

Coverage and Capacity Improvement in GSM Network

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Abstract: As the demand for wireless service increases, the number of channels assigned to a cell eventually becomes insufficient to support the required number of users. This has been a major concern for both the users and network operators. It is required to offer a very high capacity within limited spectrum allocation. The allocated spectrum gradually becomes congested and eventually becomes used up. Congestion in the spectrum leads to increase in call blocking probability which is not desired in the system. Therefore, several techniques can be used to improve the channel capacity and total area coverage with the limited spectrum allocation. This paper mainly looks at the various techniques of enhancing or improving cellular capacity with Cell splitting, Cell sectoring, Microcell zone and Repeaters.

Keywords: Capacity, Co-channel, Frequency reuse, GSM Network, Microcell, Spectrum.

1. INTRODUCTION

Within a limited frequency spectrum, cellular system accommodates a large number of users over a large geographic area. This expands the need to make the maximum use of quality of service provision for improved data throughput [8]. Improvement in GSM network through cell splitting, cell sectoring, microcell zone and use of repeaters happen to be among the techniques used to minimize the effect of interference in GSM network [9]. Cell splitting achieves capacity improvement by rescaling the system. It increases the number of times that channels are reused. Due to smaller cells, capacity increases which is due to additional number of channels per unit area [6]. While in cell sectoring, a large cell is divided into a number of wedge-shaped sectors each with its own set of channels. Therefore, any base station that is not within the sector covered by the directional antenna cannot interfere with the transmitted signal from the base station. Microcell zone concept significantly plays a vital role in improving channel capacity as the area in question can be divided into a particular number zone site which are connected to a single base station and share the same radio equipment. The approach is far superior to sectoring since antennas are placed at the outer edges of the cells, and any base station channel may be assigned to any zone by the base station. Repeaters are increasingly used to provide coverage into and around buildings, where signal is weak.

2. CONCEPT OF FREQUENCY REUSE

The design process of selecting and allocating channel groups for all of a cellular base station within a system is called frequency reuse or frequency planning. The actual radio coverage of a cell is called footprint. When using hexagons to model a coverage area, base station transmitters are depicted as either being of the centre of the cell. Normally omnidirectional antennas are used in centre excited cells and sectored directional antennas are used in corner excited cells [9]. 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. This spatial frequency reuse concept led to the development of cellular technology which allows a significant improvement in the economic use of frequencies. The area to be covered is subdivided into cells (radio zones) for easier

manipulation. These cells are modelled in simplified way as hexagons. Most models show base station in the middle of the cell [1]. To each cell, a subset of frequencies is assigned from the total set (bundle) assigned to the respective mobile radio network. Two neighbouring cells must not use same frequencies, since this leads to severe co-channel interference from the adjacent cells. Only at distance, d (frequency reuse distance), can a frequency from the set be reused i.e. cells with distance d , are assigned one or all of the frequencies from the set. If the frequency reuse distance, d is chosen sufficiently large, the co-channel interference remains small enough to affect the speech quality [1]. In the figure below, cells with the same alphabet are assigned same frequency.

