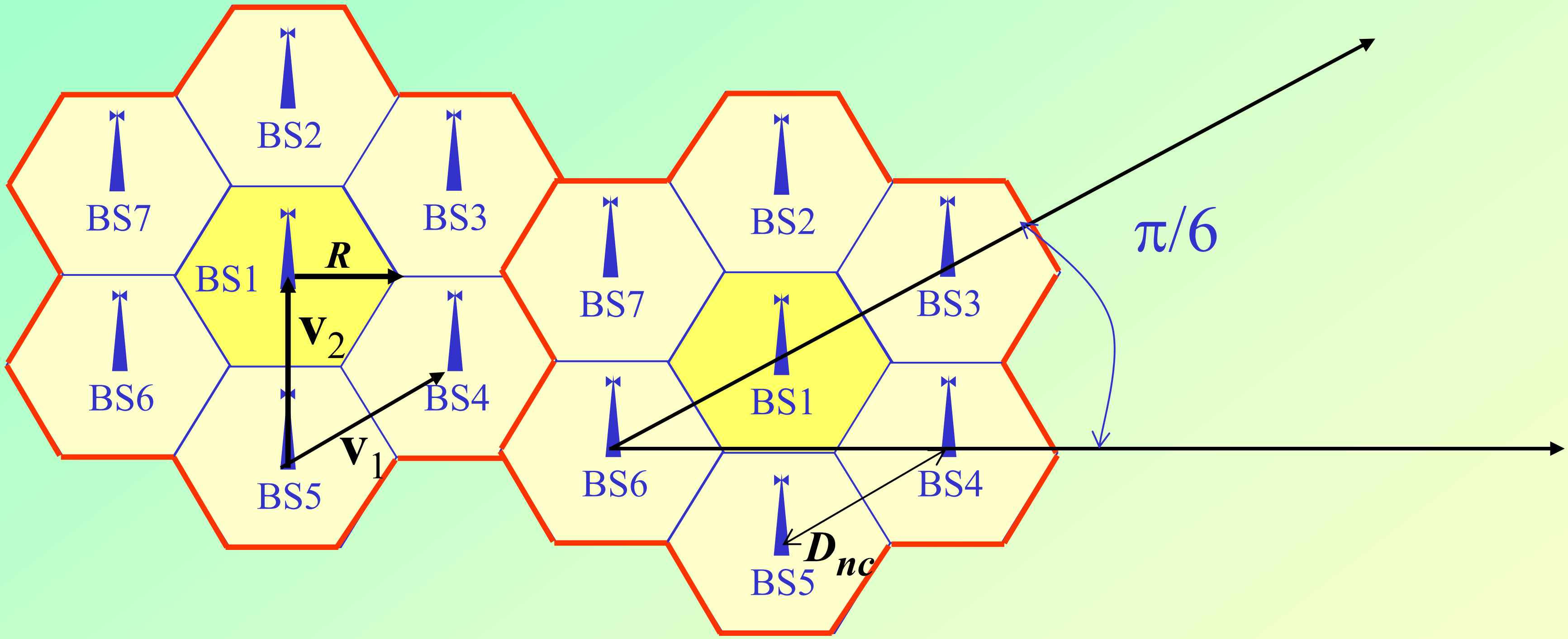
Frequency Reuse – *contd.*



Cells with the same number have the same set of frequencies

U$_i$: Frequency re-use vector

Frequency Reuse Distance

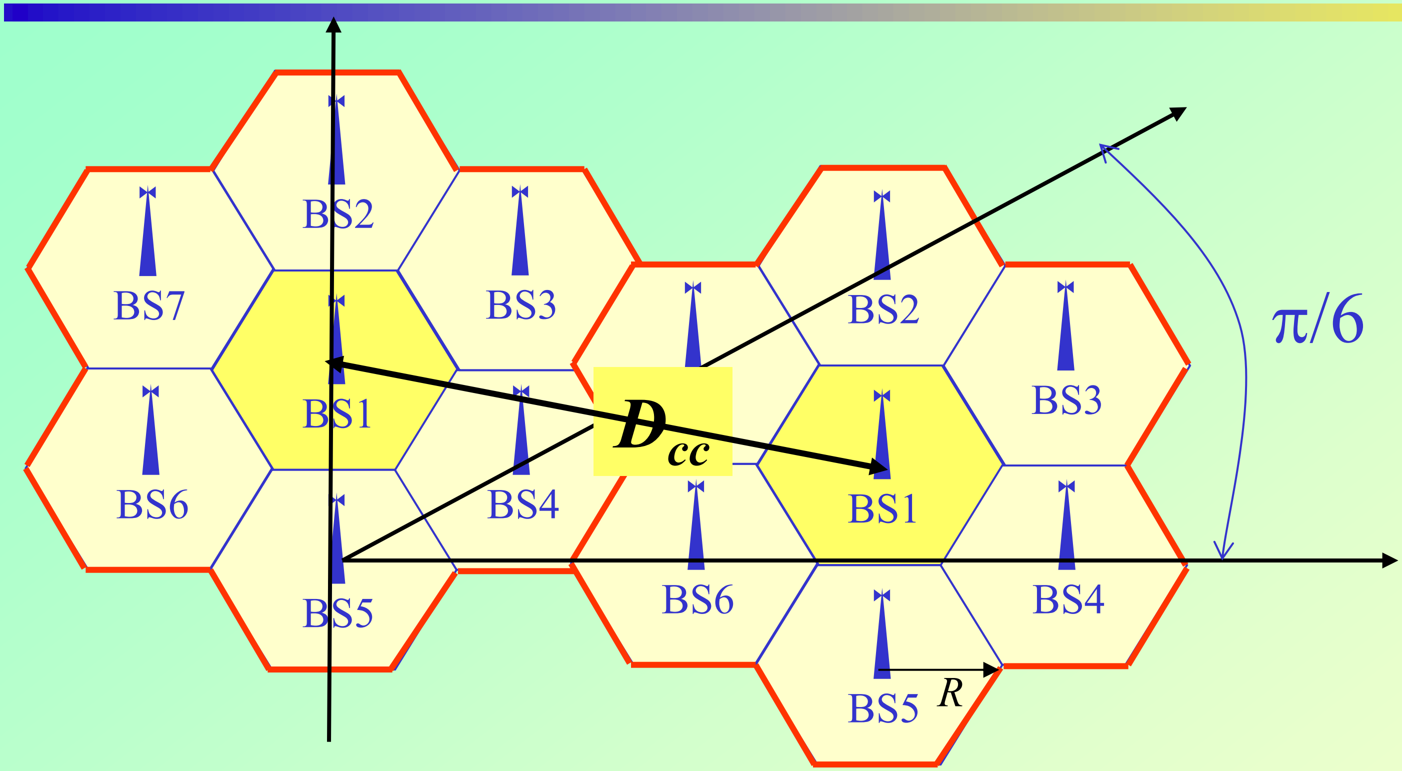


Distance between any two cells can be expressed as a linear combination of the two basis vectors $\mathbf{v}_1$ and $\mathbf{v}_2$ having an angle of 60°. Then $|\mathbf{v}_1|$ and $|\mathbf{v}_2| = (3)^{0.5}R$.

Or, the centre-to-centre distance between two neighbouring cells is

$$D_{nc} = 2R\cos(\pi/6) \text{ or } \sqrt{3}R$$

Frequency Reuse Distance *contd.*



Cell area

$a = |\mathbf{v}_1 \times \mathbf{v}_2|$
$= 3R^2 \sin(30°)$

$$a = \left(\frac{3\sqrt{3}}{2}\right) R^2$$

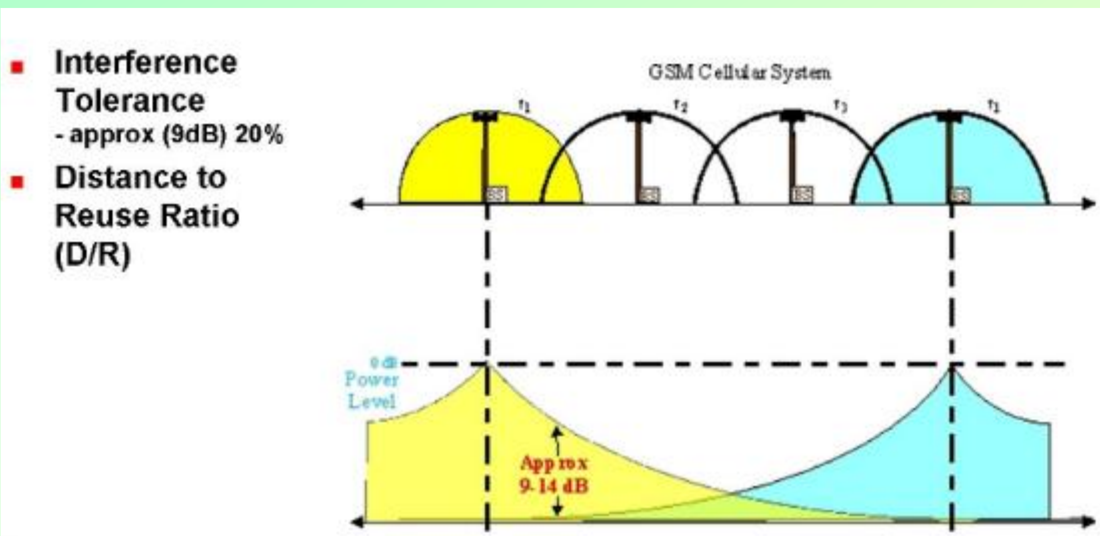
The centre-to-centre distance between any two co-channel cells is

$$D_{cc} = \sqrt{i^2 + j^2 + ij} \cdot (\sqrt{3}R)$$

Where *i* = *j* = 0, 1, 2 etc. represent the centre of a cell (reference). For adjoining cells, either *i* or *j* can change by 1, but not both

Frequency Reuse Distance *contd.*

- The greater the ***reuse distance***, the lower the probability of interference. Likewise, the lower the power levels used in cells sharing a common channel, the lower the probability of interference.
- Thus, a combination of power control and frequency planning is used in cellular systems to prevent interference.



