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Network Capacity Problems in Mobile Phones

B.Chithra[1], R.Latha[2]
[1]*Research Scholar, St.Peter's University, Chennai.*
[2]*Prof. & Head, Dept. of Computer Science & Applications,*
St.Peter's University, Chennai
bchithra11@gmail.com

Abstract-- *Network Coverage and Capacity is an important objective, when characterizing the performance of high-data-rate services. The use of soft-handoff may have an impact on the downlink of cellular CDMA systems. The capacity of the mobile is commonly limited by interference. In order to reduce the interference level in downlink, power control techniques are proposed in the system. The power control techniques are used to reduce the system interferences in the downlink.The purpose of this thesis is to give an overview on power control in CDMA cellular systems. It gives general definition of handoff, power control, objectives, and its employment in forward links.*

Keywords: *Soft-handoff, CDMA, Downlink, forward link control.*

I. INTRODUCTION

In cellular telecommunications, the term handover or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. A hard handover is one in which the channel in the source cell is released and only then the channel in the target cell is engaged. Thus the connection to the source is broken before or 'as' the connection to the target is made—for this reason such handovers are also known as break-before-make. Hard handovers are intended to be instantaneous in order to minimize the disruption to the call. A hard handover is perceived by network engineers as an event during the call. It requires the least processing by the network providing service. When the mobile is between base stations, then the mobile can switch with any of the base stations, so the base stations bounce the link with the mobile back and forth. This is called 'ping-ponging'.

A soft handover is one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken, hence this handover is called make-before-break. The interval, during which the two connections are used in parallel, may be brief or substantial. For this reason the soft handover is perceived by network engineers as a state of the call, rather than a brief event. Soft handovers may involve using connections to more than two cells: connections to three, four or more cells can be maintained by one phone at the same time.

When a call is in a state of soft handover, the signal of the best of all used channels can be used for the call at a given moment or all the signals can be combined to produce a clearer copy of the signal. The latter is more advantageous, and when such combining is performed both in the downlink (forward link) and the uplink (reverse link) the handover is termed as softer. Softer handovers are possible when the cells involved in the handovers have a single cell site.

HANDOFF

A handoff refers to the process of transferring an active call or data session from one cell in a cellular network to another or from one channel in a cell to another. A well-implemented handoff is important for delivering uninterrupted service to a caller or data session user. Cellular networks are composed of cells, each of which is capable of providing telecommunications services to subscribers roaming within them. Each cell can only serve up to a certain area and number of subscribers. Thus, when any of these two limits is reached, a handoff ensues. For instance, if a subscriber moves out of the coverage area of a particular cell while entering another, a handoff takes place between the two cells.

The cell that served the call prior to the handoff is relieved of its duties, which are then transferred to the second cell. A handoff may also be triggered when the number of subscribers using a particular cell has already reached the cell's maximum limit (capacity). Such a handoff is possible because the reach of the cell sites serving these cells can sometimes overlap. Thus, if a subscriber is within an overlapping area, the network may opt to transfer one subscriber's call to the cell involved in the overlap. Sometimes a handoff can take place even if no limit is breached. For example, suppose that a subscriber initially inside the jurisdiction of a large cell (served by an umbrella-type cell site) enters the jurisdiction of a smaller cell (one served by a micro cell). The subscriber can be handed off to the smaller cell in order to free up capacity on the larger one.

Handoffs may be classified into two types:

- Hard Handoff: Characterized by an actual break in the connection while switching from one cell or base station to another. The switch takes place so quickly that it can hardly be noticed by the user. Because only one channel is needed to serve a system designed for hard handoffs, it is the more affordable option. It is also sufficient for services that can allow slight delays, such as mobile broadband Internet.
- Soft Handoff: Entails two connections to the cell phone from two different base stations. This ensures that no break ensues during the handoff. Naturally, it is more costly than a hard handoff.

SOFT HANDOFF

Soft handoff technology is used by code-division multiple access (CDMA) systems. Older networks use frequency division multiplex (FDM) or time division multiplex (TDM). In CDMA, all repeaters use the same frequency channel for each mobile phone set, no matter where the set is located. Each set has an identity based on a code, rather than on a frequency (as in FDM) or sequence of time slots (as in TDM). Because no change in frequency or timing occurs as a mobile set passes from one base station to another, there are practically no dead zones. As a result, connections are almost never interrupted or dropped.

