A Review on Reuse Partitioning in Cellular System with Mobile Users

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Abstract - *Reuse partitioning (RP) is a straightforward procedure that can be utilized to expand the traffic capacity in a cellular system. With RP, a cell is divided into several concentric regions, each associated with a different cluster size. In this article, a movement or traffic model is produced to dissect the effect of versatile clients on a two-region RP system using fixed channel assignment. The influence of user speed and cell size on the new call blocking probability, P_b, and the call dropping probability, P_d, is investigated. A simpler model that can be used to estimate P_b and P_d in some cases is described. The effect on system capacity of reserving some channels for handoff calls is also studied.*

Key Words: Cellular System, Blocking Probability, Fixed Channel Assignment, Handoff, Reuse Partitioning.

1. CELLULAR SYSTEM

The concept of cellular mobile systems developed with the advent of mobile radio systems. The cellular system consists of three main components: Mobile Switching Center (MSC) , Cell Site (Base Station Equipment), and Mobile User Equipment. The three components work together to provide cellular service. The system can be visualized functionally as seen in Figure 1. The MSC coordinates all cellular system activities between mobile users, cell sites and the Public Switched Telephone Network (PSTN). These activities include establishing connections, assigning channels, verification of users and handoff coordination to name a few. The MSC incorporates the features of a regular telephone switching center with added capabilities to handle the activities throughout the system. The MSC software controls the necessary signaling needed to perform the activities which are sent to the cell sites and the mobile users. Cellular systems operate in the frequency region of 825-890 MHz with a difference of 45 MHz between transmitting and receiving frequencies.

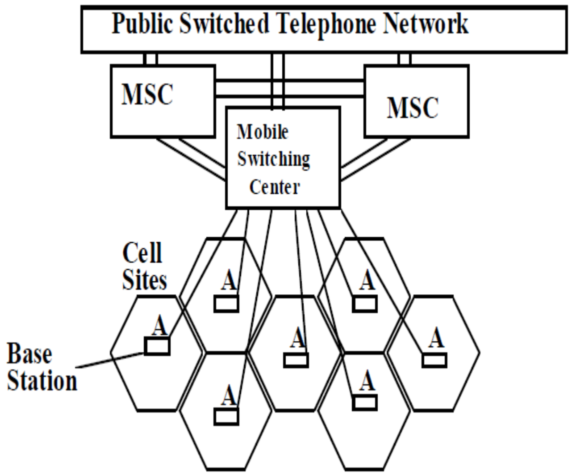

Figure 1: Cellular System Architecture.

In the cellular system, the MSC provides connection to the PSTN via land lines and to the cells sites and other MSC's via land lines or microwave links. The cell site serves as the location for the base station equipment. The bas station equipment consists of antenna (about 30 to 91 m. or 100 to 300 ft. high), transmitters, receivers, combiners and a power supply. The cell site also has a computer processor equipped with software to handle the necessary functions it has to perform. The cell site has 16 about channels, 1 control channel for signaling and 15 voice channels. These channels are usually full duplex allowing two way communications and having two different frequencies ranges, one for transmitting and one for receiving. At the base station, it is possible to have an amplifier for each channel that feeds into a single combiner for a transmitting antenna or a single amplifier for all channels that use a single transmitting antenna. The first scenario is known as a channelized scheme and the latter scenario is known as a frequency division multiplexed scheme as seen in Figure 2. The dashed lines in each scheme are control channels.

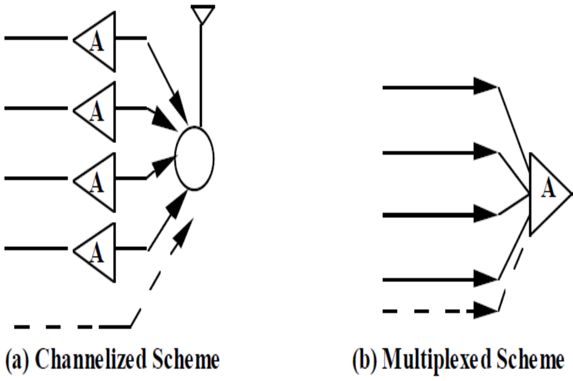

Figure 2: Channel Schemes.

The base station antenna has several set ups, the most common being an omnidirectional combination of antennas, with two antennas for receiving and one for transmitting. Depending on the placement of the antennas, cells are considered center excited, edge excited, or umbrella cells. The center excited cells use the omnidirectional configuration discussed above. Edge excited cells use directional antennas placed in the corner of a cell site, which is best for co-channel interference. The umbrella cells use tilted beam pattern antennas that provide a shadow effect of the cell site area. The amplifier(s) in each scheme provide enough gain to each channel frequency. The combiner then serves the function of combining all individual channels and sending them to the transmitting antenna. The receivers at the base station receive the incoming electromagnetic signals and convert them to perceptible forms.