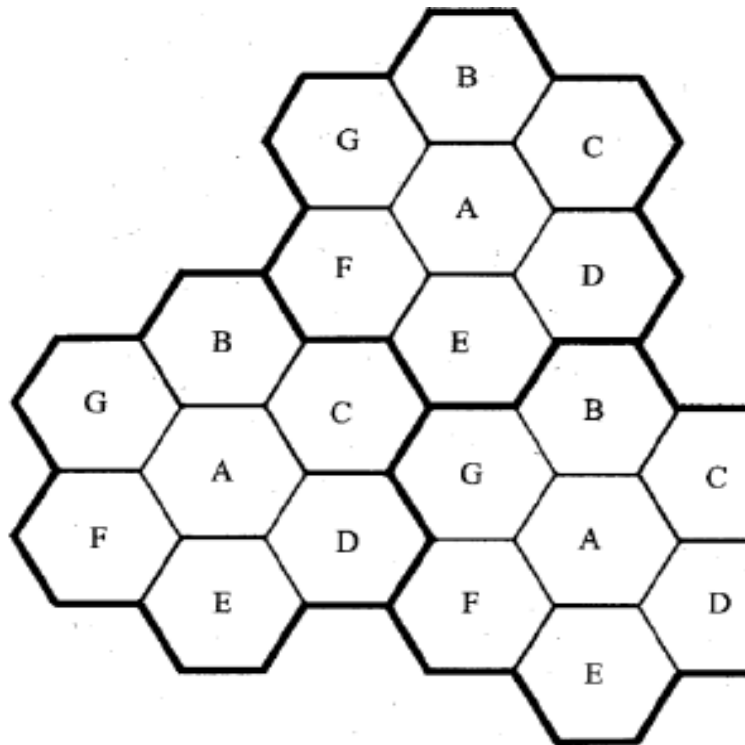


Fig.1 cellular network with frequency reuse

2.1 Frequency Reuse Distance:

The distance between the nearest co-channel cells of adjacent cluster is given by:

$$D^2 = 3R^2(i^2 + ij + j^2) \tag{1}$$

Where i and j are non-negative integers and are the displacements in number of cells from the reference cell. R is the cell radius, which is the largest possible distance between the centre of a (base station) and its edge. The number of cells per Cluster N is

$$N = (i^2 + ij + j^2) \tag{2}$$

For hexagonal cells reuse distance is given by

$$D^2 = 3R^2(N)$$

$$D = \sqrt{3N} \cdot R \tag{3}$$

3. CELL SPLITTING

Cell splitting is the process of subdividing a congested into smaller cells, each with its own base station and a corresponding reduction in antenna height and transmitter power. Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused. By defining new cells which have smaller radius than the

original cell, and installing these smaller cells (called microcells) between the existing cells, capacity then increases due to additional number of channels per unit area [5]. Cell splitting can be done by reducing the cell radius from R to R/2 or R/4.

