Cellular handover approach for better efficiency in 3G cellular system

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Abstract- With the advancement of technology, mobile devices nowadays incorporate multiple Radio Access Technologies (RAT). So, switching from one RAT to another becomes obvious. This procedure is called vertical handover. Universal Mobile Telecommunication System (UMTS) and Wireless Local Area Network (WLAN) are two such networks whose interoperability is being studied for years. WLAN covers relatively smaller area but provides a high data rate, on the other hand, UMTS covers a larger area but has comparatively lower data rates. We know heavy load on a particular cell can deteriorate its performance. Therefore, both the networks can co-ordinate to facilitate each other if loads of their neighboring cells are quite high. In this work we propose a dynamic load balancing heuristics using adaptive handover thresholds, which adapts as per the traffic load in a given cell. This can improve the service provided to the end users who are at the edge of the cell or closer. The metrics for performance considered in this work are outage probability and handover area.

Index Terms- Adaptive Hysteresis, Adaptive Threshold, Cell breathing, Load balancing, Vertical Handover Algorithm..

I. INTRODUCTION

Since the rollout of 3rd Generation (3G) cellular systems, the network providers have experienced an ever-growing subscriber base. In today's era where everyone wants to remain connected to the network seamlessly, the network operators find it difficult to manage the overall traffic load. Therefore, if heterogeneous networks co-ordinate to share load then better performance can be achieved. Two such networks considered here are Universal Mobile Telecommunication System (UMTS) and Wireless Local Area Network (WLAN). UMTS provides data rates of 384 kbps to 2 Mbps whereas WLAN provides data rates of up to 54 Mbps. Hence, co-ordination with WLAN can help UMTS users achieve higher data rates. On the other hand, UMTS provides wide-area coverage, so, coordinating with it, WLAN, which has comparatively smaller coverage area can provide seamless connectivity to its users on the move.

The concept seems feasible in today's era because there are cities in some countries where there are areas are intended to be completely Wi-Fi (or WLAN) enabled. Wirelessness seems to be the buzz word of the current generation. As such with the enhancement of wireless security the WLAN has also crossed the traditional walls of college campuses, airports, offices etc.

As the literature survey mentions, the concept of vertical handover is not novel and has been accepted and used since a decade or more. As we know, a well-known vertical handover is one that takes place between Global System for Mobile communication (GSM) and UMTS in majority of places because the rollout of UMTS or 3G spectrum was in phases, in most of the geographies. In this work vertical handover between UMTS and WLAN is being studied. The algorithm has been equipped to adapt the Received Signal Strength (RSS) threshold according to the load of the cell. The load of a cell causes major signal attenuation to the users who are there at the edge of the cell or in the vicinity.

Nowadays users not only want to remain connected to the network but also want to experience the best service. Always Best Connected (ABC) [3] is the basic idea behind most of the algorithms today. So, the users close to the border of the serving cell even need to be served as the ones closer to the centre of the cell. Keeping this in mind the handover algorithm measures the RSS and compares it against calculated hysteresis and threshold values to make the decision for handover. Any handover procedure can be divided into three phases [2]: a) Measurement, b) Decision and c) Execution.

a) Measurement Phase: In the measurement phase necessary parameters such as RSS, data rate, user preference etc., are taken into consideration for measurement to make the handover decision.

b) Decision Phase: In the decision phase measurement results are compared against the predefined or pre-calculated thresholds and then it is decided whether to initiate the handover or not. Different handover algorithms have different trigger conditions.

c) Execution Phase: In the execution phase, the handover process is completed and the relative parameters, such as operating frequency etc. (if required) are changed according to the different types of handover.

When a cell has low traffic then it can serve a larger area. On the other hand, with the increase in traffic the cell tends to serve a relatively smaller area. This is called cell breathing [6]. Also, with the increase in traffic load in a particular cell the performance of that cell or in other words, the RSS for each Mobile Station (MS) deteriorates. Therefore, the adjacent cells, which have lower load can co-ordinate to share the load. The threshold at which handover is to take place can be set according to the load of that particular cell.