2. CELL REUSE PARTITIONING

The mobile cellular communication services industry is expected to continue growing rapidly in the next decade. The main limitation to supporting a large number of subscribers is the shortage of available radio frequency spectra. The system capacity, i.e., the number of subscribers per unit area that can be supported at some minimum quality of service level, is an important parameter. One method to increase the capacity of cellular systems is to reduce the cell size. However, this solution results in an increase in the number of base stations (BS), and hence, cost. An alternative method is reuse partitioning (RP) [2], which uses multiple reuse distances. In a conventional mobile cellular system using fixed channel assignment (FCA), a single cluster size is used [3]. The aim is to achieve a minimum target carrier-to-interference ratio (CIR) at any point in the cell. For a system that does not employ power control, the received signal power for a mobile station (MS) close to its BS is higher than that for a more distant MS. As a consequence, the signal from a nearby MS can tolerate a higher interference level and the channel reuse distance may be smaller. In RP, this characteristic is exploited to increase the system capacity. RP is implemented by dividing the cell into two or more concentric regions as shown in Figure 3.

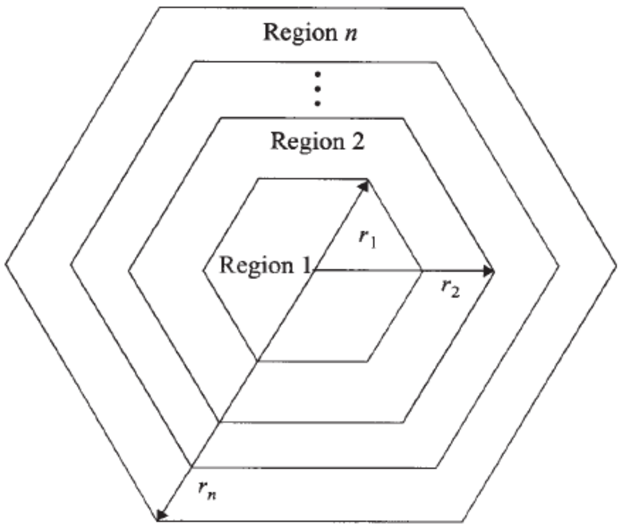

Figure 3: Frequency Reuse Partitioning.

Each region has a different cluster size (and therefore a different reuse distance) and is assigned a set of channels according to the FCA scheme. The capacity can be improved by allowing calls in an inner region to use (i.e., overflow into) channels allocated to higher-numbered regions [4].

The call blocking probability of RP with FCA, hereafter referred to as fixed reuse partitioning (FRP), for stationary users has been examined in [4] and [5] by computer simulation. The results show that RP can increase the capacity compared to conventional FCA with a single reuse distance. Other studies of FRP assuming stationary users include [6] and [8]. In [9], the performance of an overlapping coverage scheme with RP for mobile users is studied. However, because the inner and outer RP regions correspond to the non-overlapping and overlapping regions, respectively, the effect of RP cannot be separated from that of overlapping. In this article, an analytical traffic model is developed to study the impact of mobile users on the new call blocking probability, P_b, and the call dropping probability, P_d, in a two-region FRP system. This model allows P_b and P_d to be evaluated numerically. A simplified model that allows the derivation of approximate closed-form expressions for Pb and P_d in certain cases is also presented. The effect of a cutoff priority scheme for handoff calls on capacity is considered, with the capacity defined as the total offered traffic that can be supported in a cell at a certain value of grade of service (GOS) as given by [10].

$$GOS = (1-\alpha)P_b + \alpha P_d$$

Where $\alpha \in [0,1]$ is the GOS parameter and indicates the relative importance of P_b and P_d in a given system. This article is organized as follows. The traffic model for a two-region FRP system is formulated. The channel assignment scheme is described, followed by the performance analysis of the two-region FRP system for both stationary and mobile users.

3. TRAFFIC MODEL

In analytic model, a two-region FRP system with hexagonal cells and omnidirectional antenna base stations is assumed. An example with an inner region cluster size, $N_A = 3$, and outer region cluster size, $N_B = 7$, is shown in Figure 4. With a reuse cluster size of N_A, we have [3]

$$d_A / r_B = (3N_A)^{1/2}$$

where d_A is the reuse distance associated with inner region and r_B is the radius of the cell as shown in Figure 4. Because the targets CIR for both inner and outer region calls are the same, we have

$$d_A / r_A = d_B / r_B = (3N_B)^{1/2}$$

where r_A is the radius of the inner region. From above equations, it follows that

$$(r_A / r_B)^{1/2} = N_A / N_B$$

Note that $N_B = N$, the cluster size for the conventional FCA.