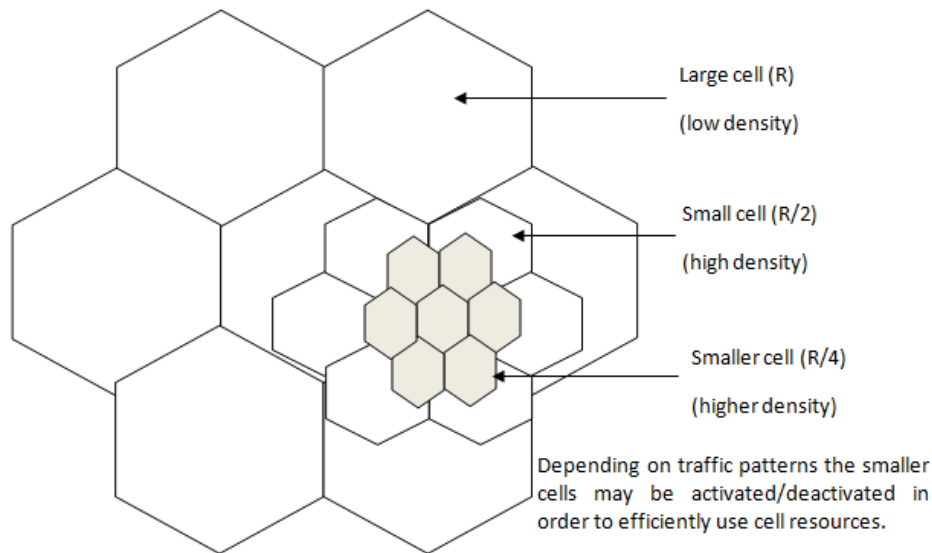


Fig.2 Cell splitting

If the radius of the new smaller cell is R/2, in order to cover the entire service area with small cells, approximately four times as many cells would be required. The increased number of cells would increase number of cluster over the coverage region which in turn would increase the number of channels, and thus capacity, in the coverage area. Cell splitting allows a system to grow by replacing large cells with smaller cells. In cell splitting, a large number of low power transmitters can take over an area previously served by a single, high powered transmitter. Reduction of cell radius makes the cell capable to handle extra traffic [2]. These new cells have smaller radius than the larger cell and capacity increases as the number of channels per unit area increases [3]. Trunking inefficiencies experienced by sectored cells are not faced by cell splitting technique. It enables the base station to oversee all handoff chores related to the microcells and reduces the computational load at the mobile switching centre (MSC) [4].

For the new cells to be smaller in size, the transmitter power of these cells must be reduced.

The transmit power of the new cells with the radius half that of the original cells can be found by examining the received power P_r at the new and old cell boundaries and setting them equal to each other. This is necessary to ensure that the frequency reuse plan for the new microcells behaves exactly as for the original cells.

The received power at larger (old cell) is:

$$P_r[\text{at old cell boundary}] = P_{t1}(R)^{-\alpha} \tag{1}$$

The received power at smaller is

$$P_r[\text{at new cell boundary}] = P_{t2}(R/2)^{-\alpha} \tag{2}$$

Where P_{t1} and p_2 are the transmit powers of the larger and smaller cells and is the path loss exponent. On the basis of equal received power, we have,

$$P_{t1}(R)^{-\alpha} = P_{t2}(R/2)^{-\alpha} \text{ or } \frac{P_{t1}}{P_{t2}} = 2^\alpha \tag{3}$$

Taking the logarithm we can express this as

$$10 \log_{10} \left(\frac{P_{t1}}{P_{t2}} \right) = \alpha \log_{10} 2 = 3(\alpha) \text{dB} \tag{4}$$

$$\text{for } \alpha = 4, \left(\frac{P_{t1}}{P_{t2}} \right) = 12 \text{dB}$$

Thus with a cell splitting where the radius of the new cell is one-half that of the old cell, a 12dB reduction in the transmit power can be achieved. This means the transmit power must be reduced by 12dB in order to fill in the original coverage area with microcells.

4. CELL SECTORING

Cell sectoring gives a room for increasing capacity by keeping the cell radius unchanged and seeking methods to decrease D/R ratio. Sectoring increases S/I so that the cluster size may be reduced. In this approach S/I is improved by using directional antennas, then capacity improvement is achieved by reducing the number of cells in a clusters, thus, increasing the frequency reuse. However in order to do this successfully, it is necessary to reduce the relative interference without decreasing the transmit power. The co-channel interference in a cellular system may be decreased by replacing a single omnidirectional antenna at the base station by several directional antennas, each radiating with a specified sector. By using directional antennas, as given cell will receive interference and transmits with only a fraction of the available co-channel cells. The technique for decreasing co-channel interference and thus increasing system performance by using directional antennas is called sectoring.

The factor by which co-channel interference is reduced depends on the amount of sectoring used.

A cell is normally partitioned into three 120° sectors or six 60° sectors.

