The Impact of Beamforming, Power Control, and Sectorization on CDMA Capacity

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Abstract
Capacity of CDMA was limited by interferences and could be optimaized by reduce interferences to fulfill requirements of multiclass services. In this research, the impact of imperfect power control and imperfect sectorization to reverse-link user capacity of CDMA system based on signal to interference ratio (SIR) by using beamforming at mobile station transmitter and base station receiver have been analyzed. Beamforming would be used with assumed each element has uniformly excited, equally spaced linear array. CDMA system use hexagonal macro cell in home cell base station, which divided effectively into 3 sectors with 120° beam width. User capacities was influenced by power control factor, number of antenna beamforming elements and sectors, overlap angle due to imperfect sectorization, imperfect power control, SIR and processing gain CDMA. Results of this research indicate that the system with power control and sectorization using beamforming has larger capacity of multiclass system than without beamforming.

Keywords: Beamforming, Power Control, Sectorization, Multiclass, CDMA.
imperfect power control and imperfect sectorization is increase. [4] have investigated the imperfect power control on reverse-link capacity of CDMA systems with fast power control and multipath fading. The results showed a reduction in user capacity due to the imperfect power control. In [5], the reverse-link capacity of CDMA systems using beamforming has been investigated. Beamforming was used at the sender and receiver, and power control was assumed by the signal to interference ratio (SIR). The results of this study indicate that an increase in capacity by using beamforming.

To support third-generation technology (3G), the CDMA has been selected as a technology for 3G systems to meet the service needs of audio, data, and video with a large capacity system. Audio, data and video services can be viewed as a multiclass CDMA system.

The result of imperfect sectorization is the interference increases then the capacity of multiclass CDMA system decreases. Therefore, to minimize the interference impact and increase capacity of multiclass CDMA system used beamforming for sectorization.

In this research, the effects of imperfect power control and imperfect sectorization in the reverse-link capacity of multiclass CDMA systems with beamforming have been analyzed. Beamforming is used at the sender and recipient of BS and MS is assumed each element have an identical current amplitude and have the same spacing between elements (uniformly excited, equally spaced linear array). Capacity was defined as the maximum number of users per cell that is affected the number of beamforming antenna elements, the number of sectors, and overlap angel due to imperfect sectorization, imperfect power control, SIR target, and processing gain CDMA.

2. Research Method

In this research, to analyze and calculate the capacity of multiclass CDMA system on the reverse link, there is a model system used in Figure 1. In the model system, the cells contained in home cell BS with BS0 and the ring (tier), the first consisting of cells that surround home cell BS with BSj, where $j = 1, 2, ..., 6$. Each BS is placed center of each macro cell is hexagonal. To analyze the influence of imperfect sectorization, then home cell BS is divided into several sectors by using antenna beamforming, where home cell BS is divided into three sectors with an effective beamwidth of 120°.
In Figure 2(a), intra cell interference on home cell BS, derived from a number of MS present in these cells. When home cell BS is sectorized and beamforming antennas is used, as shown in Figure 2(b), then the amount of interference from the user would decrease. In Figure 2(b) indicated angel notations of BS0 beamforming receiver, $\phi_0$ is the azimuth angle from MS0 to BS0 and $\phi_i$ is the azimuth angle of the MSi to BS0, these angles evenly distributed from $\pi/6$ to $5\pi/6$ for the three sectors. Gain antenna toward the receiver from MS0 to MSi BS0 for three sectors is given by [5]:

$$G_r = E_{a.h} \left[ G_i(\phi, \phi_i) \right] = \frac{1}{\rho} \int_{\phi}^{\phi_i} \sin(0.5K, \pi \phi) f(\phi) d\phi$$

By using beamforming antenna, the total of intra cell interferences for sectorization with beamforming becomes:

$$S_{int} = F_z \sum_{i=1}^{N-1} S_i \cdot G_r$$

Where

$$F_z = \frac{S_{sotio}}{S_{soloo}} = \frac{1}{z} \frac{\omega}{360^\circ}$$

$z$ is number of sector, and $\omega$ is overlap angle between sectors [3].

