Frequency Planning in GSM Mobile

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Abstract: — GSM mobile system like other communication systems has the frequency band used in the systems depends on the type of the GSM system, cellular system means dividing the area region the system installed in it in to many cells, each cell and each channel must has it's own frequency, so the frequency planning is very important to the future of the system installed because of continuously expanding the area of each city and increasing the users of GSM system, the frequency band for the system is limited, so it must be taken account the number of frequencies using, in this paper, frequency planning before installing the system has been studied and the advantages of this process for system future installed in that area.

Keywords: — GSM Mobiles, Cellular system, Clusters, Frequency reuse.

1 INTRODUCTION

Today, GSM is used mainly for speech communication, but its use for mobile data communications is growing stendtly. The GSM Short Message Service (SMS) is a great success story: several billion text message are being extended between mobile users each month. The dividing factor for new (and higher bandwidth) data services is the wireless access to the internet. The key technologies that have been introduced in GSM, the General Packet Radio Service (GPRS) and the Wireless Application Protocol (WAP) [1].

Because of the very frequency bands a mobile radio network has only a relatively small number of speech channels available .for example ,the GSM system has an allocation of 25MHZ bandwidth in the 900MHZ frequency rang ,which amounts to a maximum of 125 frequency channels each with carrier bandwidth of 200KHZ . within an eightfold time multiplex for each carrier ,a maximum of 1000 channels can be realized . this number is further reduced by guard bands in the frequency spectrum and the overhead required for signaling . in order to be able to serve several 100 000 or millions of subscribers in spite of this limitation ,frequencies must be spatially reused ,i.e. deployed repeatedly in a geographic area . in this way ,services can be offered with a cost-effective subscriber density and acceptable blocking probability .

This spatial frequency reuse concept led to the development of cellular technology , which allowed a significant improvement in the economic use of frequencies . the essential characteristics of the cellular network principles are as follows:

* The area to be covered is subdivided into cells (radio zone).for easier manipulation ,these cells are modeled in simplified way as a hexagons .most models show the base station in the middle of the cell …

* To each cell (i) a subset of the frequencies (fb) is assigned from the total set (bundle) assigned to the respective mobile radio network .two neighboring cell must not use the same frequencies ,since this world lead to severe co-channel interference from the adjacent cells.

* Only at distance (d) (the frequency reuse distance)can a frequency from the set (fbi)be reused …i.e. cells with distance (d) to cell(i) are assigned one or all of the frequencies from the set (fb1)belonging to the cell I. if (d)is chosen sufficiently large ,the co-channel interference remains small enough to affect on the speech quality [2].

* When a mobile station moves from one cell to other during a ongoing conversation ,an automatic channel /frequency change occurs (handover) , which maintains an active speech connection over cell boundaries.

2 CELLULAR TECHNOLOGY

The frequency band of the GSM mobile depends on the type, for example, for GSM900, the frequency band is :
Band : 890 – 915 MHz and 935 – 960 MHz, channel spacing : 200 kHz (but signal bandwidth = 400 kHz), For GSM1800, the frequency band is :
Band : 1725 – 1780 MHz and 1820 – 1875 MHz, channel spacing : 200 kHz.
For UMTS, the frequency band is :
Band : 1920 – 1980 MHz and 2110 – 2170 MHz, channel spacing :200 KHz .
Absolute Radio Frequency Channel Number (ARFCN) lower band:

F1(n) = 890.2 + 0.2 *(n* - 1) MHz upper band: F1(n) = F1(n) + 45 MHz *n1,2,...*124
(1)

Each frequency channel can be obtained from the above relation depending on the channel assignment and the cell in the system which is an example for the GSM900, for the others depend on the mentioned bands.

2.1 . Frequency Reuse

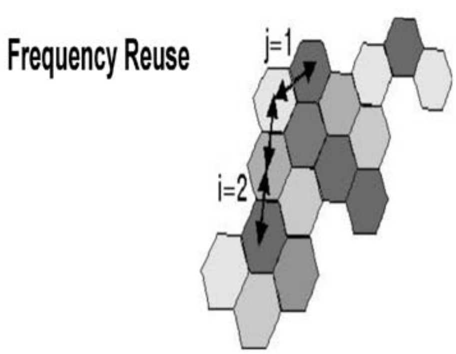

Fig.1 . : Frequency reuse

• Frequency Reuse is the core concept of cellular mobile radio.
• Users in different geographical areas (in different cells) may simultaneously use the same frequency.
• Frequency reuse drastically increases user capacity and spectrum efficiency .
• Frequency reuse causes mutual interference (trade off link quality versus subscriber capacity).