Soft handoff is so called to distinguish it from the more traditional hard handoff process. With hard handoff, a definite decision is made on whether to handoff or not. On a positive decision, the handoff is initiated and executed without the user attempting to have simultaneous traffic channel communication with the two base stations. With soft handoff, a conditional decision is made on whether to hand off. Depending on the changes in pilot signal strength from the two or more base stations involved, a hard decision will eventually be made to communicate with only one. This normally happens after it is clear that the signal from one base station is considerably stronger than those from the others. In the interim period, the user has simultaneous traffic channel communication with all candidate base stations.

Disadvantages

- Additional network resources are used during a soft handoff. These resources thus become unavailable for use elsewhere.
- Increased downlink interference.
- Soft handoff is more complex.

Downlink interference increases when soft handoff is in progress, since several base stations are transmitting what would otherwise be transmitted by one base station. This can add to the uplink interference too, if the same frequency is used for uplink as for downlink. The interference increasing effect should normally be slight, if it is assumed that only a small fraction of the duration of a typical call is spent in soft handoff. Clearly, it is difficult to conclude that one type of handoff is better in absolute terms. Soft-handoff is a well-known technique used in mobile CDMA systems, which allows a mobile station to communicate with more than one base station simultaneously during handoff. This makes a seamless handoff possible, besides providing a better signal quality due to macro diversity. The employment of this technique has very little impact on the capacity of the uplink, since the same signal is transmitted by the mobile station, whether it is in soft-handoff or not. However, the same will not be true for the downlink. In this case, the same signal will be transmitted by two or more base stations, thus increasing the overall interference and consequently decreasing the capacity.

POWER CONTROL SYSTEM

Objectives of power control:

The main purposes of power control is 1) To maintain all users' signal energy received at the base station nearly equal in the spread spectrum which is shared in common. 2) To make the received power level less dependent on the fading and shadowing effects of the transmission channel.

The overall objectives of power control can be summarized as follows:

- Overcoming the near-far effect in the uplink.
- Mitigates fading.
- Compensates changes in propagation conditions.
- Optimizing system capacity by controlling interference.
- Maximizing the battery life of mobile terminals.

Types of Power Control:There are two types of power control in CDMA systems:

- Open-loop power control
- Closed-loop power control

Open loop power control

The open-loop power control (OLPC) adjusts the transmitted power according to its estimating the channel, it does not attempt to obtain feedback information on its effectiveness. The major benefit of open loop power control, which is analog in nature and has about 80 dB dynamic range, is to provide for a very rapid response over a period of just a few microseconds (i.e. it does not wait for the feedback information) for cases of sudden change in the channel condition such as a mobile behind a building. It adjusts the mobile transmit level and thus prevents the mobile transmitter power from exceeding some threshold with respect to the forward link received power level. The open-loop power control is not very accurate since it does not have feedback information for its effectiveness.

Closed loop power control

In cellular Frequency Division Duplex (FDD) CDMA systems, the frequency separation between links is greatly more than the coherence bandwidth of the channel. This frequency separation has very important implications for the power control process: It causes multipath fading on the forward and reverse links to be independent. This means that the mobile cannot measure the path loss of the reverse link by measuring the path loss on the forward link. This measurement technique, which is used for the open loop, usually provides the correct average transmit power, but additional provisions must be made for the effects of asymmetric Rayleigh fading. Therefore, the mobile transmitter power is also controlled by its cell. Each cell site demodulator measures the received signal power Pm from each mobile. The measured Pm is compared to the desired power level Pd 5 for that mobile and a power control adjustment command is sent accordingly. If the measured value is above the set point, then a one bit command is sent; to lower power by Δp dB, if below, the one bit command is sent to raise power by Δp dB. The transmitter adjusts its power up or down, relative to the open loop estimate. The closed loop power control (CLPC) is a sort of "fine tuning" on the open loop power estimate. It should be fast enough to keep up with the fast fading. So, it is the crucial component of any effective scheme to combat Rayleigh fading.