In Figure 3 is shown home cell BS sectorize into 3 sectors with $120^\circ$ beamwidth per sector. Sectorization is performed using beamforming antennas in BS0. If the beamforming
antenna is also used on the MSi, j, then the total inter cell interference with sectorization $S_0$ at BS0 can be expressed by

$$S_0 = F_0 \int_{r_0}^{r_0} S(\rho, \theta) \left( \frac{\rho}{r_0} \right)^n \theta \phi \theta \theta \theta \theta \rho \xi \xi \xi \mu \beta$$

$$d r \rho r \rho \rho S F S m o u r m u t$$

$G_i(\theta_u, \theta_m)$ and $G_j(\theta_u, \phi_j)$ are the gain pattern beamforming of MS sender and BS receiver. $\theta_u$ and $\theta_m$ is the azimuth angle of MSi, j to BS0 and BSj who serve it. $\theta_0$ is the azimuth angle of BSj to BS0. In Figure 3 is shown angle notations on the sender beamforming at MSI, j. When there is a sender $K_t$ beamforming antenna element in MS, then the antenna gain of sender in the direction MSi, j to BS0 [5] is

$$G_i(\theta_u, \theta_m) = \frac{\sin(0.5 K, \pi \sin(\theta_u - \pi) - \sin(\theta_m - \pi)))}{K, \sin(0.5 \pi \sin(\theta_u - \pi) - \sin(\theta_m - \pi)))}$$

(4)

If there are elements of the receiving antenna beamforming $K_r$ at BS0 to receive signals from MS0, then the gain of the receiving antenna from MSi, j to BS0 [5] is

$$G_j(\theta_u, \phi_j) = \frac{\sin(0.5 K, \pi \sin(\theta_u - \sin \phi_j))}{K, \sin(0.5 \pi \sin(\theta_u - \sin \phi_j))}$$

(5)

In this research, each traffic audio, data, and video on multiclass CDMA system uses a different spreading code with processeing gain $G_a$, $G_d$, and $G_v$. In this way, the services with different rates are accommodated with a spreading sequence with a variety of processing gain. If the processing gain is normalized by $G = G_a$, then the processing gain has been normalized to the audio, data, and video services into $g_a$, $g_d$, and $g_v$. The total inter cell interference from all traffic is

$$S_2 = S_{a2} + S_{d2} + S_{v2}$$

then

$$E[S_2] = E[S_{a2}] + E[S_{d2}] + E[S_{v2}]$$

(6)

Three types of spreading sequences with different processing gain $G_{ga}$, $G_{gd}$, dan $G_{gv}$ used to meet the needs of the different rate. To achieve the target SIR ($\gamma_a$, $\gamma_d$, $\gamma_v$) for different services, and $P_a$, $P_d$, and $P_v$ is the power received for each service, where $S_a = P_a g_a$, $S_d = P_d g_d$ and $S_v = P_v g_v$. A normalization of the power received for each traffic audio, data, and video, so that the $E_b/I_0$ multiclass CDMA system for each class:

$$\left\{ \begin{array}{l}
E_{a1} \\
E_{d1} \\
E_{v1}
\end{array} \right\} = \frac{1}{2} \left( \frac{S_a - G_F G_{gd} \frac{N_S S_G F_E}{g_e} G_{v} + S_v}{g_e} + \gamma \right) + W_{\gamma_{S}}$$

(7)

In equation (7), if $E_{a1}/I_0$ for different traffic equal to the target SIR of each traffic, then $S_a$, $S_d$, and $S_v$ can be expressed in Sz:

$$S_a = \frac{S_a + 1.5 \eta_{a} W}{C}$$

$$S_d = B_d S_a$$

$$S_v = B_v S_a$$

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The averages of the total inter cell interference by using beamforming for sectorization $S_z$ in multiclass system can be rewritten into the following equation:

$$E[S_z] = E[S_{u_a}] + E[S_{u_d}] + E[S_{u_v}]$$

$$= E[S_{u_a}] F(\mu, \sigma) F_e + E[S_{u_d}] F(\mu, \sigma) F_e + E[S_{u_v}] F(\mu, \sigma) F_e,$$

$$= \frac{1}{g_a} \left[ \frac{N_a}{g_a} \frac{N_{a_{r}}} {g_a} \frac{N_{a_{f}}} {g_a} + \frac{N_{a_{f}}} {g_a} \frac{N_{a_{r}}} {g_a} + \frac{N_{a_{r}}} {g_a} \frac{N_{a_{f}}} {g_a} \right] F(\mu, \sigma) F_e$$

