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Analysis of Adaptive Hysteresis Based Horizontal Handoff Algorithm for GSM

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Abstract: The GSM cellular system is one of the most popular 2G/2.5G/2.75G digital cellular telecommunications systems, which is widely used throughout the world. One of the most attractive features of GSM cellular system is handoff. It is the process of continuation of an active call when the mobile is moving from one cell to another without call termination. Usually, continuous service is achieved by properly designed handoff algorithm which reduces the switching load of the network. So, efficient handoff algorithms are a cost – effective way of enhancing the capacity and QoS of cellular system. In this paper, the handoff mechanism in GSM cellular systems, various handoff initiation algorithms of GSM are described and a new RSS based handoff algorithm with adaptive hysteresis is proposed for a GSM cellular network.

I. INTRODUCTION

The Global System for Mobile (GSM) technology is the most popular 2G digital cellular system technology. The development of 2G digital cellular systems was triggered by standardization efforts in Europe. These systems have many advantages compared to 1G cellular system such as high security, superior quality of voice transmission over the long distances, low average transmitted power, increased capacity with more efficient utilization of the radio spectrum. With these advantages the GSM cellular system has attracted more subscribers with more attention in the field of mobile telecommunication. Presently, GSM supports more than one billion mobile subscribers in more than 210 countries throughout the world. Mobility is the most important feature of a cellular system. Even though the mobile phone users are moving inside or outside the cells, they are able to communicate with each other. The active call should be transferred from one cell to another in order to achieve call continuation during boundary crossing levels. This can be achieved by the handoff process. In a cellular network, the entire geographical area is divided into small cells in order to achieve high system capacity due to limited spectrum. Smaller cells cause the mobile station (MS) to cross several cells during ongoing active call conversations [2] and[4]. In this paper, the handoff mechanism, handoff parameters, purpose of handoff, handoff initiation algorithms are discussed and a new RSS based handoff algorithm with adaptive hysteresis is proposed for a GSM cellular network.

II. HANDOFF IN GSM

Handoff is a mechanism of transferring an ongoing active call from one cell to another or from one base station to another or one channel to another as a user moves through the coverage area of a cellular system [8],[5]. The transfer of current communication channel could be in terms of a time slot, frequency band, codeword, or combination of these for time-division multiple access (TDMA), frequency-division multiple access (FDMA), code-division multiple access (CDMA), or a hybrid scheme, respectively [1], [6].

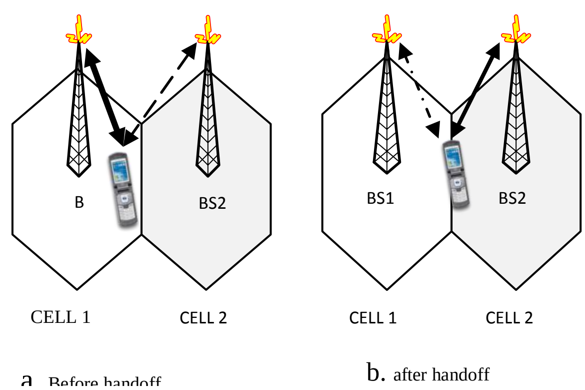

Fig. 1 Handoff process

Fig. 3.1 indicates the transferring of a call from one base station (BS1) to another base station (BS2) as mobile moves from one cell to another [7].

Handoff parameters

- The signal strength of the base station with which communication is being made, along with the signal strengths of the surrounding stations.
- The availability of channels also needs to be known.

Purpose of handoff

- It avoids call termination [3].

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- It frees up some capacity for other users.
- Handoff improves the QoS by reducing factors such as the call drop rate and the congestion rate.
- In GSM, when a particular channel used by phone becomes interfered by another phone using the same channel in a different cell, then call is transferred to a different channel in same cell or to a different channel in another cell in order to avoid interference.

III. HANDOFF ALGORITHMS USED IN GSM CELLULAR SYSTEMS

Handoff algorithms used in GSM are:

- RSS based handoff algorithm
- RSS based handoff algorithm with Threshold
- RSS based handoff algorithm with hysteresis
- A new RSS based horizontal handoff algorithm with Adaptive hysteresis

RSS based handoff algorithm

According to this algorithm, the received signal strengths of two base stations are compared and when the received signal strength of base station 1 is less than the received signal strength of BS2 then the call is handover to BS2 otherwise the mobile station is in connection with the BS1.

A major problem with this approach is that the received signals of both base stations often fluctuate if the mobile is moving and cause the mobile to rapidly switch links with either base station. This phenomenon is called ***ping-ponging***. To avoid unnecessary handoffs, RSS with threshold is used.