II. MATERIALS AND METHODS

There are several factors responsible for handover initiation to take place [5]. RSS and hysteresis are some of the parameters which serve to decide for the handover to take place. Several algorithms mentioned in the literature have used these parameters. Nevertheless, when heterogeneous networks are taken into consideration then signals of two different networks cannot be compared [1]. Therefore, normalized power from the two networks is taken into consideration for comparison.

System Model:

The Third Generation Partnership Project (3GPP) mentions the UMTS network as UMTS Terrestrial Radio Access Network (UTRAN) [20]. UTRAN consists of NodeB, also referred to as base station in case of GSM. NodeB provides the services of the UMTS network to the MS. Similarly, the WLAN network has an Access Point (AP), which provides services to the devices under that network. The MS here is considered to move with constant speed from NodeB towards the AP in linear motion. Meanwhile, the RSS is calculated for the MS, which it receives from NodeB as well as AP. The service point for a MS should be single (i.e. either NodeB or AP) but it can listen to both simultaneously.

The signal transmitted from NodeB (or AP) faces several attenuations. The attenuation is modeled as follows [8]:

$$\alpha(d, \zeta) = d^{\eta} 10^{\zeta / 10} \qquad (1)$$

Here, d is the distance in meters of the MS from its service point, η (eta) is the path loss exponent and ζ is the attenuation component due to shadowing [21]. If the losses are to be written in dB, then (1) can be modified as follows [8]:

$$\alpha(d, \zeta)[\mathrm{dB}] = 10\eta \log d + \zeta \qquad (2)$$

The transmitted signal from NodeB or AP faces the above mentioned attenuation therefore the signal strength received (or RSS) can be expressed as follows [1]:

$$S(d) = P_t - \alpha(d, \zeta) \qquad (3)$$

Where, P_t is the transmitted signal strength in dBm from the NodeB or AP, $\alpha(d, \zeta)$ is the total attenuation and S(d) is the RSS.

The RSS is compared against a threshold value, which in turn is computed via a uniform quantizer. The quantizer takes the load of the cell and signal attenuation threshold (sat) for that load level as inputs and computes the threshold value for a given load level. This is the adaptive threshold, which varies according to the load level.

$$T_{adt} = Q\,(sat, l) \qquad (4)$$

Here T_{adt} is the adaptive threshold in dBm for a given load level l and a predefined signal attenuation threshold (sat) in dBm, for that given load level. T_{adt} is the instantaneous threshold for a given cell, a given load level at a given time. The mobile stations refresh the value of T_{adt} stored with them repeatedly at an interval of 1 sec in anticipation of mobile stations entering or exiting a given cell. T_{adt} is separately calculated for UMTS and WLAN cells by NodeB and AP respectively. The uniform quantizer Q is a function that accepts two inputs as described above and uses floor and ceil functions to find the quantization step. On the basis of the outputs from the floor and ceil functions the final quantized value i.e. T_{adt} is produced.

Many algorithms mentioned in literature use the uniform quantizer to build dynamic load levels [4]. The concept of dynamic load level sounds great but dynamicity has its own costs. It's so because constructing the load levels dynamic can cause further deterioration of services to the NodeB (or AP) which is already struggling with heavy traffic load. Hence, predefined load ranges can combat the problem of heavy traffic load better. Further, looking into the patterns of traffic load the load levels can be changed by the network administrator as per the usage.

In order to lessen the attenuation due to shadow fading in the RSS a rectangular window is used as follows [1]:

$$S(k) = \frac{1}{N_w} \sum_{n=0}^{N-1} S(k-n)\, W_n \qquad (5)$$

Here the LHS of the equation (5) represents the averaged signal strength and S(k – n) in the RHS represents signal strength before the averaging process. W_n (n=0, 1, 2…) is the weight assigned for each signal strength value. N is the number of samples taken into consideration for the process of averaging. N_w can be given by the following equation [1]:

$$N_w = \sum_{n=0}^{N-1} W_n \qquad (6)$$

As a common practice, if we consider rectangular window then $W_n = 1$ for n=0, 1, 2…

Further, Gauss-Markov assumption can be used to approximate the shadowing process [7]:

$$x[i] = a x[i-1] + \sqrt{1 - a^2}\, n[i] \qquad (7)$$

Here, x[i] represents the shadowing, a is the coefficient of correlation and n[i] is the Additive White Gaussian Noise (AWGN) with N(0, 1). Shadowing is always described with a random variable whose logarithm is normally distributed [7]. So, N(0, 1) represents the same.

