Reduction of Error in Handoff Initiation Time Calculation for Next-Generation Wireless Systems

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***Abstract*— Recent research in wireless communications technologies has focused to the development of Next-generation wireless systems (NGWS) which integrate various existing wireless networks technologies, each of which is optimized for some specific services such as WLANs, WiMAX, General Packet Radio Service (GPRS) and Universal Mobile Telecommunications System (UMTS). The most important and challenging issue is to realize seamless handoffs with small handoff latency and packet loss to ensure the Quality of Service (QoS) in NGWS. In this paper, we propose a handoff management architecture using relative signal strength of the present and neighboring base stations to calculate the handoff initiation time. To take the right decision of handoff initiation time we use mobile's speed, handoff signaling delay information and also the size of the present and neighboring cell and reduce the errors associated with them. The performance analysis shows that the approach ensures successful handoff and reduces call blocking probability.**

***Index Terms*— Next Generation Wireless Systems (NGWS), Handoff, Handoff latency, BS (Base Station), MT (Mobile Terminal), Relative signal strength. HMIP (Hierarchical Mobile IP).**

I. Introduction

In order to achieve continuous communication during the mobile terminal's mobility the active call should be transferred from one cell to another potential cell. Transition of an active call from one cell to another can be assumed to be the proper definition of hand-off/hand-over process. The transfer of a current communication channel could be in terms of a time slot, frequency band, or a code word to a new base station (BS) [1-4]. A new BS assigns one of unoccupied channels for the hand-off process. However, if all of the channels are in use at the handoff time there are two possibilities: To drop the call or to delay it for a while. Different handoff techniques are proposed in literature and two of the most important metrics for evaluating a handoff technique are forced termination probability and call blocking probability.

In recent literatures, though many works are available in reducing hand-off failure probability by decreasing latency and execution times, there is no approach for incorporating error factors in the expression thereby ensuring hand-off success.

We propose such a scheme here.

I.1Handoff Initiation

It is essential to be very precise on the time of requisition for hand-off process. Otherwise unnecessary calculations need to be performed and this will result wastage of resources.

Handoff initiation is the process of deciding when to send a request for handoff. Handoff decision is based on the received signal strengths (RSS) from the current BS and neighboring BSs. In Fig. 1, we examine the RSSs of the current BS (BS1) and one neighboring BS (BS2). The RSS gets weaker as the MS moves away from BS1 and gets stronger as it gets closer to BS2 as a result of signal propagation characteristics. The received signal is averaged over time using an averaging window to remove momentary fading due to geographical and environmental factors [1-2]. Below, we will examine the four main handoff initiation techniques mentioned in [2-3]: relative signal strength, relative signal strength with threshold, relative signal strength with hysteresis, and relative signal strength with hysteresis and threshold.

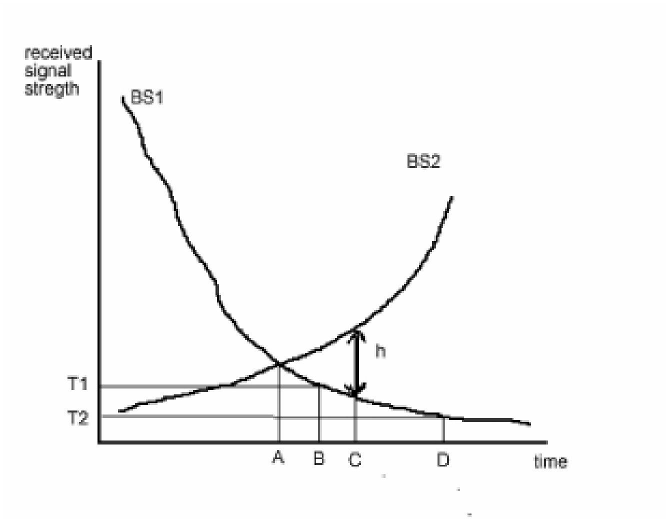

Fig.1 Movement of an MS in the handoff zone

I.2 Handoff Types

In this section we will describe the different types of handoff. First, we will concentrate on channel usage. Then, we will investigate handoff in microcells and multilayered systems. Finally, we will explain handoff in homogeneous and heterogeneous systems.