RSS based handoff algorithm with Threshold

RSS of BS_1 is less than the threshold value and RSS of BS1 is less than the BS2 the handoff is made to BS2 otherwise there is no handoff and MS still in connection with the BS_1. In this method the "Ping – Pong effect will be avoided but still unnecessary handoffs are presented because BS1's signal strength is still satisfactory for continuing the call.

RSS based handoff algorithm with Hysteresis

According to this when the RSS of BS2 exceeds the BS1 with hysteresis then call handoff to the BS2 otherwise it is connected to BS1. It minimizes the unnecessary handoffs. In this method the hysteresis is fixed that means the hysteresis value is either small or large. If it is large, more burden on the network and delay increases. Otherwise, if it is too small more unnecessary handoffs are occurred. To avoid this adaptive hysteresis based handoff algorithm is proposed.

RSS based handoff algorithm with Adaptive Hysteresis

Traditional handoff algorithms depend on RSS with a fixed handoff hysteresis value H. This hysteresis value is designed to reduce the ping-pong effect in the handoff procedure. Therefore, selection of this hysteresis value becomes important for optimizing handoff performance. If hysteresis (H) is too small, numerous unnecessary handoffs may be processed, increasing the network burden. However, if H is too large, the long handoff delay may result in a dropped-call or low QoS. The main objectives of a handoff algorithm are to: (i) prevent unnecessary handoffs (ii) minimize handoff delay (iii) maintain desired cell-boundaries, thereby reducing the system interference level and (iv) improve call quality during handoff. Since tradeoffs exist among these requirements, the design of a handoff algorithm is a difficult task.

Consider two cell model. In which the MS is moving from BS1 to BS2. For this model the adaptive hysteresis is given by,

$$Adaptive\,h = \max\left\{20\left(1-\left(\frac{d}{R}\right)^4\right),0\right\} \quad (1)$$

where, d is the distance between the MS and serving BS, and R is the cell radius.

For a hexagonal cell $R = \frac{D_C}{\sqrt{3}}$ where D_c is the distance between two base stations.

From Eq.1, as adaptive h decreases from 20 to 0 dB that is the MS moves away from the serving BS. In setting the above adaptive hysteresis value h, the number of unnecessary handoff is decreased. Because of a large h, if the MS is near the serving BS and the MS are encouraged to hand over to adjacent cells and because of a small h if it is near the boundary of the current cell. In this way, the handoff area is optimized. .

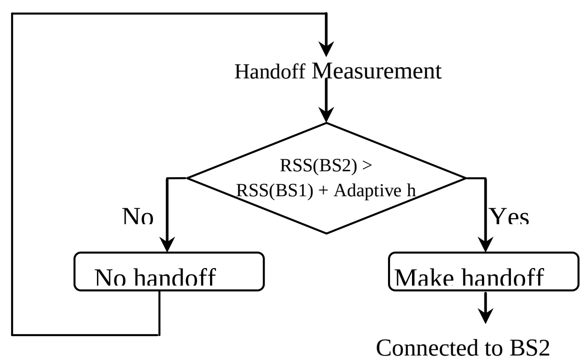

Fig. 2 RSS based handoff algorithm with Adaptive Hysteresis

In this when the RSS of BS2 is higher than RSS of BS1 with adaptive hysteresis value h, the call is handover to BS2 otherwise it maintains the current connection with BS1. This adaptive handoff algorithm is developed by dynamically determining the hysteresis value as a function of the distance between the MS and the serving BS.

Okumura-Hata model

Okumura-Hata model is widely used for signal prediction in urban areas is useful for finding the pathloss of GSM cellular network. It is most popular empirical model. This model is applicable for frequencies in the range 150 – 2000 MHz and distances of 1– 100 Km. It also can be used for base station effective antenna heights ranging from 30 to 1000 m and mobile antenna heights of 1 to 10 m [9].

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Pathloss for okumura-Hata model is given as,

For mobile to BS 1:

$$PL1(dB) = 69.55 + 26.16\log(f) - 13.82\log(h_{b1}) - a(h_m) + (44.9 - 6.55\log(h_{b1}))\log(d) \quad (2)$$

For mobile to BS 2:

$$PL2(dB) = 69.55 + 26.16\log(f) - 13.82\log(h_{b2}) - a(h_m) + (44.9 - 6.55\log(h_{b2}))\log(D_c - d) \quad (3)$$

PL1, PL2 = total path loss in dB using HATA for BS1 and BS2 respectively,

f = Carrier frequency = 900 MHz

h_{b1}, h_{b2} = Effective Transmitter antenna heights for BS1 and BS2.

h_m = Effective Receiver (Mobile) antenna height.

