Implementation of RSS based CDMA handoff Algorithm for estimation of Optimal Hadd and Hdrop values

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Abstract

Proper design of handoff is one of the main challenges in cellular networks, since it has a great impact on the system performance and capacity. Soft Handoff is used in CDMA and WCDMA systems provide a smoother transition and improve the perceived Quality of Service (QoS) by proper selection of Hysteresis add (Hadd) and Hysteresis drop (Hdrop) values. In this paper, optimum Hadd and Hdrop values are estimated by using new Received Signal Strength (RSS) based CDMA handoff Algorithm. In this paper, first the analysis is done for variable base station (BS) and mobile station (MS) antenna heights with fixed Hadd and Hdrop values (12 dB and 4 dB) for estimating the practical BS and MS antenna heights at minimum RSS but in this analysis the soft handoff distance is more (approx. 500m) which causes forward link interference. In the next step, with the estimated BS and MS antenna heights (35m, 1.5m) are taken into consideration and the effect of variable Hadd, Hdrop values on soft handoff distance is evaluated. By this analysis the optimum Hadd, Hdrop values (3dB to 5dB) are estimated for a CDMA cellular system with moderate soft handoff distance which improves the quality of service.

Keywords: Handoff, Soft Handoff, RSS, Hadd, Hdrop, CDMA

1. Introduction

The CDMA and WCDMA systems are more popular because of soft handoff mechanism which provides seamless call transmission. The 2G TDMA based GSM cellular system provides the hard handoff mechanism which is “break before make” approach. In this, MS breaks the connection to the old BS and then make the communication with the new BS which causes the “Ping –Pong effect” and communication quality is degraded [1], whereas, in 2G CDMA and 3G WCDMA cellular systems allow “soft handoff” between the cells because of its unique universal frequency reuse feature[2]. Soft handoff allows the mobile stations to communicate with two or more base stations at the same time. The mobile station does not interrupt the communication with old base station until a new connection is obtained with the new base station and eliminates “Ping-Pong effect” and lower switching load on the network signaling and provides smooth call transmission; together with power control and also used as an interference-reduction mechanism [3]-[5]. The mobile stations are separated by unique pseudo - random sequences and multiple data flows are transmitted simultaneously via radio interface. Consequently, due to the usage of soft handoff mobile station (MS) is able to get benefit from macro diversity thereby enhancing both quality of service and capacity. Proper design of soft handoff is one of the main challenges in 2G/3G cellular networks, since it has a great impact on the cellular system performance and capacity [6]. So, in this paper, a soft handoff algorithm is implemented for improving the CDMA cellular system performance by estimating the Hysteresis add and Hysteresis drop with practical BS and MS antenna heights.

II. CDMA Cellular System

CDMA cellular technology is initially known as IS-95 (Interim Standard - 95) and is competing with GSM technology for dominance in the cellular world. The CDMA cellular system is based on Code Division Multiple Access (CDMA) scheme which was demonstrated in 1998. It operates in 800 MHz and 1.9 GHz PCS bands [7]. Compared to GSM cellular systems, CDMA requires fewer cell towers and provides a calling capacity improved by five times. CDMA also provides more than 10 times the voice traffic of earlier analog system (1G cellular system).

In CDMA cellular system, unique spreading codes are used to spread the base band data before transmission [8]-[9]. CDMA assigns a unique code sequence to each user that is used to code data before transmission. If a receiver knows the code sequence related to a user, it is able to decode the received data. The codes are shared by the mobile station and the base station. These codes are called “Pseudo Random Sequences”. Using these sequences, the entire spectrum is utilized by all the users at all times.
Handoff Mechanism

Mobility is the most important feature of a cellular and mobile communication system. Even though the mobile phone users are moving inside or outside the cells, they are able to communicate with each other. This can be achieved by the process handoff. Handoff is a mechanism of transferring an ongoing active call from one cell to another or one base station to another or one channel to another as a user moves through the coverage area of a cellular system [10]-[11]. The cellular handoff is not an easy process to implement in practically, as the cellular network needs to decide when to handoff and to which cell.