GSM - A common frequency reuse plan **is the ability to reuse a radio frequency on every 4th site** that has three 120 degree sectors each (i.e., 12 total sectors). This plan is commonly called “4/12”.

The diagram shows that a frequency in a GSM system can be reused at nearby cell sites provided the radio signal level from the interfering (unwanted) cell is 9 dB to 14 dB below the desired signal level.

Cluster Size

Area of a region can be expressed by:

$$A = D_{cc}^2 \sin 60°$$

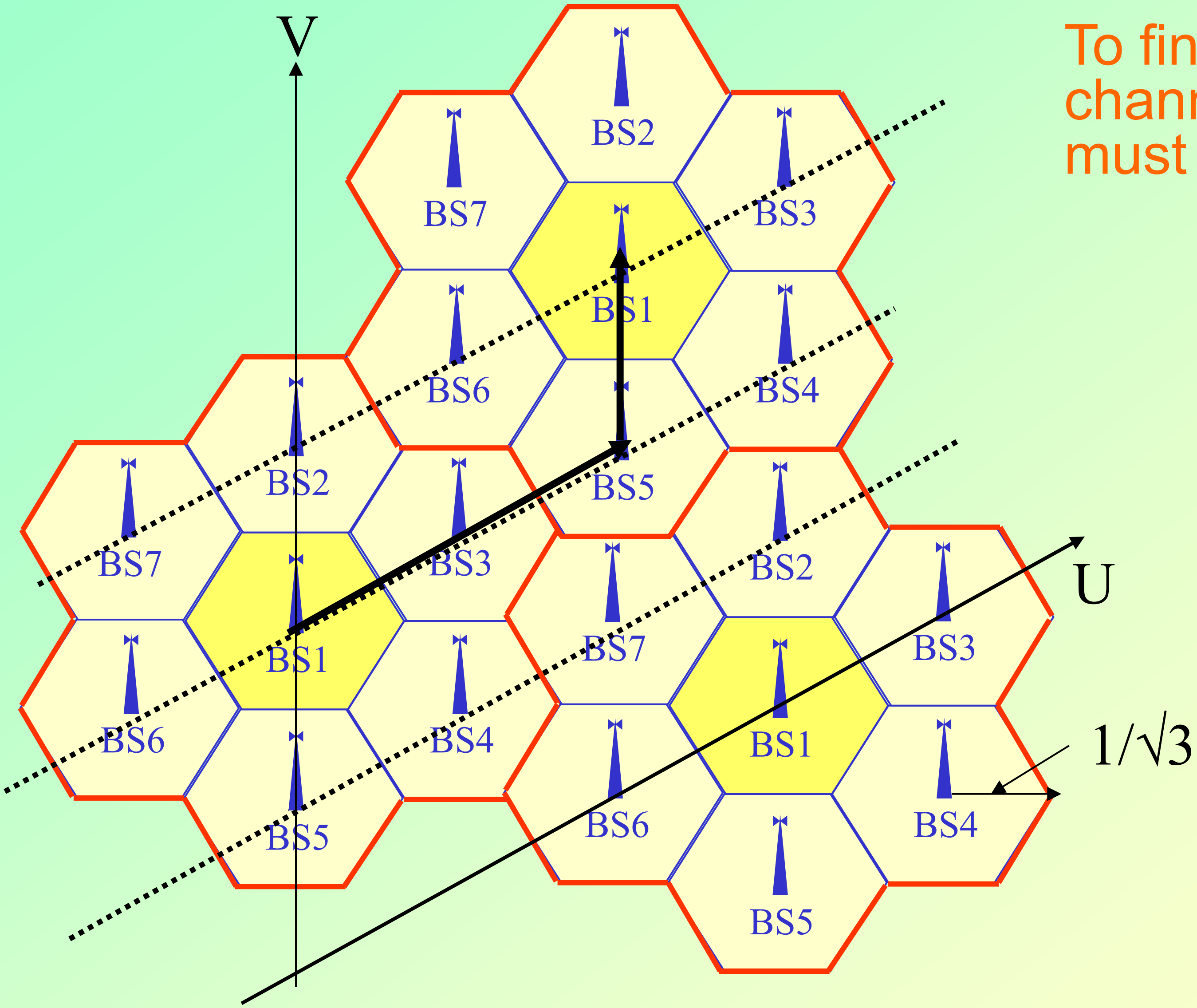
- The number of cells per cluster within an area of radius D_{cc} (i.e in reuse pattern) is:

$$N = \frac{|U_1 \times U_2|}{|V_1 \times V_2|} = \tfrac{1}{3}\left(\frac{D_{cc}}{R}\right)^2$$

Also $N = A/a$

- **Frequency reuse factor = 1/*N***
- **Area of the cluster** $A = \sqrt{3}\frac{D_{cc}^2}{2}$

Locating Co-Channel Cells



To find the nearest co-channel neighbours one must do the followings:

1. move *i* cells in the U direction
2. turn 60º counter-clockwise and move *j* cells in the V

see Fig. $N = 7$, $i = 2$ and $j = 1$

Data

- **Co-channel reuse ratio $Q = D_{cc} / R = \sqrt{(3N)}$**

i	*j*	*N*	*Q=D/R*	*Transmission quality*	*Traffic capacity*
1	0	1	1.73	Lowest	Highest
1	1	3*	3		
2	0	4*+	3.46		
2	1	7*=	4.58		
3	0	9*	5.2		
2	2	12*+	6	Highest	Lowest
		21*=			

* Most common, + Digital network, = Analogue network

Frequency Reuse efficiency

$$\eta_{fr} = \frac{No.of\ available\ user\ channels\ in\ real\ system}{No.of\ available\ user\ channels\ in\ ideal\ system}$$

Note: In ideal system there are no co-channel interference

- **Frequency reuse factor** = 1/*N*

N is the number of channels

Radio Channel - Structure

- Is the division and coordination of a radio communication channel into:
  - **frames** (groups) of data
  - **time slots**
  - **fields** within the frames that hold specific types of information.
- Divided into frames with **8 time slots/**frame (**0 through 7**), and time slots are divided into field dependent on the purpose of the time slot
- A forward (downlink) radio channel is paired with a reverse (uplink) channel to provide simultaneous duplex voice communication
  - This pair of frequencies is known as absolute radio frequency channel number (ARFCN) or just plain channel.
- Between the downlink channel and uplink channel, the **time slot** numbers are **offset by 3 slots**
  - This allows the mobile telephone to transmit at different times than it receives.
  - This allows the design of the mobile device to be simplified by replacing a frequency filter (duplexer) with a more efficient transmit/receive (T/R) switch.

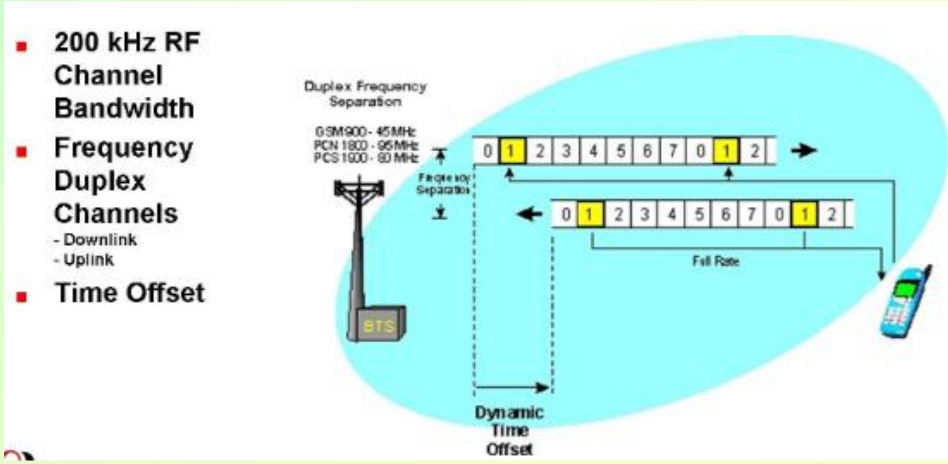


Figure shows the GSM system
- uses a single type of radio channel.
- Each radio channel with a bandwidth of 200 kHz and a data rate of 271 kbps.