2.2 Formation of clusters

The regular repetition of frequencies results in a clustering of cells . The clusters generated in this way can comprise the whole frequency band, in this case all of the frequencies in the available spectrum are used within a cluster, the size of a cluster is characterized by the number of cells per cluster K , which determines the frequency reuse distance D . figure (2.2) shows some examples of clusters . The number s designate the respective frequency sets Fbi used within the single cells.

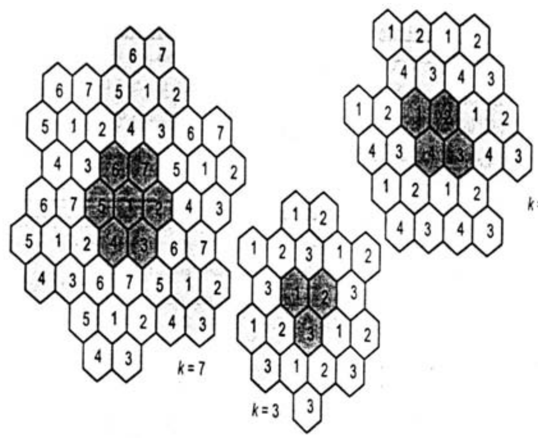

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Fig. 2. Frequency reuse and cluster formation [2]

Distance between cell centers Reuse distance :

$$R_u = \sqrt{i^2 + j^2 + 2ij\cos\frac{\pi}{3}}\ \sqrt[3]{R} \qquad \textbf{(2)}$$

where :R is Cell Radius, R_u is Reuse Distance and

$\cos(\pi/3) = 1/2$

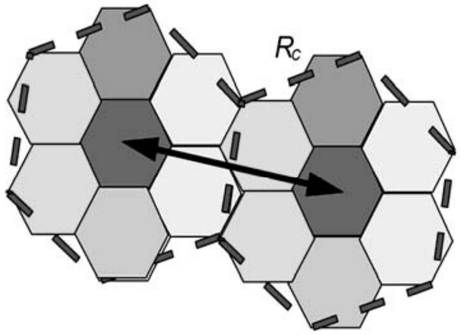

Fig. 3. Cluster radius [3]

Radius of a cluster :

$$R_c = R_u / \sqrt{3} = \sqrt{\frac{i^2 + j^2 + ij}{3}}\, R \qquad (3)$$

Cluster Size :
C: number of channels needed for (i,j) grid

C: is proportional to surface area of cluster
Surface area of one hexagonal cell is :
$S_R = (3\sqrt{3} / 2) R^2$
Surface area of a (hexagonal) cluster of C cells is

$$\mathbf{S_{Ru} = CS_R = (3\sqrt{3} / 2) \{ R_u / \sqrt{3} \}} \qquad (4)$$

Combining these two expressions gives $R_u = R\sqrt{C}$

Possible Cluster Sizes :
We have seen : $R_u = R\sqrt{3C}$
and also :

$$\mathbf{R_u} = \sqrt{i^2 j^2 + ij}\ \sqrt{3}\ \mathrm{R} \qquad (5)$$

Thus:
c= $i^2 + j^2 + ij$
with integer i and j

3 CELLULAR TELEPHONY

Choose C to ensure acceptable link quality at cell boundary
Typical Cluster Sizes :
Cluster size $C=i^2+ij+j^2$= 1,3,4,7,9,...