D_c = distance between BS1 and BS2=2000 m.

d = distance of BS1 to MS in Km

D_c-d = distance of MS to BS2 in Km

a (h_m)= correction factor in dB for effective receiver (mobile) antenna height and it is given by

$$a(h_m) = [1.1\log(f) - 0.7]h_m - [1.56\log(f) - 0.8 \quad (4)$$

For the Okumura - Hata model, let the received signal strength due to BS1 located at a distance of d from the mobile station is,

RSS1=Pt-PL1 (5)

And the received power due to BS2 located at a distance of D_c-d from the Mobile Station is,

RSS2=Pt-PL2 (6)

Results and Discussion:

RSS based handof algorithm is applied for the two cell model in which the base station antenna heights are equal which are 35 m and mobile antenna height is 1.5 m.

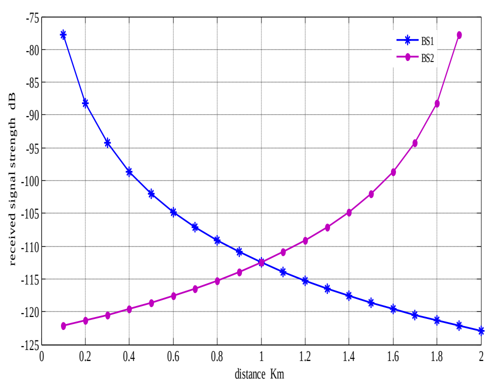

Fig. 3 Received Signal strength vs. distance at h_{b1}= h_{b2}=35m and h_m=1.5m

From the Fig. 3 the ping – pong effect which is undesirable and is observed at 1Km from BS1 and BS2 at which mobile receives equal RSS from the two base stations. To overcome the limitations of the RSS based algorithm, RSS with threshold algorithm is proposed.

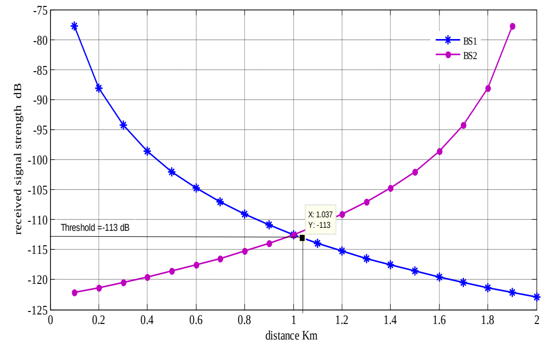

Fig. 4 RSS based handoff algorithm with Threshold

In Fig.4 shows the threshold set at -113 dB and the handoff occurs 1038 m at which the signal strength is still satisfactory. So,unnecessary handoffs occurs and therefore prior knowledge of crossover signal strength between the current and target base stations are also needed. So, this method is impractical.

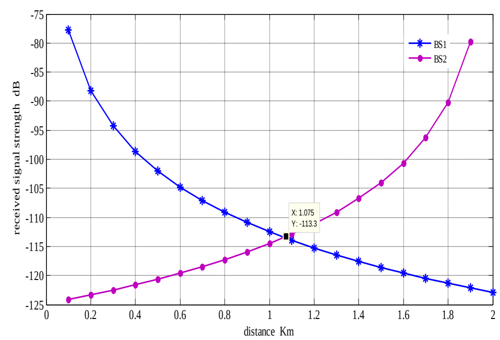

Fig. 5 RSS based handoff algorithm with hysteresis, H=2 dB

Fig. 5shows the RSS based handoff algorithm with hysteresis 2dB.

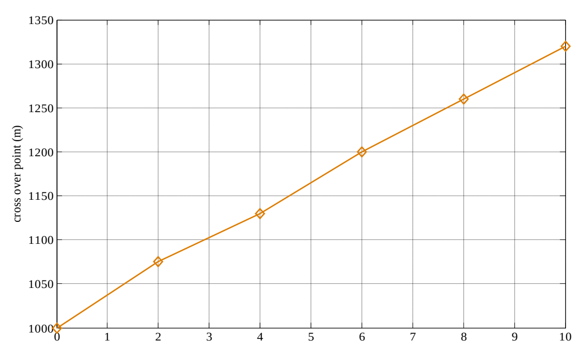

Fig. 6 Crossover point vs. Hysteresis

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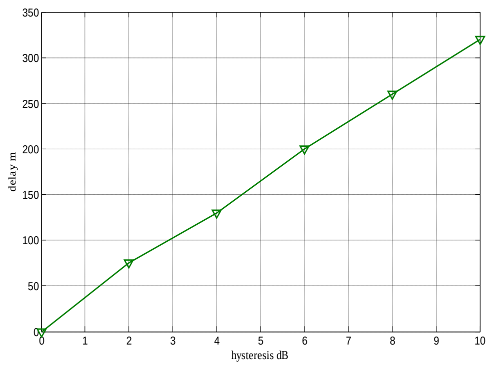

g. 7 Delay vs. hysteresis

Fig. 6 and Fig. 7 illustrate the effects of hysteresis margin on the cross over point and handoff delay.