http://www.althos.com/tutorial/GSM-tutorial-radio-channel-structure.html

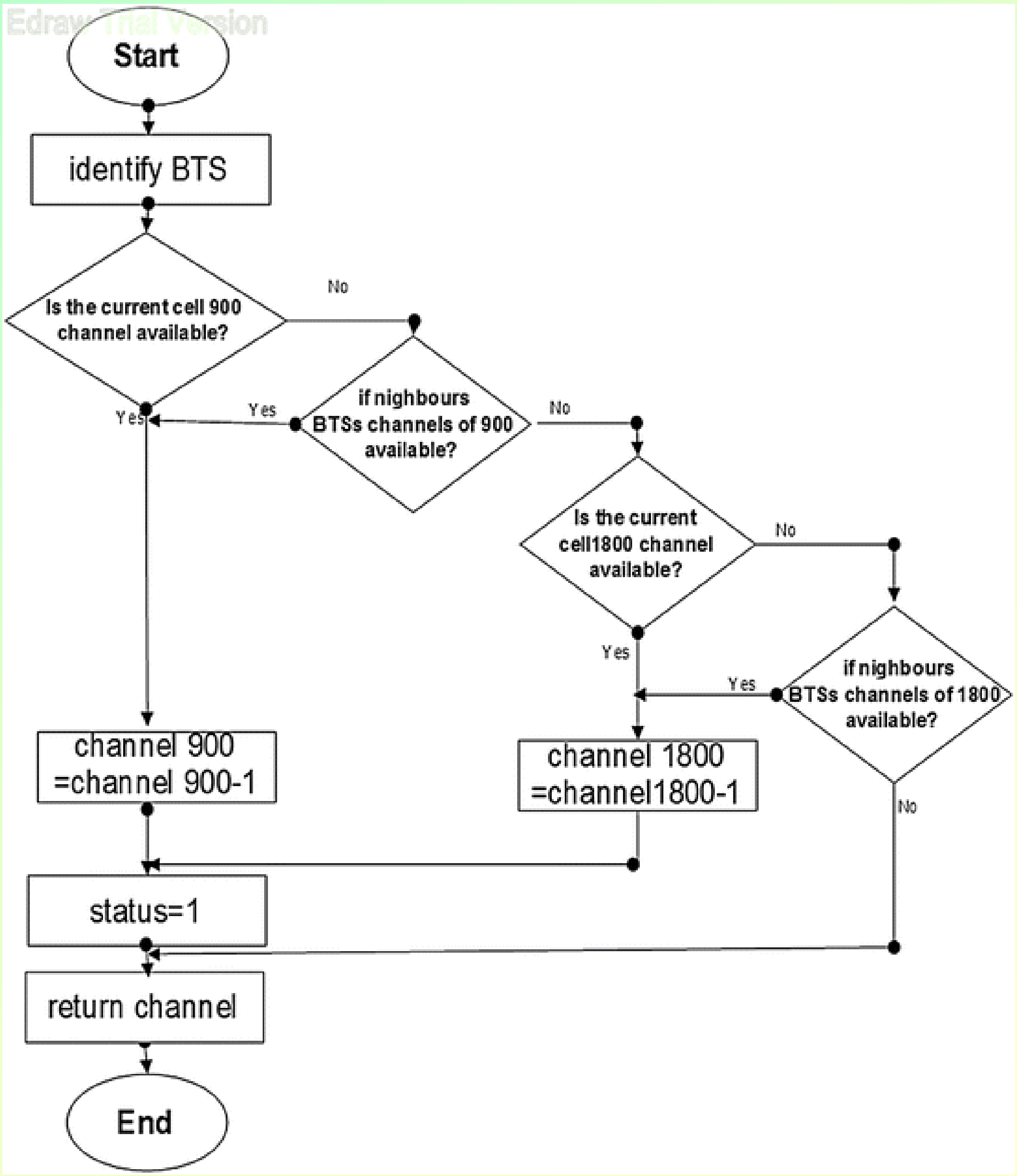
Channel Assignment Strategies

- The choice of channel assignment strategies impacts the performance particularly as to how calls are managed when a mobile user is handed off from one cell to another.
- **There are basically three strategies:**

Fixed

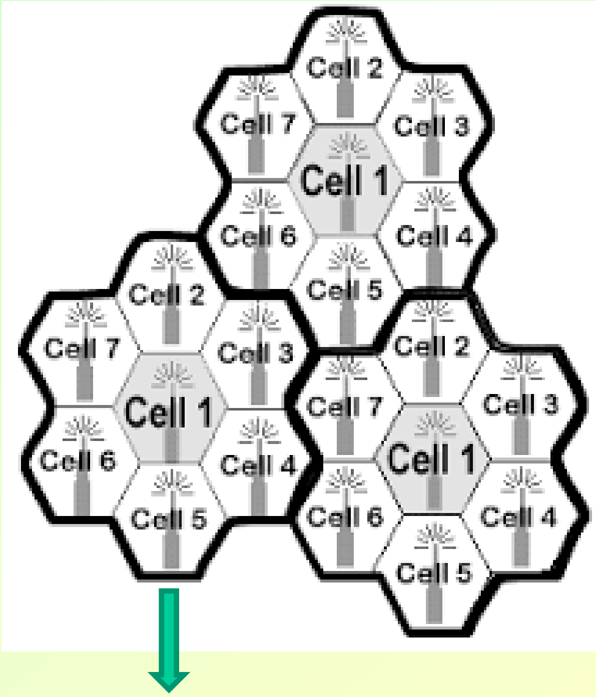
Borrowed

Dynamic



Channel Assig. Strat. - Fixed

- Each cell is allocated a predetermined set of voice channels irrespective of the number of users in that cell. *This results in traffic congestion and some calls being lost when traffic gets heavy*
- A user is always served by the unused channels in that particular cell
- Call is *Blocked* if channels are occupied
  – This means blocking probability in fixed channel assignment is high which degrade the network performance.
- If all channels are occupied, cell may be allowed to use channels from a neighbouring cell
- Used in TDMA/FDMA cellular radio systems

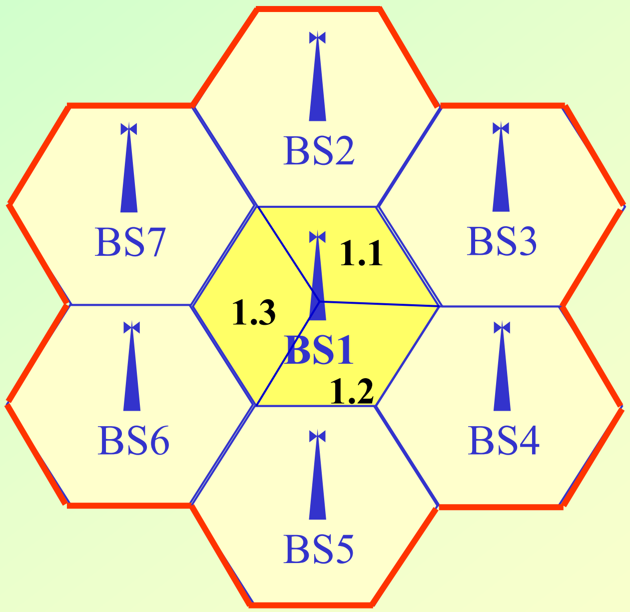


Cell 1: Ch. 1-20
Cell 2: Ch. 21-40
..
.
Cell 7: Ch 120-140

Channel Assig. Strat. - Borrowed

- Revised (modified) version of the fixed channel assignment

- A channel is borrowed from the near base station when all channels are busy.
- The borrowed channel is returned back to the original base station when the call is ended.
- The borrowing process is supervised by MSC while taking care of frequency reuse.



A call initiated in Cell 1.A (1.1) can borrow a channel from cells 6 and 7.