The data rate is important for a network to outperform other networks. Shannon's theorem serves the best when it comes to calculate the data rate as a function of bandwidth (B) and signal-to-noise ratio (SNR) [1]:

$$DR = B * \log_2 (1 + S/N) \qquad (8)$$

Here DR is data rate in bps and S/N is the average signal power to average noise power.

Algorithm:

Each cell (NodeB or AP) updates its handover threshold based on its load as mobile stations enter or exit the cell. When the load of a certain cell is high, a high threshold value gets computed; otherwise, a low threshold value gets computed.

Different load levels such as L_1 to L_{i-1}, Li to L_{k-1} …L_j to L_n are constructed such that the load of each cell belongs to one or other load level. Corresponding to each load level a predefined sat (signal attenuation threshold) is set. This sat_j and load l_i is offered as input to the uniform quantizer.

1) The uniform quantizer uses two functions, namely floor and ceil to compute the high and low values for a particular sat_j.

$$high = ceil(sat_j) \qquad (9)$$

$$low = floor(sat_j)$$

2) These two values serve to calculate the quantization step for the quantization process.

$$qstep = (high - low) / l_i \qquad (10)$$

After further calculation the output of the quantization process comes out as T_i.

$$T_i = Q\ (sat_j, L_i),\ i=1,\ 2\ldots.. \qquad (11)$$

3) T_i is the instantaneous value of T_{adt} in dBm which becomes the adaptive threshold for that cell at that particular load. T_i and as a consequence T_{adt} are updated by in or out movement of mobile stations.

4) When the normalized power of the MS received from the WLAN cell, RSS_{WLAN} (in dBm) exceeds the normalized power received from the UMTS cell, RSS_{UMTS} (in dBm) the MS enters the Handover Ready state:

$$RSS_{WLAN} > RSS_{UMTS} \qquad (12)$$

Data rate plays an important role in selecting the network in case of Wireless Heterogeneous Networks (WHN).

5) If data rate in WLAN (DR_{WLAN}) in bps, becomes higher than data rate in UMTS (DR_{UMTS}) in bps, and RSS_{UMTS} falls further below T_{adt} then the MS is handed over to WLAN.

$$RSS_{UMTS} < T_{adt} \text{ AND } DR_{WLAN} > DR_{UMTS} \qquad (13)$$

6) An MS in WLAN enters Handover Ready state when the following condition occurs [1]:

$$RSS_{UMTS} > RSS_{WLAN} + \textit{hys margin} \qquad (14)$$

where,

$$\textit{hys margin} = \max\{20[1 - (X/R)^4], 0\} \qquad (15)$$

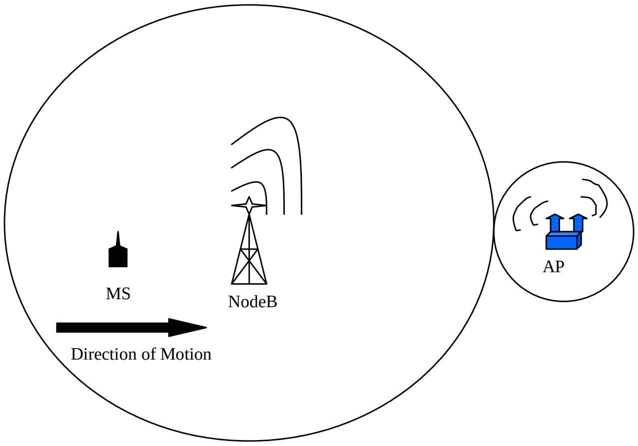
X is the distance of MS in meters from WLAN Access Point.
R is the radius of the WLAN cell in meters.
hys margin is in dBm.