III. RSS Based CDMA Handoff Algorithm Implementation for estimating optimum Hadd and Hdrop values

CDMA systems support the soft handoff process. Active set is defined as the set of base stations to which the Mobile station (MS) or User Terminal (UT) is simultaneously connected [12]-[13]. In soft handoff region, UT is connected with more than one base station. Initially when UT is very near to BS, the active set consists of only one BS but as distance from BS1 increases and when soft handoff region starts then active set size changes with distance. The primary objective of a soft handoff algorithm is to provide good signal quality. Signal quality can be improved by including more base stations in the active set, but this comes at the cost of increased use of system resources. For minimizing the active set size, one alternative is to frequently update the active set at each time instant, to maintain the smallest active set with sufficient signal quality. However, frequent updates or handoffs bring switching costs with them [14]. A soft handover algorithm is implemented to maintain the user’s active set. The following parameters are needed to describe the soft handoff algorithm which is shown in Fig. 1.

RSS based CDMA Handoff Algorithm:

Active set is reorganized in following manner.

- If active set consists of BS1 and RSS1> RSS2 and |RSS1-RSS2| is greater than Hadd, then active set consists of BS1 itself.
- If \( |RSS1 - RSS2| < Hadd \), active set consist of BS1 and BS2.
- If active set consists of BS1 and BS2 and \( |RSS1 - RSS2| \) becomes greater than or equal to Hdrop, active set consist of that base station whose average signal strength is higher. Base station with smaller signal strength will be dropped from the active set.

Effect of Soft Handoff Distance and Soft Handoff Parameters on CDMA Cellular System

The soft handoff distance is the difference between the distance at which Hadd started and the distance at which Hdrop assigned. The soft handoff distance is a marker of how long a soft handoff will take place. The soft handoff distance and Hadd and Hdrop are very important parameters in determining system performance and need to be carefully optimized for a given situation.

- A wider margin results in longer average soft handoff duration. By changing the Hadd and Hdrop the handoff region will be affected. Reducing and expanding the cell boundaries, increases the soft handoff region.
- If the soft handoff distance is more, it allows more MSs to be in soft handoff mode. It will decrease reverse link interference and benefits from macro diversity. That is, the UTs in handoff are connected to the best available link and therefore, do not transmit excessive power.
- However, the increase in the number of UTs in soft handoff and the increase in the average handoff duration can increase system complexity and tie up previous inadequate system resources. In soft handoff, by allowing multiple BSs to transmit to one UT the forward link interference increases.

The challenge is to optimize the Hadd, Hdrop and soft handoff distance so that the capacity and quality of service requirements are satisfied, while keeping the operational cost and system complexity reduced.

CDMA Cellular System Model

Consider, cellular network as shown in Fig. 2. A user terminal moves from the cell served by base station1 (BS1) towards another with BS2 with...
constant speed along a straight line. \( D \) is the distance between the two base stations. Both of the base stations are assumed to be located at the centre of the respective cell and operating with the equal transmitting power.

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\text{Received signal strength (RSS) at user terminal is affected by the pathloss. Path loss is the deterministic component of RSS, which can be evaluated by propagation path loss model which is Cost 231 Hata model.}
\]

**COST-231 Hata Model**

To extend Hata-Okumura model for personal communication system (PCS) applications operating at 1800 to 2000 MHz, the European Co-operative for Scientific and Technical Research (COST) came up with COST-231 model [15]. This model is derived from Hata model and depends upon four parameters for prediction of propagation loss which include frequency, height of mobile antenna, height of base station and distance between base station and mobile antenna. For CDMA and WCDMA cellular systems, the Cost 231 model is most suitable for estimating the path loss and RSS.

According to this model, the path loss in urban areas is given by,

\[
\text{Pathloss for UT to BS1:} \\
\text{PL1(dB)=} 46.33 + 33.9 \log(f) - 13.82 \log(h_1) - a(h_m) + [44.9 - 6.55 \log(h_1)] \log(d) \\
\text{PL2(dB)=} 46.33 + 33.9 \log(f) - 13.82 \log(h_2) - a(h_m) + [44.9 - 6.55 \log(h_2)] \log(D_c-d) \\
\]

\[
a(h_m)\text{in dB=}[1.1 \log(f) - 0.7]h_m[1.56 \log(f) - 0.8] \\
\]

\[
\text{PL=}\text{ Path loss, in dB} \\
\text{h}_1, \text{h}_2 = \text{Height of the base station in meters, 30m to 200m} \\
\text{h}_m = \text{Height of the mobile station in meters, 1m to 10m} \\
\text{f=} \text{Carrier frequency in MHz=1800 MHz} \\
\text{d=} \text{Distance between base station and mobile station in kilometers, 1Km to 2Km} \\
\text{D_c=} \text{distance between two base stations=2000m} \\
\text{Pt=} \text{Transmitter Power =43 dBm =13 dB} \\
\text{The RSS from BS1} \\
\text{RSS1=}\text{Pt-PL1} \\
\text{Received signal strength from BS2} \\
\text{RSS2=}\text{Pt-PL2} \\
\]

**IV. Results and Discussion**

The RSS based CDMA handoff algorithm is implemented for estimating optimum Hadd and Hdrop values for 2G and 3G cellular systems.