A. Hard Handoff vs. Soft Handoff

The hard hand-off can be taken as an analogy to "make-after-break" characteristics. Thus, the hard handoff term is used when the communication channel is released first and the new channel is acquired later from the neighboring cell. Hence there is a service interruption when the handoff occurs reducing the quality of service. Hard handoff is used by the systems which use time division multiple access (TDMA) and frequency division multiple access (FDMA) such as GSM and General Packet Radio Service (GPRS) [13].

Apart from a hard handoff, a soft handoff can establish multiple connections with neighboring cells. Soft handoff is used by the code division multiple access (CDMA) systems where the cells use same frequency band using different code words. Each MS maintains an active set where BSs are added when the RSS exceeds a given threshold and removed when RSS drops below another threshold value for a given amount of time specified by a timer. When a presence or absence of a BS to the active set is encountered soft handoff occurs. The sample systems using soft handoff are Interim Standard 95 (IS-95) and Wideband CDMA (WCDMA) [2, 4, 13].

B. Microcellular vs. Multilayer Handoff

This is another criteria on which handoff can be classified into. In this section we will first look at the handoff issues in microcellular environments. Later, we will investigate some systems that use microcells overlaid by macro-cells in order to minimize number of handoffs.

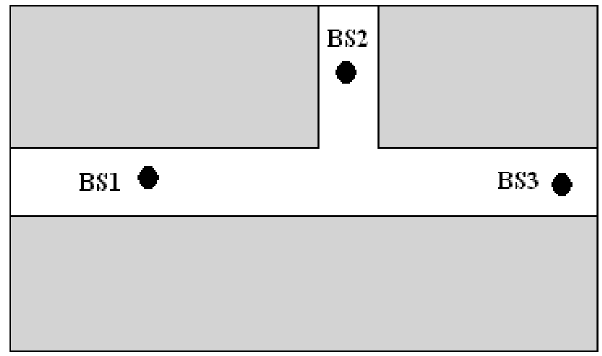

Fig. 2 A city segment with three BSs deployed on streets

1) Microcellular Handoff

Microcells are cells with small radii and employed in highly populated areas such as city buildings and streets to meet high system capacity by frequency reuse. In Fig. 2 we have two streets intersecting with three BSs employed on streets. BS1 and BS3 have line-of-sight (LOS) with each other. The handoff between BS1 and BS3 is called LOS handoff while the handoff between BS1 and BS2 is a non-LOS (NLOS) handoff since they don't have LOS [2, 4, 9]. In NLOS handoffs, when a MS lose LOS (by turning the corner) with current BS, a drop in RSS (20-30 dB) occurs [4, 9]. This effect is called corner effect and needs faster handoff algorithms since the RSS can drop quickly below receiver threshold resulting in a call drop.

2) Multilayer Handoff

Macrocellular and microcellular hand-off coverage areas can occur simultaneously. This has given rise to the multilayer approach in hand-off mechanism. It has the advantage to decrease the number of handoffs and to increase system capacity. A number of microcells are overlaid by a macrocell and the users are assigned to each layer according to their speeds. Microcells and macrocells coverage area are respectively about 500 meters and 35 km for GSM900. Since slow users are assigned to the microcells and fast users are assigned to the macrocells, the total number of handoff requests is decreased. So their co-existence is beneficial. Macrocells not only serve the fast users but also serve slow users when the microcells are congested. When a microcell allocates all of its channels, the new and handoff calls are overflowed to the macrocell layer. When the microcells load decreases it is possible to assign slow users back to the microcell. This type of handoff is called take-back. So far, we have four types of handoffs: microcell-to-microcell, microcell-to-macrocell, macrocell-to-macrocell, and macrocell-to-microcell [4].

C. Horizontal vs. Vertical Handoff

Horizontal Handoff: Handoff between two BSs of the same system.

Horizontal handoff can be further classified into:

- Link-Layer Handoff: Horizontal handoff between two BSs that are under the same foreign agent (FA), e.g., the handoff of a Mobile Terminal (MT) from BS10 to BS11 in Fig. 3.
- Intra-system Handoff: Horizontal handoff between two BSs that belong to two different FAs and both the FAs belong to the same system and, hence, to same gateway foreign agent (GFA), e.g. , the handoff of the MT from BS11 to BS12 in Fig. 3.

Vertical Handoff (Intersystem Handoff): Handoff between two BSs that belong to two different systems and, hence, to two different GFAs, e.g., the handoff of the MT from BS12 to BS20 in Fig. 3.