Channel Assig. Strat. - Dynamic

- Channels are not allocated to different cells permanently
- Is ideal for bursty traffic
- Each time a call request is being made, the serving BS request a channel from MSC

- MSC allocate a channel by using an algorithm that takes into account:
  - likelihood of future blocking within the cell
  - frequency reuse of the candidate channels
  - reuse distance of the channels
  - cost functions

- MSC requires to collect real time data on:
  - channel occupancy and traffic distribution
  - frequency reuse
  - radio signal strength of the channels on a continuous basis

Channel Assig. Strat. - Dynamic

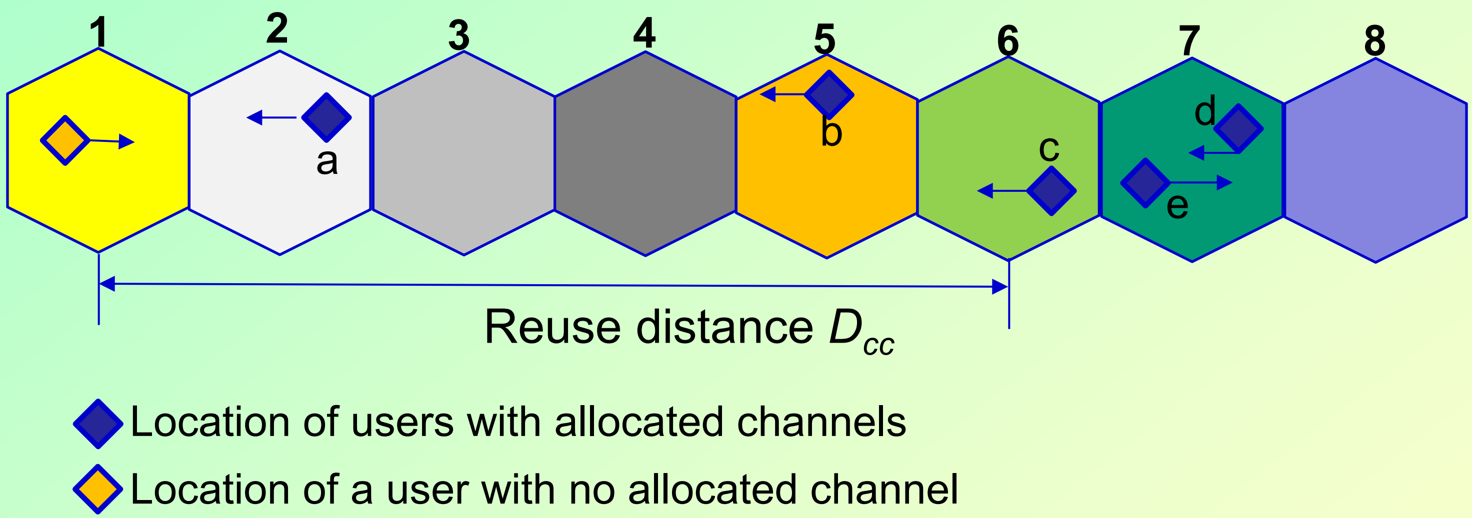
- Since a cell is allocated a group of frequency carries (e.g., *f*1-*f*7) for each user, then

Bandwidth of that cell B_{ce} = a range from carrier frequencies

- Adopted in GSM, DCS and other systems

Channel Allocation – One-dimensional

- A new call initiated in cell 1.



- A new call is made in cell 1
- Current location of channels a, b, c, d, e
- It is best to assign channel e to mobile in cell 1.
- Assuming that as cell 1 moves to cell 2, and user in cell 7 moves to cell 8

Cellular System - Power Control

- It desirable to introduce ***dynamic power*** control
  - To have a high signal to noise ratio (SNR)

    received power must be sufficiently above the background noise for effective communication i.e., $P_r > N_T$ (noise total power)

    Rapid changes to the received power is due to:
    - ***Reflection*** - ***Diffraction and*** - ***Scattering***

  - To reduce co-channel interference, alleviate health concerns, save battery power:

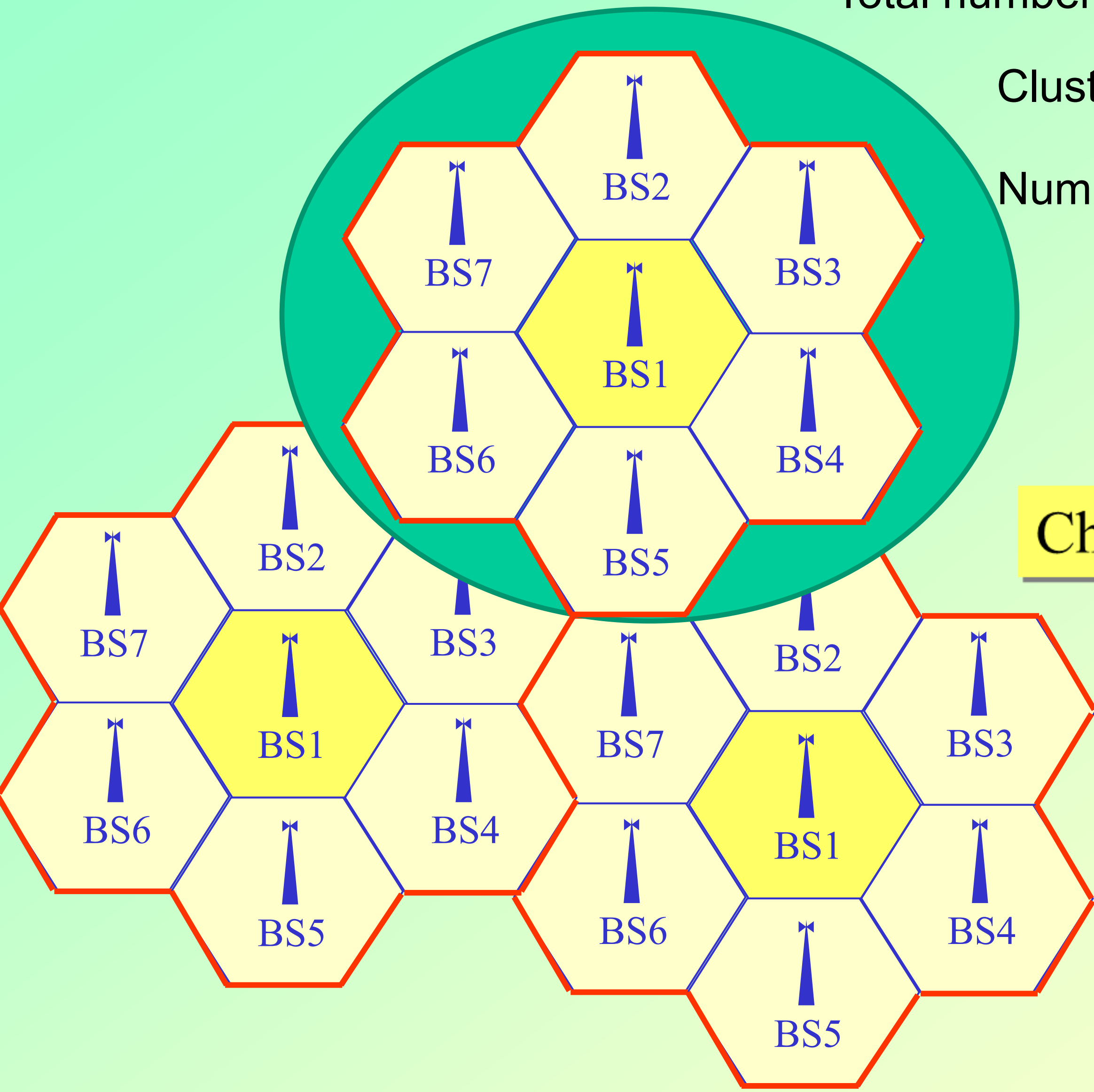
    minimize mobile transmitted power

  - To equalize the received power level from all mobile units at the BS

Power Control - Types

- Open-loop power control
  - Depends solely on mobile unit and with no feedback from BS
  - Continuous transmission of a “Pilot Signal, thus allowing MU to use it for
    - Timing for forward link (BS → MU)
    - Phase reference for demodulation
    - Power control
  - Assumptions: Forward and reverse links are correlated
  - Not as accurate as closed-loop, but can react quicker to fluctuations in signal strength
- Closed-loop power control
  - Adjusts signal strength in reverse channel (MU → BS) based on metric of performance in the reveres channel
    - Received power level
    - Received SNR
    - Or received bit error rate (BER)
  - BS makes power adjustment decision and communicates to a power adjustment command to the mobile on a control channel

Channel Capacity



Total number of duplex channels per cluster C_T

Cluster with size $N = 7$

Number of channels / cell $k = C_T/N$

No. of cluster

Channel capacity $C = MkNB = MS$

Duplex frequency bandwidth / channel

Total duplex channels available for reuse: $S = kNB$

Channel Capacity - GSM

- Carrier frequencies:
  - 890-915 MHz (uplink) – Transmit power: 2-8 W
  - 935-960 MHz (downlink) – Transmit power: 10-50 W
- Normally 25MHz/200kHz/channel = 125 channels /cluster
- Data rate: 271 kbps/channel
- Coding: Convolutional code, rate 1/2 ; Equalization: MLSE
- Modulation: GMSK

For N = 7, k = 17 – 18 channel/cell

And for M = 3,

C = 3 x 125 = 375 channel

Or for

S = 8, N = 9, and B = 2 x 200 kHz = 0.4 MHz

Thus k = 2.2 channels. $\text{Cell}^{-1}.\text{MHz}^{-1}$

For analogue systems

k = 1.9 channels. $\text{Cell}^{-1}.\text{MHz}^{-1}$

Spectrum Efficiency

- Defined as the traffic capacity unit (i.e. number of channel /cell) divided by the product of bandwidth and the cell area
- Is dependent on the number of radio channels per cell and the cluster size (number of cells in a group of cells):
- Cellular system capacity or **spectrum efficiency** can be most easily and inexpensively increased by:
  - subdividing cells into smaller cells
  - sectorising the cells.