In the first configuration, the analysis is done for constant soft handoff parameters (Hadd=12dB and Hdrop=4dB) and for variable base station antenna heights (150m, 100 m, 50m and 35m) and mobile station antenna heights (3m and 1.5m). By this analysis, practical base and mobile station antenna heights are chosen for minimum received signal strength.

In the second configuration, with the estimated practical base station and mobile station antenna heights are taken into consideration and the effect of different values of Hadd, Hdrop on soft handoff distance is evaluated. By this analysis the optimum Hadd, Hdrop values are estimated for a CDMA cellular system which improves the quality of service with moderate soft handoff distance.

**Configuration 1**

![Fig. 3 RSS based Soft handoff algorithm at Hadd =12 dB, Hdrop =4 dB, h_1=h_2=150 m and h_m=3 m](http://www.ijettjournal.org)
Considering, $h_{b1}$ is 150m, $h_{b2}$ is 100m and $h_m$ is 3m at $H_{add}=12$ dB and $H_{drop}=4$ dB. Then, results are shown in Fig. 4.

![Fig. 4 RSS based Soft handoff algorithm at $H_{add}=12$ dB, $H_{drop}=4$ dB, $h_{b1}=150$ m, $h_{b2}=100$m and $h_m=3$m](image1)

Fig. 4 RSS based Soft handoff algorithm at $H_{add}=12$ dB, $H_{drop}=4$ dB, $h_{b1}=150$ m, $h_{b2}=100$m and $h_m=3$m.

For these considerations, the mobile is found to be in the soft handoff region between 650 m and 1250m and thus the soft handoff distance is 500m. It is also observed that as the height of neighboring base station (BS2) antenna decreases, the soft handoff region moves towards the BS2.

![Fig. 5 RSS based Soft handoff algorithm at $H_{add}=12$ dB, $H_{drop}=4$ dB, $h_{b1}=150$m, $h_{b2}=50$m, and $h_m=3$m.](image2)

Fig. 5 illustrates that as height of the BS2 decreases to 50m, the soft handoff region moves towards BS2 and the MS is in the soft handoff region between 825m and 1325m. Thus, soft handoff distance is equal to 500m and signal strength of BS1 at which the mobile is completely handoff to BS2 is observed as -112 dB at a distance of 1325m. As the mobile is moving away from the BS1 the received signal strength of mobile reduces. As the height of the antenna reduces, the signal strengths of BS2 reduce and the soft handoff region moves towards the BS2.

![Fig. 6 RSS based soft handoff algorithm at $H_{add}=12$ dB, $H_{drop}=4$ dB & $h_{b1}=h_{b2}=35$m and $h_m=3$m.](image3)

Fig. 6 shows that as the antenna heights of BS1 and BS2 both are reduced to 35m and for mobile antenna height of 3m, the received signal strengths are found to be less compared to the previous cases i.e. when BS1 antenna heights are 150m, 100m and 50m. In this case, the mobile is found to be in the soft handoff region between 625m and 1125m and thus the soft handoff distance is 500m.

![Fig. 7 RSS based Soft handoff algorithm at $H_{add}=12$ dB, $H_{drop}=4$ dB, $h_{b1}=h_{b2}=35$m and $h_m=1.5$m.](image4)

Fig. 7 shows that by considering antenna heights of BS1 and BS2 as 35m and mobile antenna height as 1.5m, the received signal strengths are less compared to previous case (Fig. 6), where the mobile antenna height is 3m. The mobile is in the soft handoff region between 625m and 1125m. Therefore, soft handoff distance is 500m. The corresponding values are represented in Table 1.