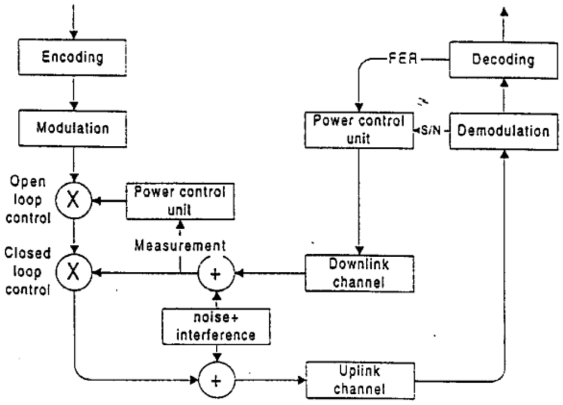

Figure 1. Simplified diagram about closed loop and open loop

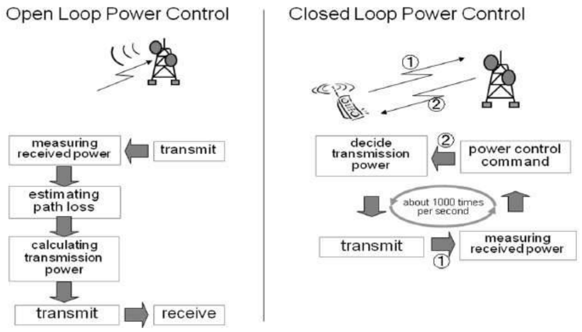

Figure 2. Comparison between open loop and closed loop power control

Forward link power control

The forward link power control is used to minimize the necessary interference outside its own cell boundary. For forward link, power control takes the form of power allocation at the cell site transmitter according to the needs of individual subscribers in the given cell. It serves the following three functions.

1. It works to make equal system performance over the service area (good quality coverage of the worst case areas).

2. It provides the load shedding between unequally loaded cells in the service area by controlling the inter cell to the heavy loaded cells.

3. It minimizes the necessary transmission power level to achieve good quality of service. This reduces the co-channel interference in other cells, which increases the system capacity and alleviates health concerns in the area around the base station.

The forward link power control figure 4 works as follows, the mobile monitors the errors in the frames arriving from the base station. It reports the frame-error rate (FER) to the base station periodically. (Another mode of operation may report the error rate only if the error rate exceeds a present threshold). The base station adjusts its transmitting power after evaluating the received frame-error. In this way, the performance of the forward links is equalized in the cell or sector. Since pilots from mobiles are usually unavailable, only closed loop power control is applied.

II. MATERIAL AND METHODS

The methods which are used in the Forward link capacity are

- nth-power-of-distance power control law
- Optimum power control

A. RESULTS

nth-power-of-distance power control law

Considering the two tiers of cells, the forward link interference geometry is shown in figure 4.The forward link capacity is given by M(r, θ) is given by

$$\mathrm{M}\ (\mathrm{r}, \theta) = \frac{\left(\left[\left(\frac{C}{I}\right)_{req}+1\right].Fj\right)}{\left(\frac{C}{I}\right)_{req}.f(r_0).X_I}$$

Where $F_j = \begin{cases} \left({}^{r_0}/_{R}\right)n & for \quad 0 < r < r_0 \\ \left(\frac{r}{R}\right)n, & for \quad r_0 < r < R \end{cases}$

$$f\left(r_0\right) = \frac{2}{n+2} + \frac{n}{n+2}\left(\frac{r_0}{R}\right)^n$$

x_I is the total interference factor. Since M depends on r, θ, r_o, to achieve at last the required C/I ratio in all locations, the minimum value of M(r, θ) is chosen as the system capacity of the forward link.

Optimum power control

For required C/I ratio, the capacity can be written as

$$M = \frac{1}{\left({}^{C}/_{I}\right)req.\frac{12}{\prod R^2 \int_0^{30^\theta} \int_0^R X_I\ (r,\theta) r\, dr\, d\theta}}$$

Evaluating equation numerically, the approximate expressions are

for m=2, $\mathrm{M} = \frac{0.3424}{(\mathrm{C/I})}$

req

for m=3, $M = \frac{0.4921}{(C/I)}$

req

for m=4, $M = \frac{0.5794}{(C/I)}$

req

For a give C/I ratio M is constant for users at any location. If M is fixed, C/I is a constant. The system can then provide uniform service for all users within the cell.