For $F(\mu, \sigma) > 0$, then the capacity of multiclass CDMA system can be expressed as follows:

$$C = \frac{g_a F_e 1.5G_a}{g_a} + \frac{1.5G_d}{g_d} \frac{g_a}{g_a} G_{a_{f}} F(\mu, \sigma) F_e + \frac{1.5G_d}{g_d} \frac{g_d}{g_d} G_{d_{f}} F(\mu, \sigma) F_e + \frac{1.5G_v}{g_v} \frac{g_v}{g_v} G_{v_{f}} F(\mu, \sigma) F_e,$$

$$B_z = \frac{g_a}{g_a} \frac{F_e 1.5G_a}{g_a} + \frac{1.5G_d}{g_d} \frac{g_d}{g_d} G_{a_{f}} F(\mu, \sigma) F_e + \frac{1.5G_d}{g_d} \frac{g_d}{g_d} G_{d_{f}} F(\mu, \sigma) F_e + \frac{1.5G_v}{g_v} \frac{g_v}{g_v} G_{v_{f}} F(\mu, \sigma) F_e$$

3. Results and Analysis

The parameters used in calculating the capacity of user audio, data, and video on multiclass system is shown in Table 4.1:

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Spreading bandwidth ($W$) [5]</td>
<td>4.096 Mbps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing Gain[5]</td>
<td>$G_a = 128$</td>
<td>$G_d = 64/g_d = 0.5$</td>
<td>$G_v = 32$</td>
</tr>
<tr>
<td>Target SIR [5]</td>
<td>$\gamma_a = 5$ dB</td>
<td>$\gamma_d = 10$ dB</td>
<td>$\gamma_v = 7$ dB</td>
</tr>
<tr>
<td>Power Control Factor $\sigma$ (dB)</td>
<td>0, 2, 4, 6, 8[1]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.1. The Impact of Power Control and Sectorization on CDMA Multiclass System Capacity.

Figure 4 shows the capacity of multiclass system towards effect of power control. Multiclass system capacity with $z = 3$ sector compared to the system without sectorization. From Figure 4 shows that the capacity of either without or with sectorization decreased with decreasing the effect of power control. As the result of the increasing imperfect power control, the signal interference between users is also increase. The increase means a decrease $E_b/I_0$ interference signals that can be used to represent the value of SIR. To achieve the target SIR or the desired signal quality then there is a decrease in system capacity.

In Figure 4 is also shown that by imperfect sectorization $z = 3$ sectors and perfect sectorization ($\omega = 0^\circ$), then the system capacity increase compared to the capacity of the system without sectorization. This occurs because the user on the multiclass system is only serviced by BS which antenna sector is facing the user. As a result, those users are only getting signal interference from users of the same sector. If there are overlap between sectors $\omega = 10^\circ$ and $\omega = 20^\circ$, the sectorization increasingly imperfect so that system capacity decreased compared to perfect sectorization. This occurs because the user is also getting signal interference from some user in other sector. However, In Figure 4 shown that the system capacity with the overlap between sectors is larger than without sectorization.
3.2. The Impact of Beamforming, Power Control, and Sectorization on CDMA Multiclass System Capacity.

Figure 5 shows the effect of addition of element receiving beamforming antenna $K_r$ on the capacity of multiclass system. On BS, the antenna element receiver $K_r$ increases from 1, 3, 5, 7 until 9. While at MS, the antenna element sender $K_T = 1$. Effect of power control on system capacity indicated by $\sigma = 0$ dB, $\sigma = 2$ dB, and $\sigma = 4$ dB.

Effect of $K_r$ on the capacity of multiclass system is shown without sectorization $z = 1$ and by performing a perfect sectorization $z = 3$. In Figure 5 shows that the capacity of multiclass systems with sectorization and beamforming is greater than without sectorization. For imperfect power control with $\sigma = 4$ dB, the multiclass system capacity increase with the increase in the number of receiver antenna elements beamforming $K_r$ compared to perfect power control $\sigma = 0$ dB using only one receiver antenna at the BS. This occurs because by adding receiver antenna elements beamforming at the BS for transmitting reverse link, signals from antenna elements are combined to form a movable beam pattern that can lead to the desired destination to follow the movement of MS. Thereby enabling the antenna system to focus radio frequency (RF) at a particular MS and minimize the impact of interference by increasing system capacity.

4. Conclusion

Sectorization with beamforming antennas produce a multiclass system capacity is greater than the use of beamforming antennas without sectorization. Imperfect sectorization can reduce the capacity of multiclass system, with the use of beamforming antennas in imperfect sectorization, can increase the capacity of multiclass system.

References