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Received Signal Strength (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS1</td>
<td>BS2</td>
</tr>
<tr>
<td>BS2</td>
<td>BS1&amp;BS2</td>
</tr>
<tr>
<td>BS1</td>
<td>BS1&amp;BS2</td>
</tr>
</tbody>
</table>

Table 1 Received signal strengths of BS1 and BS2 and soft handoff performance at $H_{add}=12$ dB, $H_{drop}=4$ dB, $h_{b1}=h_{b2}=35$m and $h_m=1.5$m.
Table 1 represents the received signal strengths of the MS from BS1 and BS2 for equal base station antenna heights of 35m and mobile station antenna height of 1.5m. The RSS values obtained for these considerations are very less, for example at a distance of 100m, the RSS observed from BS1 is -83.194 dB while the RSS observed for the mobile station antenna height of 3 m is found to be -87.515 dB and thus the base station antenna heights of 35m and mobile station antenna height of 1.5m are considered to be the practical values for CDMA cellular system. It is also observed that the soft handoff distance in each case is observed as 500m which more distance with the Hadd=12 dB and Hdrop is 4 dB.

With this first configuration practical base and mobile antenna heights are realized for minimum RSS and need to estimate the optimum Hadd and Hdrop values for moderate soft handoff distance for improving quality of service.

Configuration 2

RSS based CDMA hand algorithm is implemented for practical antenna heights and estimated optimum Hadd and Hdrop values by calculating soft handoff distance with variable Hadd and Hdrop values.

![Figure 8](image)

Fig. 8 RSS based Soft handoff algorithm at different Hadd and Hdrop values which are indicated by different colours. From the figure it is observed that if Hadd and Hdrop are at 12 dB, the soft handoff distance is more and if Hadd and Hdrop values are at 2 dB the soft handoff distance is less. Fig. 8 shows that greater value of drop hysteresis will increase active set size for larger area and hence soft handover region will increase. Large soft handover region will increase interference which is not desirable. Therefore, Hdrop should neither be very large nor very small. This figure shows that, the variations of soft handoff region with Hadd and Hdrop i.e. as Hadd and Hdrop are increased, soft handoff region increases rapidly. Large soft handover region increases forward interference and hence capacity decreases. Very small soft handoff region may increase the probability of outage. This is an interesting result and should be taken into consideration while designing soft handoff algorithm.

Table 2 represents the received signal strengths, call quality observations for different values of soft handoff parameters (Hadd, Hdrop). If Hadd and Hdrop are at 12 dB and 4 dB, the received signal strength during handoff is found to be -85 dBm and handoff distance is very large i.e. 740m. The signal strength is still sufficient to maintain the call. Also for a fixed hysteresis add and variable hysteresis drop also the soft handoff distance increases and vice versa. Large Hadd and Hdrop values create large soft handoff distance which results in increase of downlink interference. As the soft handoff distance decreases, the uplink interference increases. So, the design of soft handoff parameters is very important for improving the quality of service. From this Table 2, it is observed that the Hadd, Hdrop values from 3 dB to 5 dB range can give optimum performance with moderate soft handoff distance (200m to 320m).

V. Conclusions

CDMA cellular system is the most popular system in 2G/3G generations. Most attractive characteristic of CDMA cellular system is frequency reuse which allows the soft handoff between the cells which increases the cellular system capacity by 4 to 5 times.
the capacity of the GSM cellular system and also provides best QoS with seamless connection. In this paper, a new RSS based CDMA handoff algorithm is developed. The effect of various base station antenna heights, mobile antenna heights on the CDMA cellular system performance is investigated with the help of soft handoff algorithm. First configuration, fixed hysteresis add (12 dB) hysteresis drop (4 dB) and base station antenna height of 35 m, mobile antenna height of 1.5 m the soft handoff distance observed is more which is approximately 500 m but the received signal strength is less. Therefore, it is concluded that base station antenna height of 35 m and mobile antenna height of 1.5 m are practical values for obtaining minimum received signal strength. The effect of soft handoff parameters (hysteresis add and hysteresis drop) on CDMA cellular system using the soft handoff algorithm is also analyzed in this paper. Soft handoff performance is measured in terms of active set size and soft handover distance. Simulation results confirmed that the soft handoff parameters setting has a vital effect on the handoff performance. As the Hadd increases, the soft handoff distance increases for a fixed Hdrop and vice versa. By careful tuning and setting appropriate values for the handoff parameters, a higher system performance can be achieved. Finally, it is concluded that the optimum hysteresis add and hysteresis drop to obtain the best QoS for improving the CDMA cellular system performance are in the range of 3 dB to 5dB.

References