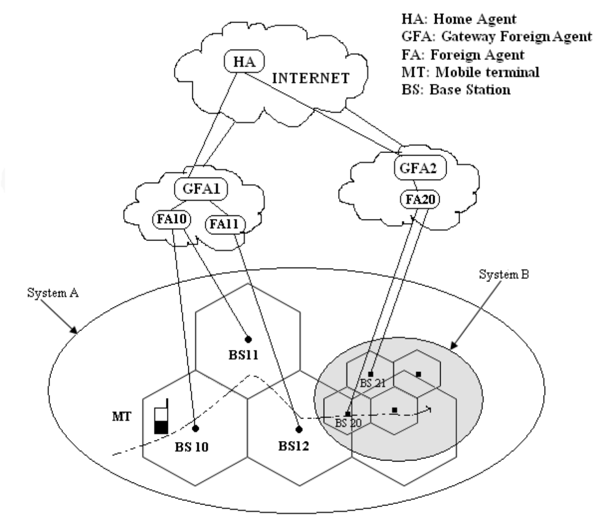

Fig3. Hand-off in the integrated NGWS architecture

II. RELATED WORK

In [5] S. Mohanty and I. F. Akyildiz proposed a cross-layer handoff management protocol for next generation wireless systems. They used mobile's speed and handoff signaling delay information to enhance the handoff performance of Mobile IP that is proposed to support mobility management in wireless IP networks. They design architecture to implement handoff management adaptive to the link layer (Layer 2) and network layer (Layer3) parameters like S_{min}, S_{ath}, d and a shown in Fig 4. Different modules of their architecture are neighbor discovery unit, handoff signaling delay estimation unit in network layer and RSS measurement unit in link layer (Fig 5)[16,17].

The neighbor discovery unit helps the MS to learn about the neighboring BSs. Handoff signaling delay estimation unit estimates the delay associated with intra and intersystem handoffs. Speed estimation unit determines mobile's speed and RSS measurement unit measures the relative signal strength of old BS and neighboring BSs. The handoff trigger unit collects information from the above three units and determines the appropriate time to start handoff. Finally the handoff execution unit starts the HMIP registration process [14].

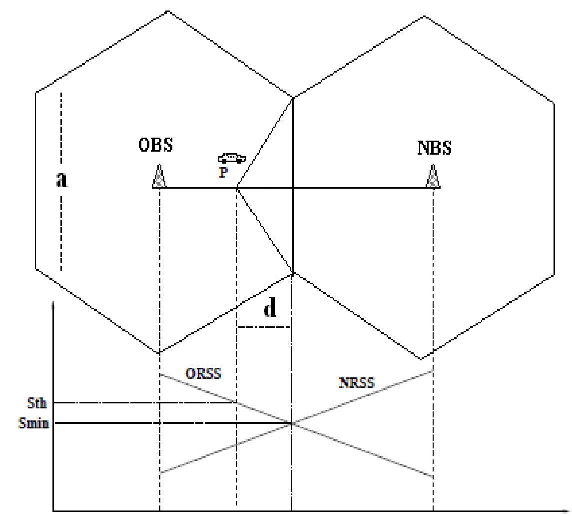

Fig 4

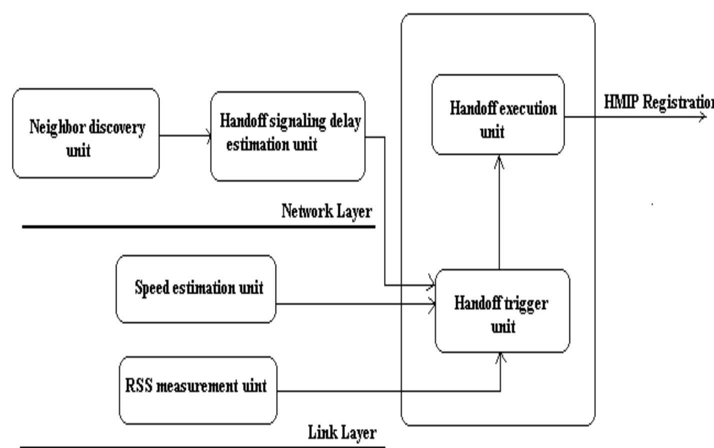

Fig5. The modules of cross-layer handoff management architecture

To reduce the false handoff probability determination of appropriate handoff initiation time is a vital issue. The handoff trigger unit determines the value of adaptive RSS threshold (Sath) to initiate the HMIP handoff procedures using speed and handoff signaling delay information. Sath is estimated as follows:

Calculation of d for a desired value of (probability of handoff failure) P_f is done using

$P_f = (1/\square)\arccos(d/vT)$; $d/v < T < \sqrt{(a^2/4 + d^2)/(v)}$,

Where *v* is MT's speed, *d* is MT's distance from the boundary of the serving BS, and T is the handoff signaling delay.[19]
This equation is a nonlinear equation of *d*. A closed form expression may not be always possible. However, an approximate value of *d* can be calculated using

$$P_f=(\cos^{-1}(d/vT))/(\tan^{-1}(a/2d))=(\pi/2-d/vT)/(\pi/2-2d/(\sqrt{4 * (d^2 + a^2)}))$$

Moreover, numerical methods can be used to calculate *d*. Here, Bisection numerical method is used [6] to solve for *d*. Once *d* is calculated, the corresponding value of Sath is calculated using the path loss model and the cell size of the serving BS. The path loss model gives by [7],

$$P_r(x) = P_r(d_0)(d_0/x)^{\alpha} + \epsilon$$

Where x is the distance between the base station and an MT, and $P_r(d_0)$ is the received power at a known reference distance (d0). The typical value of d0 is 1 km for macro-cells, 100 m for outdoor microcells, and 1 m for indoor pico-cells [7]. The numerical value of $P_r(d_0)$ depends on different factors, such as frequency, antenna heights, and antenna gains. α is the path loss exponent. The numerical value of α is dependent on the cell size and local terrain characteristics. The typical value of α ranges from 3 to 4 and 2 to 8 for a typical macro-cellular and microcellular environment. ϵ is a zero-mean Gaussian random variable that represents the statistical variation in $P_r(x)$ caused by shadowing. Typical standard deviation of ϵ is 8 dB [7]. Its actual value depends on the cell size. Using [8], the RSS value when the MT is at a d distance from the cell boundary is given by

$$S_{ath}= 10\log_{10}[P_r(a-d)]$$

Once S_{ath} is calculated, the handoff trigger unit monitors the RSS from the serving BS and sends a trigger to handoff execution unit to start the HMIP registration procedures [14] when RSS from the serving BS drops below S_{ath}.

III. PROPOSED WORK

Now every time S_{ath} becomes fixed beforehand for a fixed value of *d*. This is in accordance to the expression as given earlier
$S_{ath}= 10\log_{10}[P_r(a-d)]$
So the value of S_{ath} is very rigid and lacks robustness when an overall picture of the hand-off is mustered.
A considerable part of the handoff success depends upon correct computation of S_{ath} and its subsequent updating when any of the parameters involved in its expression gets altered as these parameters are entirely dependent on the consumer state.
Now the robustness and versatility to this method can be added using a slight modified expression for it as we incorporate the error terms in the expression.

Types of error involved:

- Error in calculation of S_{ath}.
- Inherent and non avoidable errors.
- Error due to change in the value of *d*.
- Error due to variation in different values of a.

Mathematical modifications:

Inclusion of error factor:
$S_{ath}= 10\log_{10}[P_r(a-d)]$…………………(a)
Taking the differential on both sides:
$\Delta S_{ath}=K\,\Delta d/(d-a)$…………………(b)
.where K is a constant.
The equation is represented in the above form in order to cite the nature of relation between the error arising in d and the corresponding modification in the value of S_{ath}, which comes out to be linear in this case.
Dividing (b) by (a);
$\Delta S_{ath}=S_{ath} * K\,\Delta d/((d-a)*\ln[P_r(a-d)])$
It is known that,
$S_{ath}= f(d)$
So upon incorporating the error term we get
$S_{ath} \pm \Delta S_{ath} =f(d\pm \Delta d)$
The computation for the value of S_{ath} is made beforehand and hence any change in the parameters a, *d*, in the intermediate time is not reflected and calculated while calculating the hand-off initiation instants and the hand-off failure probabilities. So the chances of hand-off failure get increased by many folds.
So if a versatile and dynamic computing mechanism is introduced which calculates the modified values of S_{ath} as it gets changed accordingly chances of false hand-off initiation and hand-off failure are decreased.
Such a method is introduced in this case in which the computation of Sath is made incorporating any error which may be due to some unavoidable factors or due to change in the state of the user i.e. the user dependent case.
This method is also useful in mobile transitions from micro-cell to macro-cell, macro-cell to micro-cell, macro-cell to macro-cell and even micro-cell to micro-cell.
Each time a new computation is being made, at first the corresponding error is calculated and this is added to the original calculation of S_{ath} made earlier.
In some literature it may be seen that the dependence of S_{ath} on d is interchangeable. Such type of discrepancies can also be removed by this method because this process provides a two way balanced and self-correcting method.
Although due to the inclusion of this method, repeated computations and subsequent modifications for S_{ath} are necessary. Inspite of such disadvantages this method becomes useful in reducIng the hand-off failure probability and in reducing the false handoff initiation process.