C= 1 i =1 , , j= 0 } Cluster size for CDMA net
C=3 $i=1,j=1$
C= 4 $i=2,j=0$
C = 7 i = $2,j$ = I } Usual cluster sizes for analogue
C= 9 i = $3,j$= 0 } cellular telephone nets
C=12 $i=2,j=2$

Design Objectives for Cluster Size :
• High spectrum efficiency
many users per cell
small cluster size gives much bandwidth per cell
• High performance
Little interference
Large cluster sizes

Adaptation to growth of system :
Decrease Cell Sizes :

• Macro-cellular 1 - 30 km
• Micro-cellular 200 - 2000 m
• Pico-cellular 4 - 200 meter

The effect of decreasing cell size :
•Increased user capacity
•Increased number of handovers per call
• Increased complexity in locating the subscriber

•Lower power consumption in mobile terminal:
• Longertalktime,
• Safer operation
•Different propagation environment, shorter delay spreads
•Different cell layout,
• lower path loss exponent, more interference
• cells follow street pattern
• more difficult to predict and plan
• more flexible, self-organizing system needed (cf. DECT vs. GSM)

4 DIFFERENT APPROACHES FOR FREQUENCY PLANNING

1) Coarse planning (no terrain data used)
2) coverage limited
step 1: find coverage of base station
step 2: make interference matrix
step 3: find useful map coloring pattern

(recursively ?) recursive approach: change transmit powers
This changes coverage and interference; redo 1-2-3
Example: Broadcasting, Netherlands PTT Ceasar
3) Interference limited
step 1: assign frequencies and powers to base stations step 2: find coverage and interference zones
recursive approach: modify powers and frequencies
Example: Ericsson plannings tool
4) Dectralized Dynamic Channel Assignments (DCA)
• DECT system, not for GSM

A) Accuracy of cell planning depends on:

• accuracy of propagation models
• resolution and accuracy of terrain data
Data bases
• often based on satellite images
• available from several companies
Measurements
When a new planning tool is used for first time in a new country, one needs to adjust propagation models [3].

B) Cell Splitting:

If the cellular system contains N cells with total allocation of **C** channel , then each cell will contain **SC/N** channels .To grow further from the capacity **S** , the cell boundaries has to be revised so that each cell now contains several cells. This process is called **(cell splitting).**

In the figure below , after reaching its capacity , **4** smaller cells were superimposed on cell **C** :

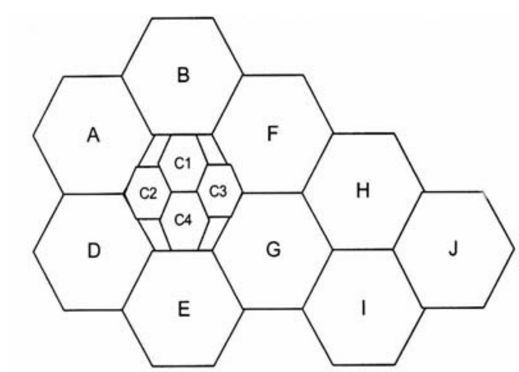

Fig. 4. Cell splitting [4]

therefore cell splitting is not necessarily done for all cells
in the system. Further cell splitting in creases the number of voice paths , or the number of simultaneous
conversations possible within the same region .
Cell splitting decreases the cell area , and thus allows the system to meet the growing cellular demand.
Problems :

Propagation path loss for signal power: quadratic or higher in distance

fixed network needed for the base stations

handover (changing from one cell to another) necessary

interference with other cells:

- **Co-channel interference:**

Transmission on same frequency

- **Adjacent channel interference:**

Transmission on close frequencies

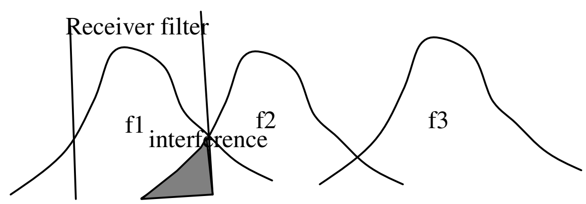

Fig. 5. Adjacent channel interference

5 SIMULATION RESULTS FOR THE PLANNING

In this paper, an area of 3500 km^2 and the cell radius of 3km has been taken as an example, but by the same steps any other area can be taken for the planning, four cases as an optimization has been calculated : without cluster, with clusters 7,9 & 13 respectively as follows :

A) Without clusters :
For GSM900, the frequency band is used completely i.e. 124 frequency because the cell area is 23.38 km^2, but for the GSM1800 there will be 152 frequency channel unused and for the UMTS, 183 channel, but by formation of clusters, in this paper 7,9&13 has been taken, the frequencies

unused be as shown in the results table and the figures 7,8&9.
The results according to the assumptions :

5.1 Without clusters :

GSM Type	Total Cells	Frequencies Used	Unused Frequencies
GSM900	124	124	1 as a guard band
GSM1800	276	124	152
UMTS	307	124	183