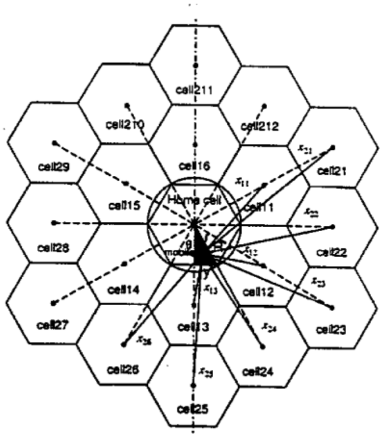

Figure 3. Forward link interference geometry

Considering $(C/I)_{req} = 0.01792$, $M(r, \theta)$ is plotted in fig.17 for r_o/R = 0. 0.6, 1.0 and $\theta = 0^0, 10^0, 20^0, 30^0$. Case A ($r_o/R = 1.0$) corresponds to the case when no power control is used. Case B ($r_o/R = 0$) corresponds to the power control scheme without threshold adjustment. Case C ($r_o/R = 0.6$) corresponds to the power control scheme with power threshold adjustment. In case A, M decreases as r/R increases because equal power is transmitted to users at any location within each cell. The signal received by the far end users becomes weak. To maintain the required C/I ratio, the number of users that can be supported will be decreased. In case B, capacity increases as r/R increases due to reduction of the transmitted power for the near-in users. Case A only benefits the close-in users and case B only benefits the far end users. Both cases are not acceptable for system design. Adjusting the transmitted power for the close-in users, we obtain curve C, which is the best case for path loss exponent m=4. The minimum value of $M(r,\theta)$ is 30.08 users/cell at r/R = 1.0 & $\theta = 30^0$, which is chosen as system capacity. When r/R > 0.6, the capacity increases to a maximum value and then decreases because the far-end users are more sensitive to the adjacent cell interference. From curves A, B, & C, capacity M is different for $\theta = 0^0, 10^0, 20^0, 30^0$, indicating that the capacity is also impacted by the direction of users. Figure 6 plots the capacity M for different path loss exponents m=2, 3, 4 and $\theta = 0^0, 10^0, 20^0, 30^0$. Curves A, B and C are the case where the largest minimum capacity for each m is obtained. It can be observed that the capacity for m=4 is obviously larger than m=2 and m=3. This is due to the smaller impact the out-of-cell interference when the path loss becomes larger.

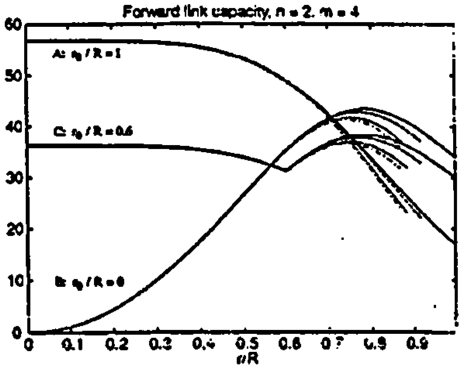

Figure 4. Forward link capacity M versus r/R for n=2,m=4 and $\theta = 0^0$ (-,-), $\theta = 10^0$ (-,-),$\theta = 20^0$ (-,-),$\theta = 30^0$ (-,-)

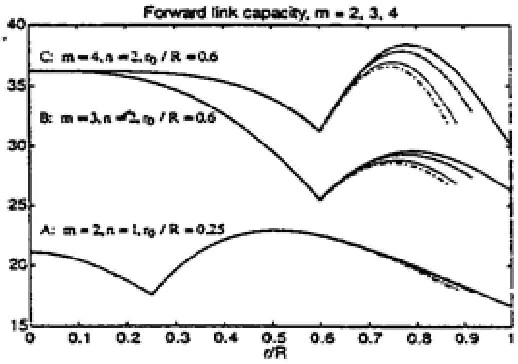

Figure 5. Forward link capacity M versus r/R for $\theta = 0^o$ *(-,-),* $\theta = 10^o$ *(-,-)*,$\theta = 20^o$ *(-,-)*,$\theta = 30^o$ *(-,-)*

III DISCUSSION

The forward link capacity with power control is smaller than the reverse link capacity. It is necessary to increase the number of users in the forward link to have similar capacity for both forward link and reverse link and to provide similar C/I ratio for acceptable performance.

IV CONCLUSION

This thesis has presented power control in CDMA cellular systems. Two mechanisms are needed to perform power control, they are open loop and closed loop, the later woks as "a fine tuning to the former ".Power control has been shown to increase the call carrying capacity. The forward link capacity of a CDMA cellular network system has been presented with the two power control schemes: *n*th power-of-distance and optimum power control. The maximum capacities are presented for different path loss factors, and the optimum power control out performs the *n*th power-of-distance scheme in all cases.

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