7) The mobile station is handed over to UMTS if the following condition occurs:

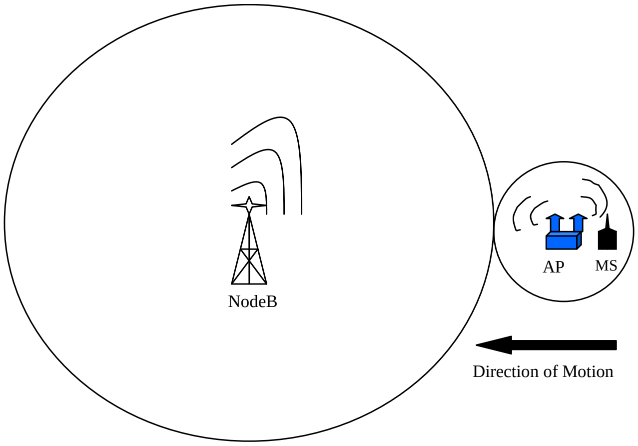
$$RSS_{WLAN} < T_{adt} \text{ AND } DR_{UMTS} > DR_{WLAN} \qquad (16)$$

Methodolgy: Fig.1 shows a scenario that has been considered initally to begin with. Here a single MS is shown to move from UMTS network to the WLAN network. As shown NodeB covers a larger area and AP covers a smaller one. The direction of the motion considered here is from left to right of the observer. The MS while moving keeps operating with RSS_{UMTS} and simultaneously measures RSS_{WLAN}. In this way the MS would be in a position to know which value of RSS exceeds which. Also the respective datarates are taken into consideration. Both these factors would be used to make the handover decision. One other parameter that needs to be calculated is the value of adaptive threshold, T_{adt}. The calculation of T_{adt} is done by NodeB and AP separately, for their respective cells. All the mobile stations fetch this value at an interval to 1 sec.

Scenario 1 comprising of single MS in UMTS network

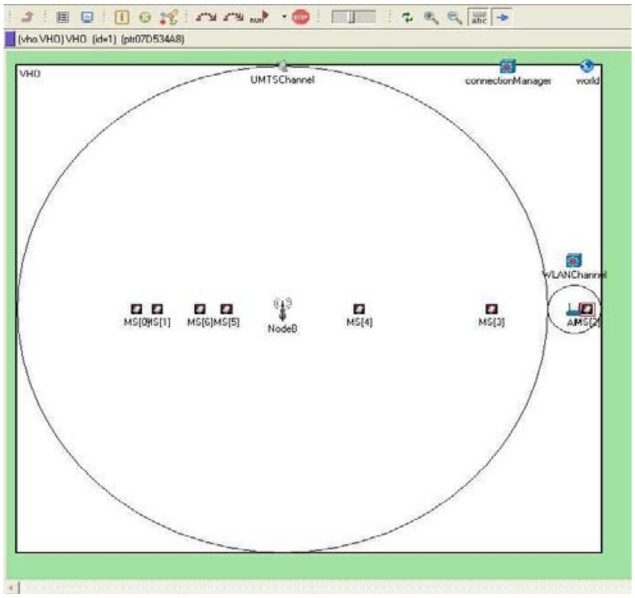


Similarly, there can be a scenario just reverse to the previous one where the MS travels from the WLAN network to the UMTS network. This is shown in Fig 2.



Scenario 2 comprising of a single MS in WLAN network.