    A **reuse pattern** of N_s/N , N_s is the number of sectors.

    Some current and historical reuse patterns are

    3/7 (North American AMPS),

    6/4 (Motorola NAMPS),

    3/4 (GSM).

System Capacity (SC)

- SC = Traffic capacity (No. of channel /cell) / (Bandwidth)(Cell area)
- Depends on the
  - number of radio channels per cell
  - cluster size (number of cells in a group of cells):
- Can be most easily and inexpensively increased by:
  - subdividing cells into smaller cells
  - sectorising the cells.
    - A **reuse pattern** of N_s/N , N_s is the number of sectors.

Some current and historical reuse patterns are

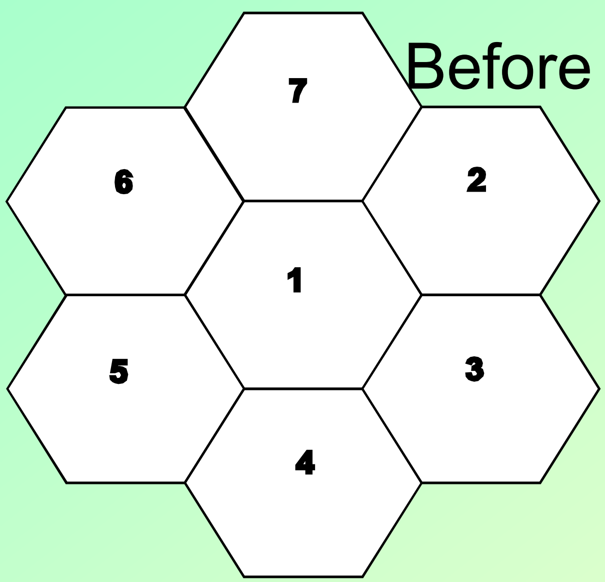
3/7 (North American AMPS),
6/4 (Motorola NAMPS),
3/4 (GSM).

Approaches to Cope with Increasing Capacity

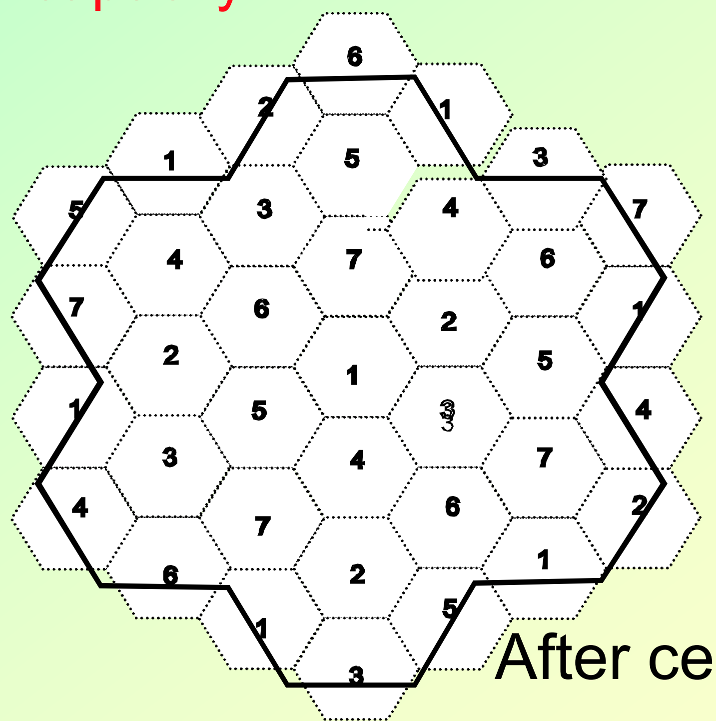
- **Adding new channels or new frequency band**
  - GSM uses two bands in Europe: 890-960 MHZ, and 1710 – 1880 MHz
- **Decrease cell size and at transmit power** (to keep CCI low)
- **Frequency borrowing -** frequencies are taken from adjacent cells by congested cells
- **Increase the number of cell per cluster -** Cell splitting
- **Cell sectoring -** cells are divided into a number of wedge-shaped sectors, each with their own set of channels
- **Microcells (100 m – 1 km in diameter)**
  - compared to the standard cell size of 2-20 km in diameter
  - antennas move to buildings, hills, and lamp posts
- **Frequency reuse**
- **Reducing interference**
- **Smart antennas**

Cell Splitting

- Consider the number of voice circuits per given service area.
  - If a base station can support *X number of* voice circuits, then cell splitting can be used to increase capacity



Before cell splitting

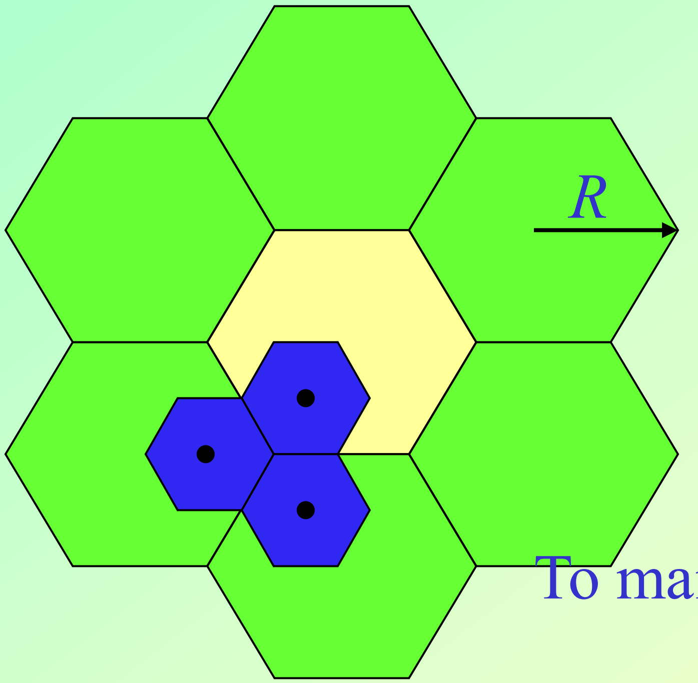


After cell splitting

- As shown above a rough calculation shows a factor of 4 increase.
- This is the reason for using more base stations in a given area

Cell Splitting

- This increase does not hold indefinitely for several reasons:
  - Eventually the BSs become so close together that line-of-sight conditions prevail and path loss exponent becomes less (e.g., 2 versus 4)
  - Obtaining real estate for increased number of base stations is difficult
  - As cell sizes become smaller, number of handoffs increases; eventually speed of handoff becomes a limiting factor
- Mini cells will have their own Tx and Rx antennas



Power at the boundary of un-split cell: $P_u = P_{tu} R^{-n}$

Power at the boundary of a new mini cell: $P_{ms} = P_{tms} (R/2)^{-n}$

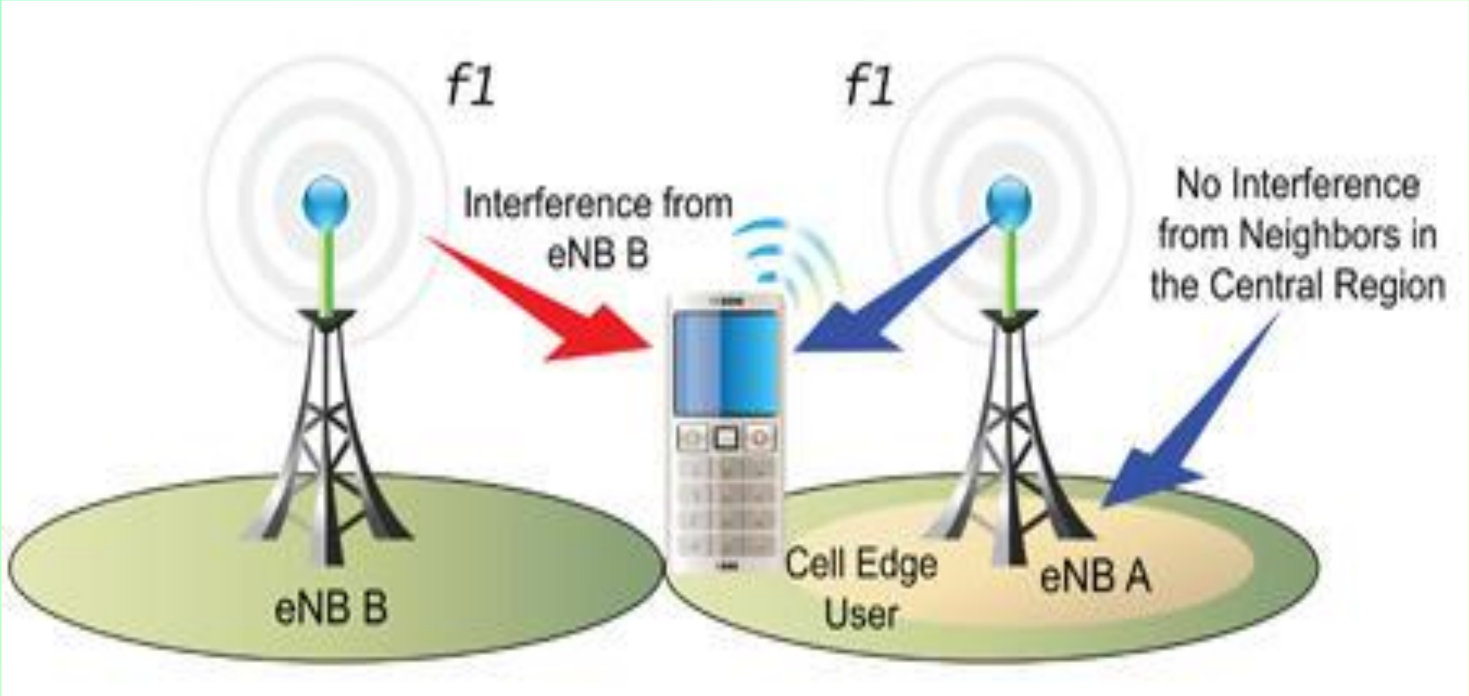
Where P_{tu} =transmitted power un-split cell