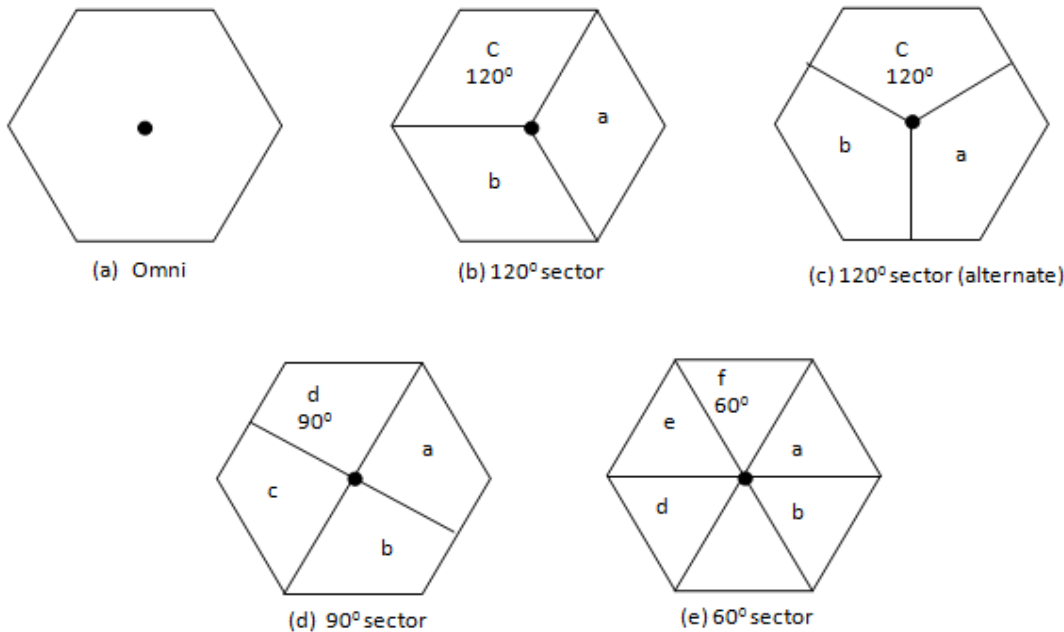


Fig.3 several sector examples

5. MICROCELL ZONE

As cells become smaller, antennas move from the tops of tall buildings or hills, to the tops of small buildings or the sides of large buildings, and finally the lamp posts, where they form microcells. Each decrease in cell size is accompanied by a

reduction in the radiated power levels from the base stations and the mobile units. Microcells are useful in city streets in congested areas, along highways and inside large public buildings [7].

As mobile travels from one zone to another within the cell, it retains the same channel. Thus, like in a sectoring, a handoff is not required at the Mobile Switching Centre (MSC) when the mobile travels between zones within cell. The base station simply switches the channel to a different zone site. In this way, a given channel is active only in the particular zone in which the mobile is travelling and hence the base station radiation is localised and interference is minimised. The channels are distributed in time and space by all three zones and are also re-used in co-channels cells in the normal fashion. This technique is useful along highways or along urban traffic corridors.