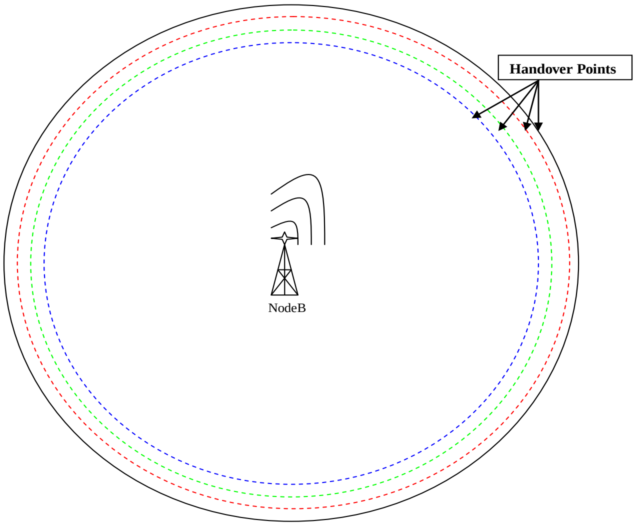
Similar considerations can be made for this scenario as well where the MS utilizes the RSS_{WLAN} and keeps sensing the RSS_{UMTS}. The above scenarios seem hypothetical since the work is all about the load of the networks. But this understanding can be ruled out by the fact that whatever the load of the network be it would definitely fall in some or the other load level and would definitely have some or the other T_{adt}. In this fashion multiple scenarios have been built, increasing the number of mobile stations and setting different directions of motion for them. Fig. 3 shows a scenario which is an exact snapshot from the simulator itself.



A scenario with seven MS in different networks.

Fig. 3 shows seven mobile stations, from which some are moving from UMTS to WLAN network while others are moving in opposite direction. The larger circle represents the UMTS coverage whereas the smaller one shows the WLAN coverage. At the center of the WLAN cell is the AP and the center of the UMTS cell is held by NodeB. The scenario above is shown to illustrate a fact that with the increase of the load in a cell there is chase for resources such as frequency, data rate, RSS etc. This chase becomes higher as we move towards the edges of the cell because RSS fades exponentially as we move away from the NodeB/AP. Hence, we in our current work propose a dynamic load balancing heuristics which adapts in accordance to the load of the cell. At low load levels the value of T_{adt} remains low so the mobile stations are served till the edge of the cell or closer. On the other hand this value is kept high at high load levels so that mobile stations are handed over much before the edge of the cell, to serve them better (The value of T_{adt} is negative so the concept of low and high value should not be misunderstood ref. Fig. 7). This fact is quite aligned to the concept of cell breathing.

The concept of cell breathing states that the cell area is larger if its traffic is low on the other hand the cell area is smaller if the traffic is high [6]. We presently in our work propose a model which tends to handover mobile stations earlier to adjacent cells if the traffic load of the cell is high. Conversely, the mobile stations are served till the border of the cell or closer when the traffic load is low. So the methodology we tend to propose is explained by the following figure.



Different serving regions for different traffic loads.

Fig. 4 clearly shows what we were describing till now. In order to keep it simple only few cases are considered here and only NodeB is shown to serve the mobile stations. At low load level the NodeB tends to serve till the red dotted line sometimes may be even till the edge of the cell marked black. At a higher level than this, the model hands over the mobile stations to the adjacent cells at the green dotted circle. At yet another higher level of load the mobile stations are handed over at the blue dotted circle. The points on the differently colored circles can rightly be called handover points, as these are the places where the mobile stations are handed over to adjacent cells. The dimension of these circles is not fixed. It can vary in accordance to the load levels set. At a particular load level only one circle operates actively. This is achieved by varying the value of T_{adt} which causes the mobile stations to handover at the point till where they can be served best.

The model proposed is made to run 100 times for each scenario. Around 85 scenarios have been simulated and the results have been recorded for the same. Each run takes different time period to complete depending on the number of mobile stations. For instance scenario one and two shown in Fig.1 and Fig. 2 take less time to complete than the scenario in Fig.3. During each run each MS has a starting co-ordinate. The run is said to complete when each MS completes one full round from its starting point to the right (or left) of the observer back to its starting point then to the left (or right) of the observer and finally back to its starting point. The direction of each MS (i.e. moving left or right) can be set in the initialization file.