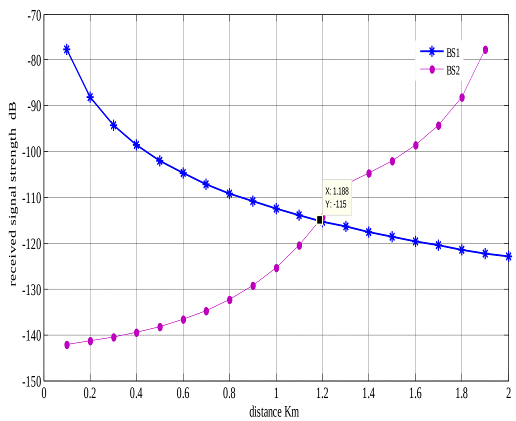

Fig. 8 Received signal strength vs distance

From the figures, it is observed that as the hysteresis increases the cross over point increases and handoff delay also increases. This hysteresis value is designed to reduce the ping-pong effect in the handoff procedure. Therefore, selection of this hysteresis value becomes important for optimizing handoff performance.

RSS based hard handoff algorithm with Adaptive hysteresis

Table 1 RSS variations with adaptive hysteresis value.
Table 1 presents the adaptive hysteresis values based and corresponding received signal strength variations withrespect to the distance between the BS1 and BS2.

S. No	Distance from BS1 to MS,d(m)	Distance from MS to BS2,D_c-d(m)	Adaptive Hysteresis(h)	RSS1(dB)	RSS2(dB)
1	100	1900	19.999	-77.691	-142.174
2	200	1800	19.988	-88.163	-141.346
3	300	1700	19.942	-94.289	-140.436
4	400	1600	19.816	-98.635	-139.395
5	500	1500	19.552	-102.006	-138.156
6	600	1400	19.072	-104.760	-136.633
7	700	1300	18.281	-107.089	-134.722
8	800	1200	17.067	-109.106	-132.300
9	900	1100	15.302	-110.886	-129.220
10	1000	1000	12.840	-112.478	-125.318
11	1100	900	9.518	-113.917	-120.404
12	1200	800	5.154	-115.232	-114.261
13	1300	700	0	-116.441	-107.089
14	1400	600	0	-117.561	-104.760
15	1500	500	0	-118.603	-102.006
16	1600	400	0	-119.578	-98.635
17	1700	300	0	-120.494	-94.289
18	1800	200	0	-121.358	-88.163
19	1900	100	0	-122.174	-77.691

Table 1 RSS variations with adaptive hysteresis value.

S.No	Hysteresis (dB)	Cross over point(m)	Delay(m)	RSS at handoff dB
1	Adaptive hysteresis	1188	188	-115
2	RSS with threshold	1037	37	-113
3	RSS (H=0)	1000	0	-112.478
4	2	1075	75	-113.3
5	4	1130	130	-114.3
6	6	1200	200	-115.1
7	8	1260	260	-115.9
8	10	1320	320	-116.6

Table 2 Hysteresis, cross over point, delay and minimum received signal strength during handoff

Table 2 shows the details such as hysteresis (dB), cross over point,delay, RSS at handoff of various handoff algorithms such as RSS, RSS with threshold, RSS with fixed hysteresis method and RSS with adaptive hysteresis method. The adaptive hysteresis method is found to be the best among as it provides optimum delay and minimum signal strength

CONCLUSIONS

In GSM, the capacity and QoS is improved by using efficient handoff techniques. So, in this paper, the performance analysis of various handoff algorithms developed for GSM technology are analyzed for practical mobile and base station antenna heights. In RSS based handoff algorithm the minimum received signal strength

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during handoff is found to be -112.478 dB. In this method the "Ping-Pong effect" is obtained. This can be eliminated by using RSS with threshold but the selection of threshold is complicated. So, RSS with fixed hysteresis method is used which eliminates the "Ping –Pong effect". The selection fixed hysteresis also causes unnecessary handoffs and dropped calls. To overcome this problem, a new RSS based handoff algorithm with adaptive hysteresis is proposed. In this method, the received signal strength at which the handoff occurs is at -115 dB and the cross over point observed is at a distance of 1188 m. The proposed RSS based handoff algorithm with adaptive hysteresis optimizes the handoff area by reducing handoff delay and call quality improves which increases the performance of the GSM cellular system.

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