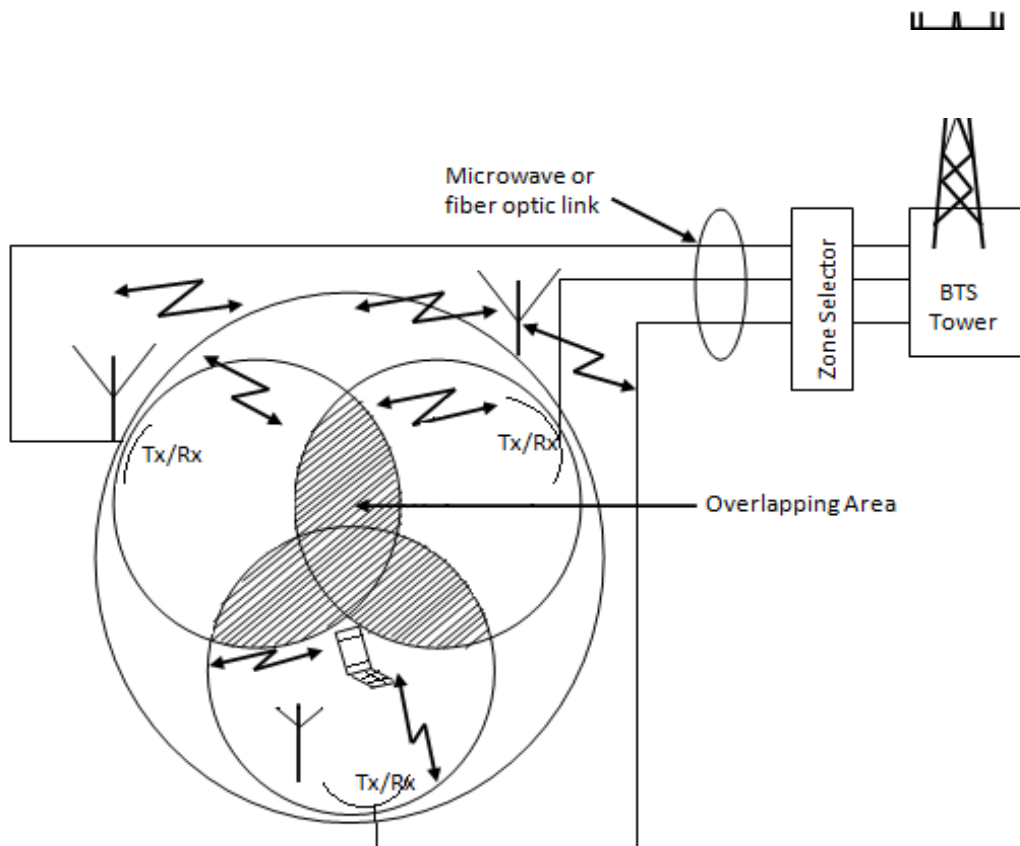


Fig.4 The microcell concept

6. REPEATERS

In current cellular mobile communication networks repeaters are typically implemented in the network optimisation phase (i.e. when the network is fully operational) or during the network evolution, when the network coverage needs to be improved temporarily or permanently. Therefore the classical applications of repeaters are typically related to coverage enhancements. Repeaters are used to increase cell coverage in weakly covered areas.

Repeaters consist of transmitter and receiver antenna, or a radio re-transmitter known as repeaters, is used to provide range-extension capabilities. Repeaters are bidirectional in nature, and the transmission and reception of signal occur at a time. Repeaters work using over the air signals, so they may be installed anywhere and are capable of repeating and entire cellular or PCS bands. Upon receiving signals from a base station forward link, the repeater amplifies and re-radiates the base station to the specific coverage region [5].

But at some time, the received noise and interference is also radiated by the repeater on both the forward and reverse link, so care must be taken to properly place the repeaters, and to adjust the various forward and reverse link amplifier levels

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and antenna patterns, however, the repeater does not add capacity to the system it simply serves to re-radiate the base station signal into specific locations.

Repeaters are increasingly being used to provide coverage into and around buildings, where coverage is weak. Determine the proper locations for repeaters and distributed antenna system (DAS) within building requires careful planning, particularly due to fact that interference levels are re-radiated into the building from the base station and from the interior of the building back to the base station. Also repeaters must be provisioned to match the available capacity from the serving base stations.

Software such as site planner, allow engineers to rapidly determine the best placements for repeaters and the required Distributed Antenna System (DAS) network, while simultaneously computing the available traffic and associated cost of the installation [5].

7. CONCLUSION

In conclusion, improving channel capacity of a GSM system can be increased using several techniques such as cell splitting, cell sectoring, microcell zone and use of repeaters. The extent to which the capacity increment can be achieved is dependent on signal to interference ratio (SIR) of the system after the cell splitting. The increment in channel capacity after cell splitting helps to reduce call blocking probability and call delay or queuing probability. In cell sectoring, the sectoring increases SIR so that the clusters size may be reduced. By this approach SIR is improved using directional antennas, and then channel capacity improvement is achieved by reducing the number of cells in cluster. Repeaters are increasingly used to provide coverage into and around buildings, where signal is weak. Repeaters serve to re-radiate the base station signal into specific locations. Microcell zones are connected by co-axial cable, fiber optic cable or microwave link to the base station. As a mobile travels within the cell, it is served by the zone with the strongest signal. This approach is superior to sectoring since antennas are placed at the outer edges of the cells and any base station channel may be assigned to any zone by the base station. All the techniques mentioned have the capability of increasing the capacity of a congested GSM system.

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