P_{tms}= transmitted power from mini cell

To maintain the same CCI performance $P_u = P_{ms}$

$$P_{tms} = P_{tu} / 2^n$$

Cell Splitting – Micro and Femto-Cells



Microcells and femtocells are deployed by most major carriers as a way to allow their customers, both businesses as well as individuals, to deploy their own network(s) anywhere there is an Internet connection.

The sheer number of cells (large and small area), the inability for the carriers to control the position and use of them, and the handover between these ad hoc cells and the overall network create significant challenges in spectrum and interference management.

Small Cells for Higher Capacity

There are two very different in-building service objectives:

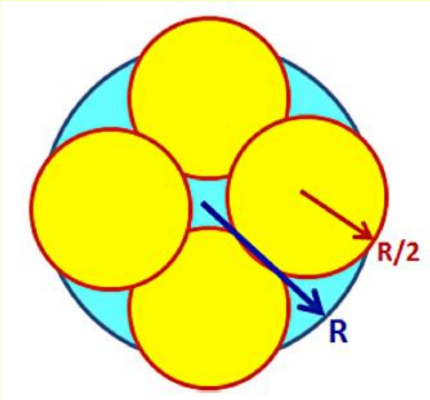
- Maximize the in-building coverage - *the footprint from each indoor cell should be as large as possible in order to minimize the total indoor cell count.*

- Maximize the in-building capacity - *the footprint from each indoor cell should be as small as possible in order to maximize the total indoor cell count, which results in maximum capacity.*

Obviously, for serving hotspots the main goal is to maximize the in-building capacity so one must minimize the footprint of each indoor cell.

Small Cells for Higher Capacity

- Data capacity from a cell is defined as the aggregate cell throughput per cell
- With identical conditions (e.g., same channel bandwidth)
- The aggregate throughput from a cell is the same regardless of the size
- Therefore, regardless of whether it is a macrocell, microcell, picocell, or femtocell, the aggregate cell throughput from each cell remains the same.
- It also means that total capacity is inversely proportional to the square of the cell radii, i.e. if the cell radii are halved, the total capacity is quardrupled.



Small Cells for Higher Capacity

- The total capacity in a building can be increased significantly by using a large number of femtocells with very small footprints.
- The cell radii of femtocells are about 10%–30% of those of picocells.
- Therefore, by using a large number of femtocells, the total indoor capacity can be increased by a factor of 10–100 compared to the case of using a few picocells.

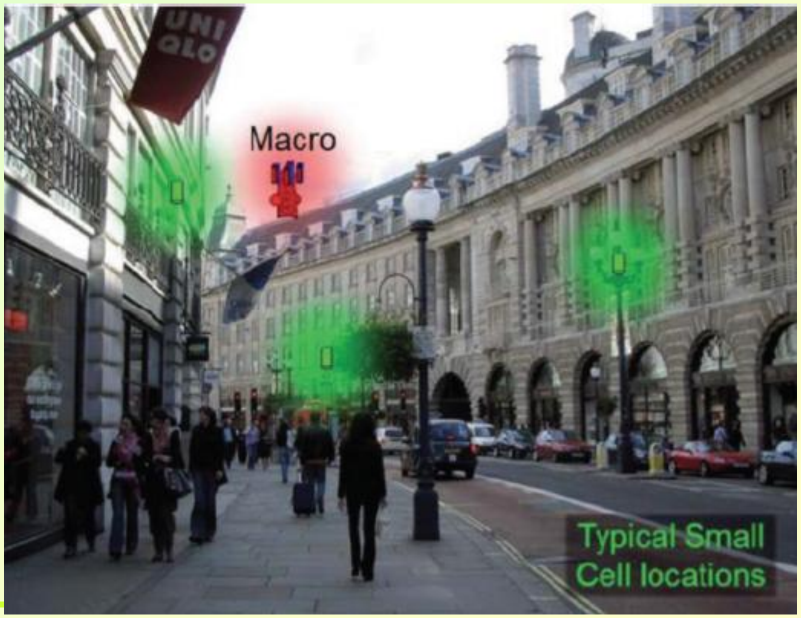
Q- Why the Picocell is not the Best Candidate for a High-Capacity Indoor Solution?

Small Cells for Higher Capacity

Q- Why the Picocell is not the Best Candidate for a High-Capacity Indoor Solution

A- The picocell has higher power and larger cell radius, which makes it a more appropriate candidate for applications that demand larger coverage footprints (> 100 meters).

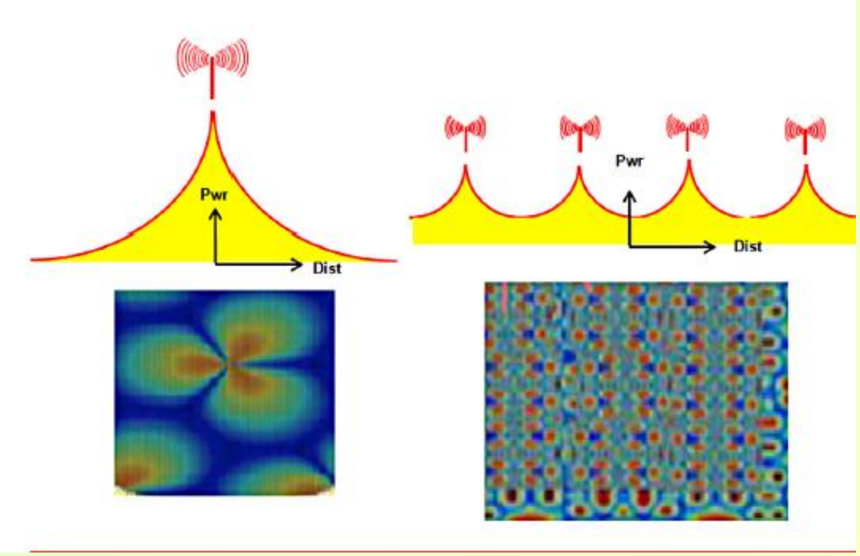
- E.g., dense "urban canyons" (see Figure), outdoor theme parks, and so on.
  - These areas need high capacity
  - But a high percentage of traffic is voice (which requires each cell to connect a higher number of active users).
  - MU may be moving at driving speed, so larger cell radii and faster handover are needed.
- Are typically more expensive than femtocells, but also the better candidate for serving outdoor hotspots.



Small Cells for Higher Capacity- Indoor Coverage

- Indoor services do not need to handle MU moving at high speed
- Within the small footprint of a femtocell, the number of simultaneous connections does not need to be as large as in an outdoor situation
- The combined factors of lower power and lower processing power make the cost of a femtocells much lower, but also make femtocells more suitable for high-capacity indoor applications

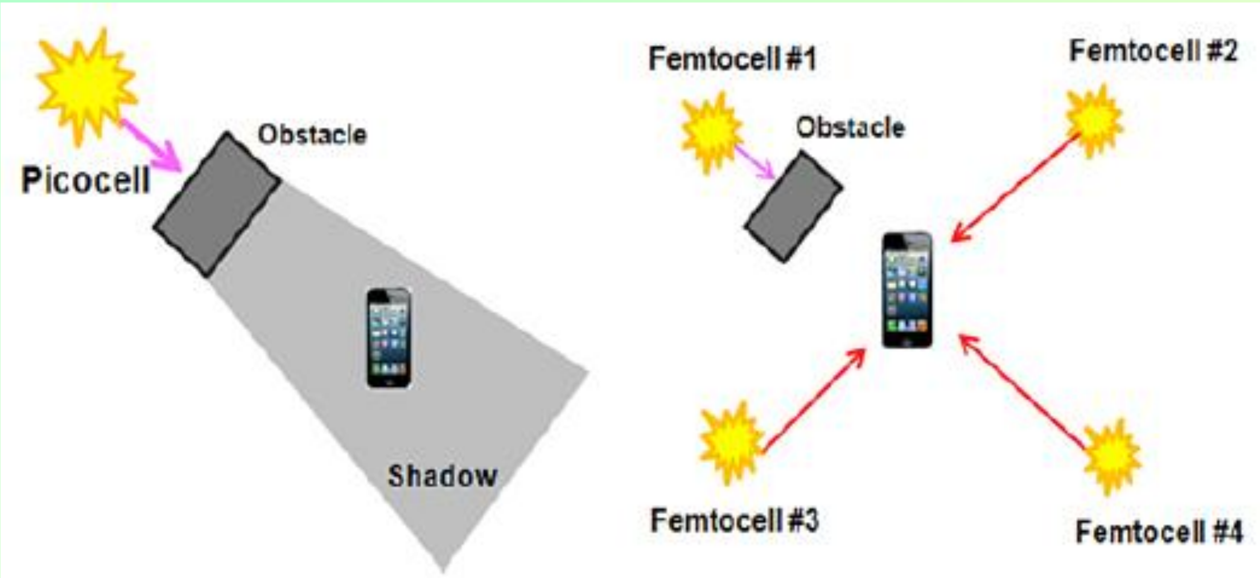
- The entire building can be covered with:
  - Small number of picocells with higher power
  - Larger number of femtocells with lower power
    - This will provide much more uniform Coverage in a highly cluttered indoor environment, see Fig.