IV. SIMULATION RESULTS

The simulation result in Fig 6. shows the relationship between ΔS_{ath} and Δd, to be linear . Here some arbitrary values for the expression |d-a| are assumed although care is taken to see that their values are within feasible ranges. It is imperative that (a-d)>0 which we get from the logarithmic expression as given earlier. But in this case the modulus value of (d-a) is taken to simplify the nature of the graphs and in any case the negative sign might be accepted in the constant k. The nature is obviously that of a straight line. In the next simulation (Fig 7.) we have shown the nature of variation of $S_{ath} \pm \Delta S_{ath}$ with f(d$\pm$ Δd) according to the derived relation given in the previous section. The graphs show some varying adaptable values which shows the versatility and robustness of the expression derived in this article. In this case it may be noted that there may be different methods for calculation of the error and subsequent incorporation of it in the expression as proposed earlier. Such methods vary in different cases but the operation and execution time must be within limits which ensure hand-off success.

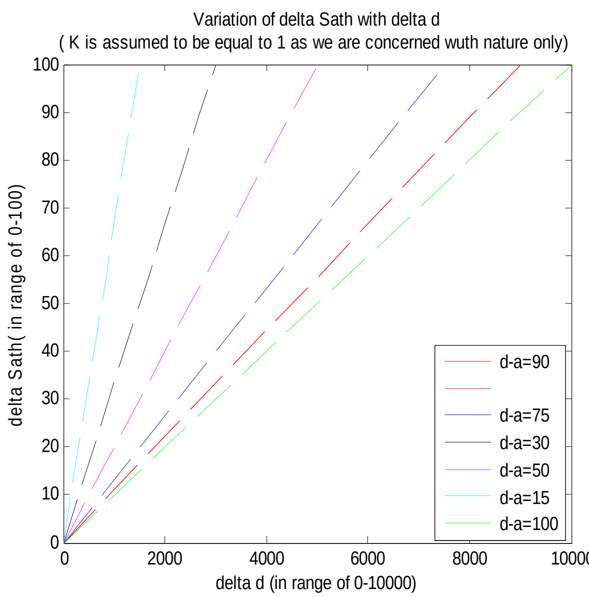

Fig 6.

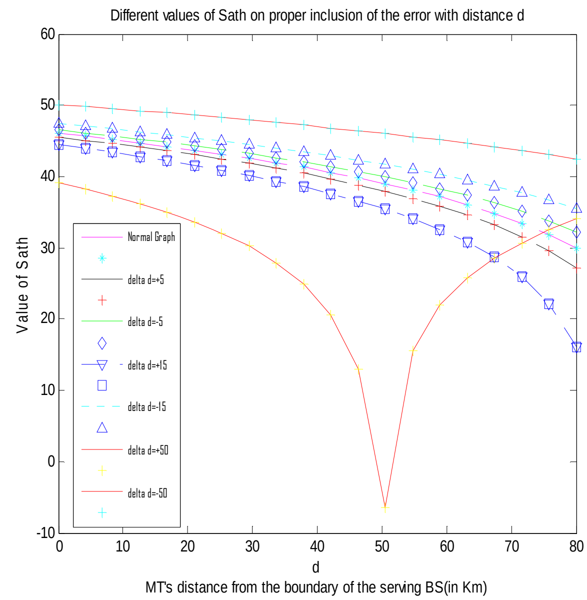

Fig7

V. CONCLUSIONS AND FUTURE WORK

Hence it can be concluded that by incorporating the error term in the equation devised for the hand-off threshold, the expression gets modified to a more versatile, robust, self-adaptable and precise equation which although increases the computation time to more or less ignorable magnitudes but ensures greater success of hand-off process and reduces the probability of false-hand-off.

Fields are open even to integrate a statistical correlation analysis for the hand-off mechanism which is a further addition to the given analysis. For proper correlation technique and its implementation we need more mathematical approach.

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