Performance Metrics: The following metrics for performance are taken into consideration:

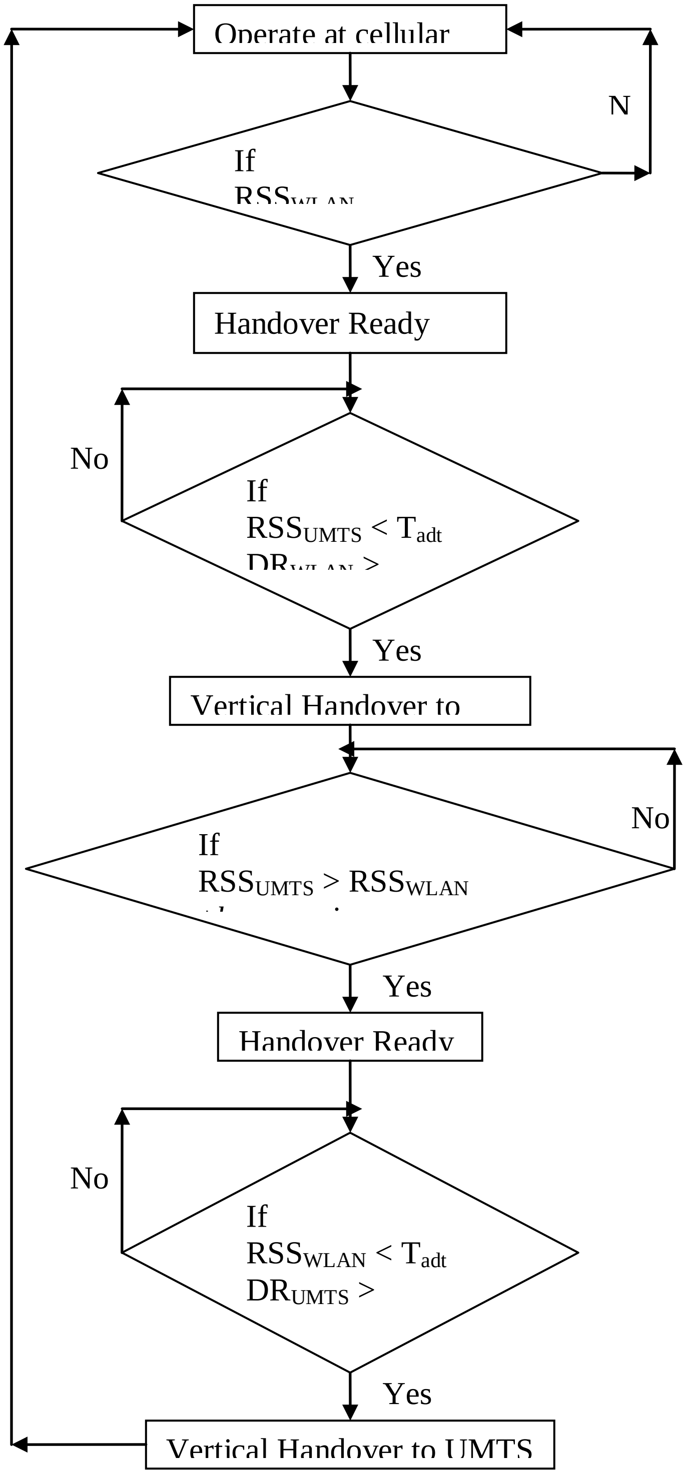
Outage Probability: Outage refers to the period of time when the MS receives insufficient signal strength or fades. The outage probability calculates such occurences during a period of time. Outages should be less or none in context to ABC.

HandoverArea: The region covered by the MS from handover initiation phase to final handover execution phase. This area should be optimal such that neither it allows a quick handover nor it causes unnecessary delay in handover.

III. RESULTS AND DISCUSSION

A. Flowchart:

Fig. 5 illustrates the flowchart, which gives the overview of the algorithm that is used for vertical handover.



Flowchart for adaptive vertical handover algorithm

B. Tables and figures:

In order to obtain the various numerical results OMNet++ 4.2.2 is used as a network simulator. Various system parameters are kept as close as to the ones used by the actual network providers. Table I. displays the UMTS network parameters set in the simulator. The radius of the UMTS cell, power transmitted by the NodeB and the bandwidth provided by the UMTS network are tabulated.