Comparison of coverage provided by one high-power source (left) versus coverage provided by many low-power sources (right)

Small Cells for Higher Capacity- Indoor Coverage

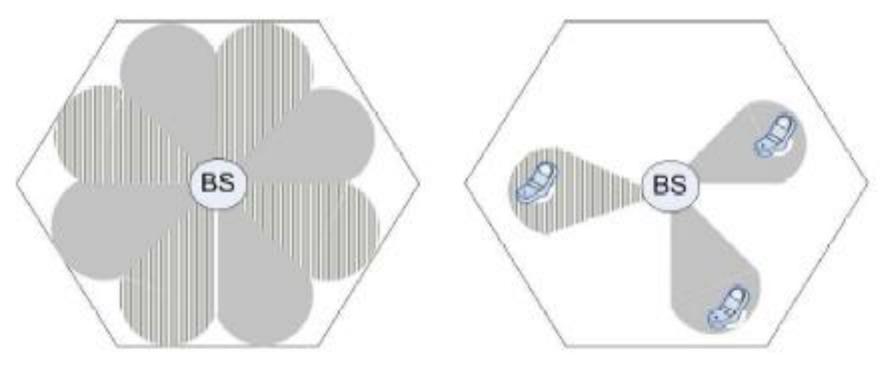
- Most in-building environments will have many man-made objects that act as obstacles to radio propagation; therefore one must consider the so-called "shadowing effect."
- A large number of low-power femtocells provides much better "macroscopic diversity" (i.e., each location will likely receive signals from multiple cells arriving from different directions), which is very effective in combatting the shadowing effect.



Single picocell: a single obstacle will cause a coverage shadow. (Right) Multiple femtocells: no shadow is caused unless all femtocells are obstructed

Smart Antennas

- BSs transmits the signal to the desired MU
  - With a maximum gain
  - Minimized transmitted power to other MUs.
- Overcomes the delay spread and multipath fading.
- Two types:
  - Switched-beam antenna
    - Cell sectrisation: a physical channel, such as a frequency, a time slot, a code or combination of them, can be reused in different minisectors if the CCI is tolerable



(a) Switched beam sytem (b) Adaptive beamforming system

  - Adaptive beam-forming antenna
    - BS can form multiple independent narrow beams to serve the MUs (i.e. two or more MUs which are not close to each other geometrically can be served by different beams. Therefore, the same physical channel can be assigned to two or more MUs in the same cell if the CCI among them is tolerable

Signal-to-Noise Ratio (SNR)

$$SNR)_{Total} = \frac{S}{N + I_T}$$

- S is the signal power
- N is the total noise power at the receiver stage.

  $N = N_{th} + N_{amp.}$
- I_T is the total interfering signal power = CCI +ACI

Average power of thermal noise $N_{th} = KTB$ $R=1$ ohm

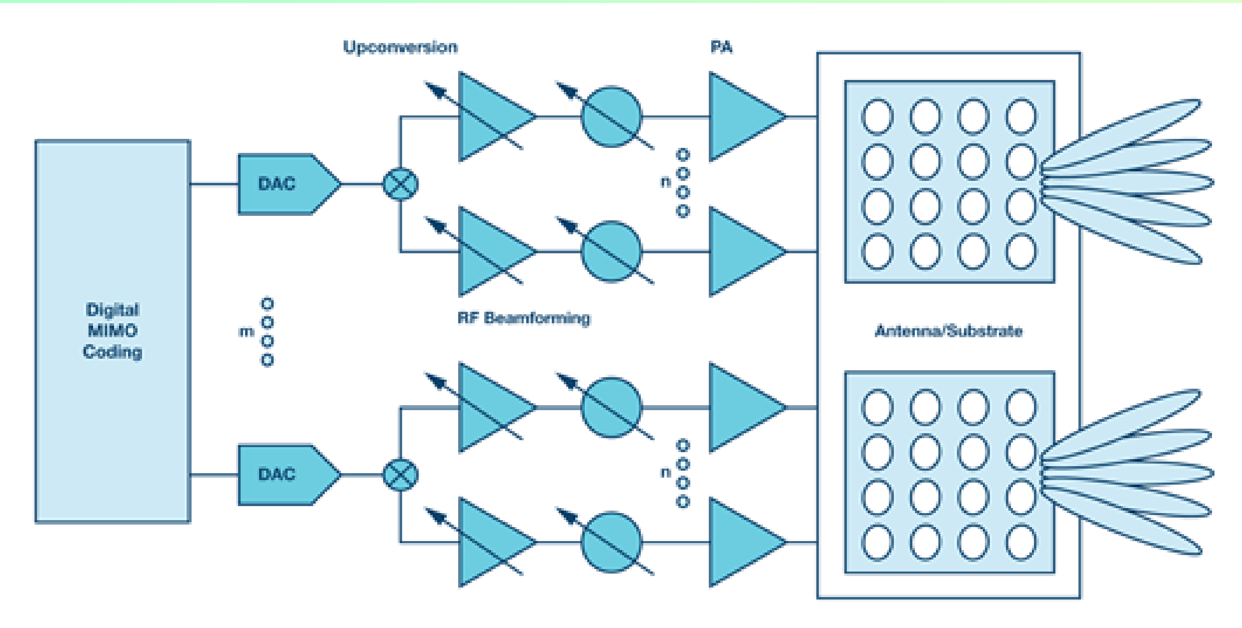
B = Bandwidth

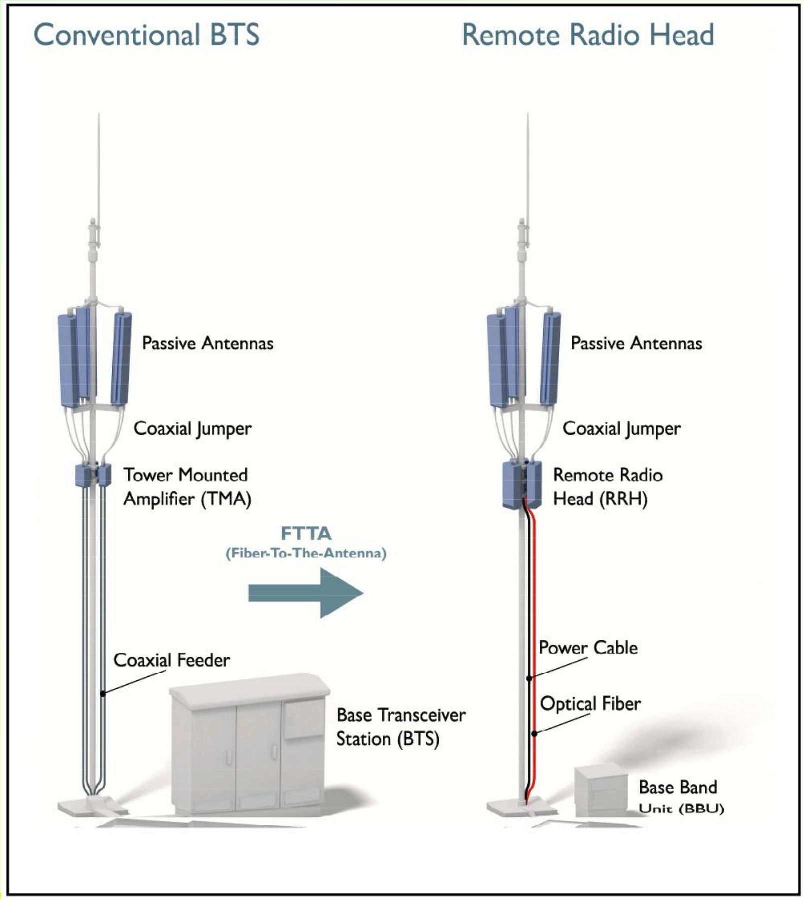
T= Absolute temperature in degree Kelvin

K = Boltzmann's constant = 1.38×10^{-23} W/Hz/K^o

Transmitter

- A typical 5G beamforming transmitter comprising digital MIMO, data converters, signal processing components, amplifiers, and antennas is shown in Figure 1.[2]
  - It is usually driven by regulatory and power-consumptions considerations
    - For example, FCC allows up to 1 W of transmit power in the United States in the 2.4 GHz band





[2] Thomas Cameron. "5G—The Microwave Perspective." Analog Devices, Inc., December 2015.