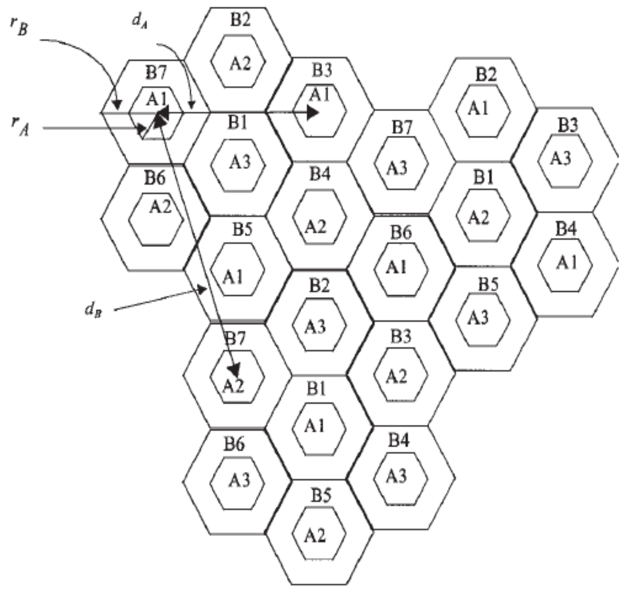

Figure 4: Cellular Grid with Cluster Sizes $N_A = 3$ and $N_B = 7$.

4. HANDOFF

During the call, the mobile user will probably move throughout several cells. As the mobile user travels from cell to cell within the cellular network, the call will be transferred between base stations within the network. This process is known as handoffs. The process is initiated when the signal strength of the mobile users call fall below a certain threshold level, usually around 32 dB.

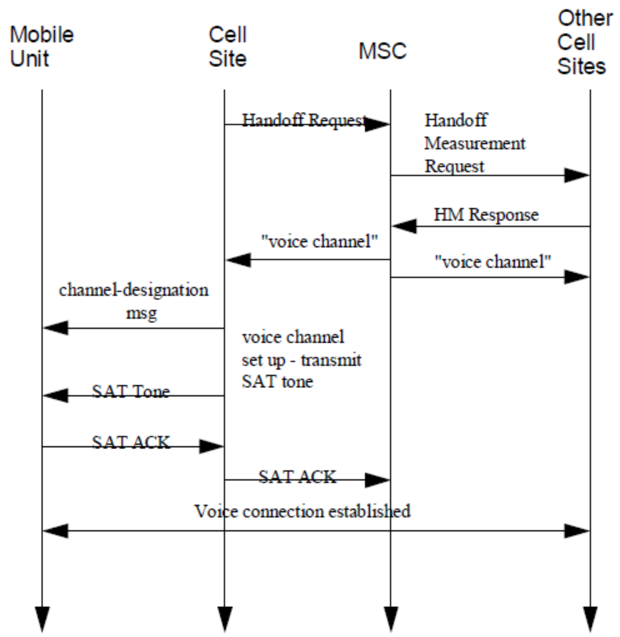

Figure 5: Mobile Call Handoff.

The base station then notifies the MSC that a call handoff will be necessary The MSC then sends out a handoff measurement request to the adjacent base stations for a measurement of the strength on a specific channel. In return, all the base stations send the signal strength level on the channel. The MSC then goes through a selection process to select the base station with the best signal level. Once the base station is selected, it is notified of the call transfer that is necessary and the channel it will be on. The MSC also forwards the same information to the base station that is currently carrying the call, which forwards the information about the new channel to the mobile unit. Once the mobile is tuned to the new channel the process is completed. This process may happen several times within a call due to the mobile user's movement. Since the handoff process is initiated by a drop in signal strength, base stations generally look for a consistent pattern of decrease in the signal strength around 10 dB per decade. The assumption made by the base station monitoring this pattern is that the mobile unit is moving toward the boundary of the cell. Figure 5 shows the process of a call handoff within the coverage of a single MSC.

Within the network, several things affect a call and its signal strength. The most common of these problems include:

- Propagation Path Loss
- Co-Channel Interference
- Multipath Fading
- Raleigh Fading
- Doppler Shifts

Propagation path loss is the dropping of the signal level due to the terrain and manmade noise (buildings, bridges, etc.). The main drivers of propagation path loss are the distance of the mobile unit from the base station and the frequency of the channel. Co-channel interference involves disturbances occurring from two mobile units operating on the same channel. Another type of channel interference is adjacent channel interference, which occurs when energy from a carrier spills over into another carrier. Solutions to deal with channel interference involve a method of channel schemes either multiplexed or channelized, which was previously discussed. Multipath Fading involves disturbances due to the multiple paths of the signals between the transmitter and the receiver as a result of the terrain and man-made noise. Raleigh Fading are rapid fluctuations in the signal strength that occur in statistical distribution known as Raleigh. Finally, Doppler Shifts are variations in the frequency of the received signal caused by the relative motion of the mobile unit. These problems all bear an effect on the signal strength of the mobile unit.

5. CONCLUSIONS

The impact of mobile users on a two-region FRP system was studied. With no channels reserved for handoffs, the new and handoff call blocking probabilities can be approximated using a product form solution. With stationary users, the capacity can be increased by about 30% compared to conventional FCA. With mobile users, the capacities for both FRP and FCA decrease with average handoff rates. In addition, the capacity improvement of FRP relative to FCA is reduced as the average handoff rates increase. It is found that even though prioritized handoff can reduce the call dropping probability, in some cases it may also degrade the capacity. The choice of the number of channels reserved for handoffs which maximizes the capacity was also examined.

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