5.2 With cluster of 13 :

GSM Type	Total Cells	Frequencies Used	Unused Frequencies
GSM900	124	24	100
GSM1800	276	24	252
UMTS	307	24	283

5.3 With cluster of 9 :

GSM Type	Total Cells	Frequencies Used	Unused Frequencies
GSM900	124	34	90
GSM1800	276	34	242
UMTS	307	34	272

5.4 With cluster of : 7

GSM Type	Total Cells	Frequencies Used	Unused Frequencies
GSM900	124	43	81
GSM1800	276	43	233
UMTS	307	43	264

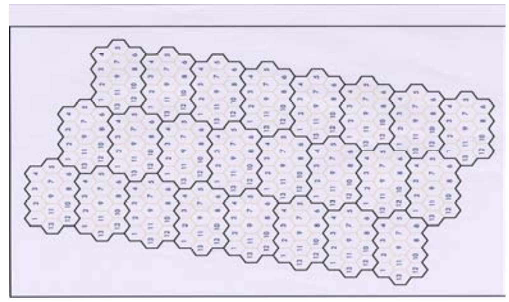

FIG. 6. WITH CLUSTER 13

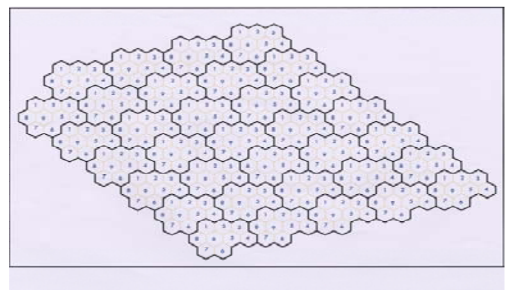

FIG. 7. WITH CLUSTER 9

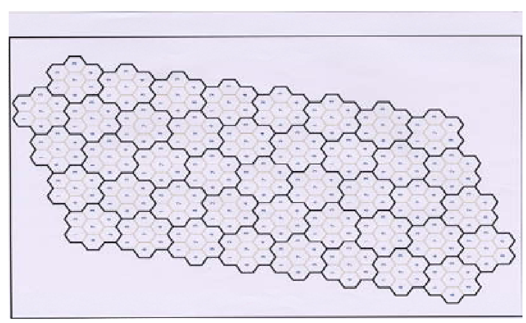

FIG 8. WITH CLUSTER 7

6 CONCLUSION

Because of the very frequency bands a mobile radio network has only a relatively small number of speech channels available, for example ,the GSM system has an allocation of 25MHZ bandwidth in the 900MHZ frequency rang, which amounts to a maximum of 125 frequency channels each with carrier bandwidth of 200KHZ, within an eightfold time multiplex for each carrier ,a maximum of 1000 channels can be realized, this number is further reduced by guard bands in the frequency spectrum and the overhead required for signaling, in order to be able to serve several 100 000 or millions of subscribers in spite of this limitation, frequencies must be spatially reused, i.e. deployed repeatedly in a geographic area, in this way ,services can be offered with a cost-effective subscriber density and acceptable blocking probability, this spatial frequency reuse concept led to the development of cellular technology, which allowed a significant improvement in the economic use of frequencies.

The clusters generated in this way can comprise the whole frequency band, in this case all of the frequencies in the available spectrum are used within a cluster, the size of a cluster is characterized by the number of cells per cluster K, which determines the frequency reuse distance D.

In this paper, frequency planning for the GSM mobiles has been studied with cases : without clusters, with cluster : K = 7,9&13, the frequencies used in each type of mobile systems, GSM900, GSM1800 and UMTS are shown in the tables and figures 1,2 &3 respectively, we see that, with the cluster using and formation, the frequencies used in the GSM band for each system reduced which is useful for the future planning and expanding the system for covering more areas and without clusters, the areas covered is limited according to BTS's used each with it's own frequency, but for the future expanding and covering there will be a big problem of the frequency using without clusters, specially the system GSM900, but this problem is less than GSM 900 in the system GSM 1800 and UMTS, specially UMTS system as shown in the results in chapter four.

So, as a conclusion in this paper, before the system installation, the frequency planning must be taken in account and must be applied for the future after installation to prevent the above problems mentioned.

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