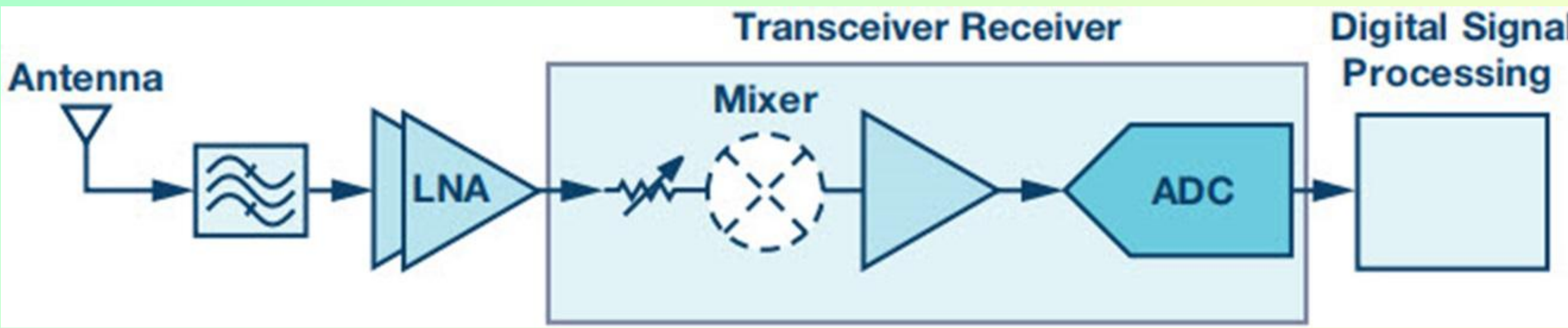
Receiver

- Typical components such as mixers, low noise amplifiers (LNAs), and analog-to-digital converters (ADCs) have progressively improved over time.
- The LNA, mixer, and variable gain amplifier (VGA) are referred to as the RF front end.
- The RF front end is designed with:
  - A noise figure of 1.8 dB,
  - ADC has a noise figure of 29 dB.

https://www.analog.com/en/technical-articles/a105755-2g-to-5g-base-station-receiver-design-simplified-by-innovative-integrated-transceivers.html

Transceiver

- Are designed with two transmitters and two receivers on chip.
- Simple integration offers a 12 dB noise figure.



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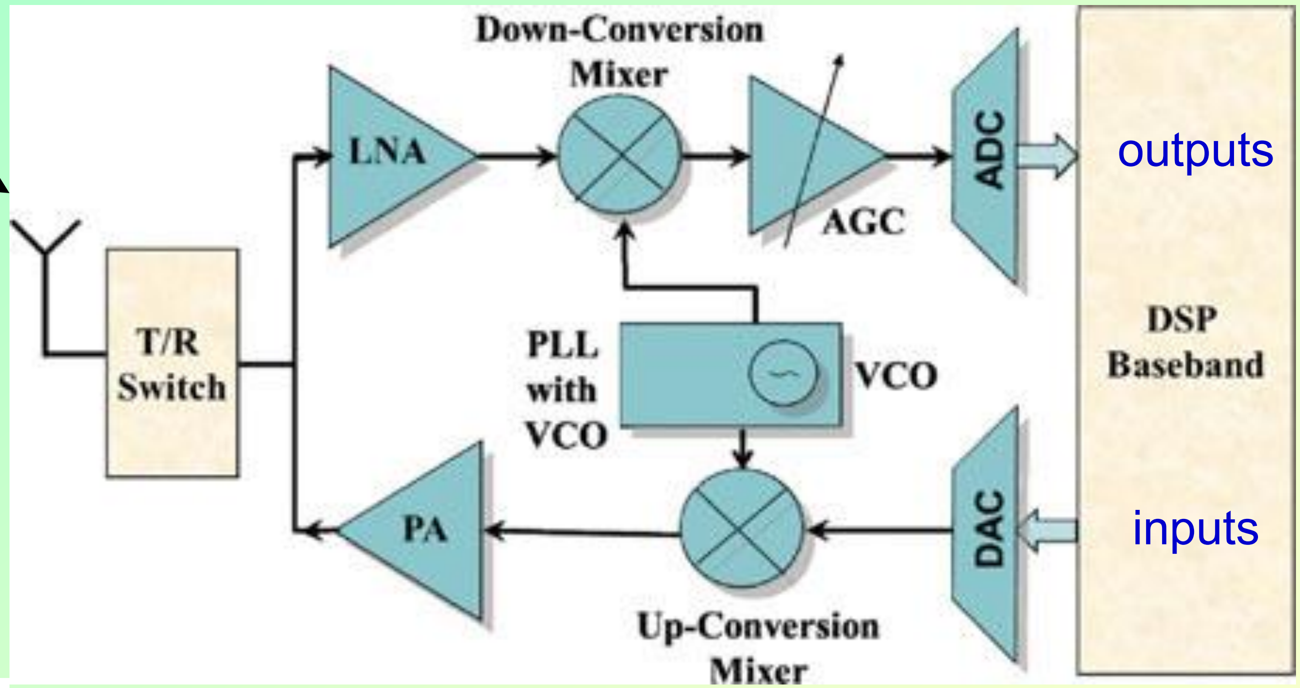
Cellular Radio Transceiver

Receiver

Received
RF signal

Transmitted
RF signal



Transmitter

Cellular Radio Transceiver - Receiving Path

- **Antenna**
- **Tx/Rx Diplexe Switch**
  - Is a high-performance selective filter for the receiving and the transmitting signals
  - Receiving and transmitting signals are in separate frequency bands.The pass-bands of the filters are designed to minimise the level of transmitting signal coupling into the receiver
- **Down and up conversion**
  - Modulation and demodulation
- **Power Amplifier**
  - To boost the signal strength
- **Voltage-controlled oscillator with phase locked loop**

Glossary

- **AMPS:** advanced mobile phone service; another acronym for analog cellular radio
- **BTS:** base transceiver station; used to transmit radio frequency over the air interface
- **CDMA:** code division multiple access; a form of digital cellular phone service that is a spread spectrum technology that assigns a code to all speech bits, sends scrambled transmission of the encoded speech
- **DAMPS:** digital advanced mobile phone service; a term for digital cellular radio in North America.
- **DCS**digital cellular system
- **E–TDMA:** extended TDMA; developed to provide fifteen times the capacity over analog systems by compressing quiet time during conversations
- **ESN:** electronic serial number; an identity signal that is sent from the mobile to the MSC during a brief registration transmission
- **FCC:** Federal Communications Commission; the government agency responsible for regulating telecommunications in the United Sates.
- **FCCH:** frequency control channel
- **FDMA:** frequency division multiple access; used to separate multiple transmissions over a finite frequency allocation; refers to the method of allocating a discrete amount of frequency bandwidth to each user

Glossary

- **FM:** frequency modulation; a modulation technique in which the carrier frequency is shifted by an amount proportional to the value of the modulating signal
- **FRA:** fixed radio access
- **GSM:** Global System for Mobile Communications; standard digital cellular phone service in Europe and Japan; to ensure interpretability between countries, standards address much of the network wireless infra
- **MS or MSU:** mobile station unit; handset carried by the subscriber
- **MSC:** mobile services switching center; a switch that provides services and coordination between mobile users in a network and external networks
- **MTSO:** mobile telephone switching office; the central office for the mobile switch, which houses the field monitoring and relay stations for switching calls from cell sites to wireline central offices (PSTN)
- **MTX:** mobile telephone exchange
- **NADC:** North American digital cellular (also called United States digital cellular, or USDC); a time division multiple access (TDMA) system that provides three to six times the capacity of AMPS
- **NAMPS:** narrowband advanced mobile phone service; NAMPS was introduced as an interim solution to capacity problems; NAMPS provides three times the AMPS capacity to extend the usefulness of analog systems

Glossary

- **PCS:** personal communications service; a lower-powered, higher-frequency competitive technology that incorporates wireline and wireless networks and provides personalized features
- **PSTN:** public switched telephone network; a PSTN is made of local networks, the exchange area networks, and the long-haul network that interconnect telephones and other communication devices on a worldwide b
- **RF:** radio frequency; electromagnetic waves operating between 10 kHz and 3 MHz propagated without guide (wire or cable) in free space
- **SIM:** subscriber identity module; a smartcard which is inserted into a mobile phone to get it going
- **SNSE:** supernode size enhanced
- **TDMA:** time division multiple access; used to separate multiple conversation transmissions over a finite frequency allocation of through-the-air bandwidth; used to allocate a discrete amount of frequency ban

Summary

- Cell Shapes & Clusters Size
- Frequency Reuse

Next Lecture

Cellular Network