[UMTS Parameters

S.No.	Various UMTS Parameters	
	Parameter Name	***Value***
1.	Radius of Cell.	1000 m
2.	Power Transmitted from NodeB	30 dBm
3.	Bandwidth	5 MHz

Table II. displays the WLAN network parameters set in the simulator. Similarly, in this table the radius of the WLAN cell, power transmitted by the access point and the bandwidth provided by the WLAN network are displayed.

WLAN Parameters

S.No.	Various WLAN Parameters	
	Parameter Name	***Value***
1.	Radius of Cell.	100 m
2.	Power Transmitted from NodeB	0 dBm
3.	Bandwidth	20 MHz

Table III. displays the parameters set in the simulator which are common to both the networks. The correlation coefficient rho (□) and eta (□) used for shadowing calculation are shown. Also the distance between NodeB and AP and the sampling distance are mentioned.

Common Parameters

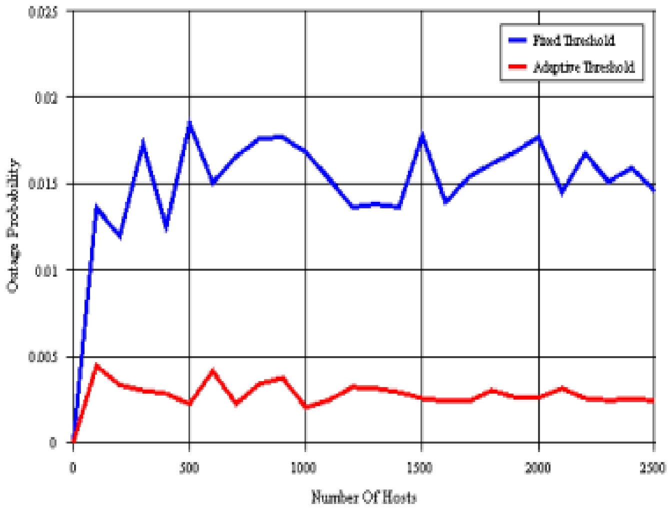
S.No.	Common Parameters	
	Parameter Name	***Value***
1.	Correlation coefficient (□)	0. 5
2.	Eta (□)	3. 6
3.	Distance between NodeB and Access Point.	1100 m
4.	Sampling distance	10 m

Fig. 6 displays the outage probability against the number of hosts for fixed and adaptive thresholds, respectively in the network. It can be easily discerned that the outage probability is low for adaptive threshold whereas comparatively high for fixed threshold.

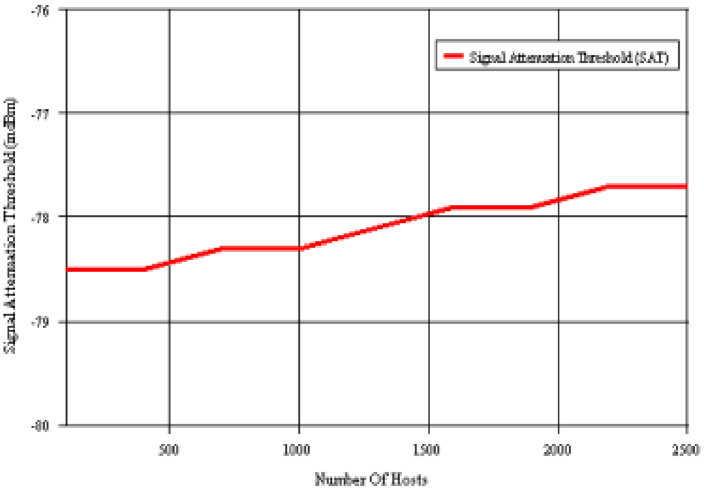
Fig. 7 shows the plot of variation of Signal Attenuation Threshold (SAT) vs. number of hosts. The graph shows that with the increase in the number of hosts in the network the SAT is quantized to a level, which is more easily achievable, by the hosts of the network to switch to the adjacent cell with higher

RSS. This graph illustrates the concept of cell breathing discussed earlier. The concept of high and low (negative) values for RSS threshold or SAT stated earlier can be understood clearly looking at Fig. 7.

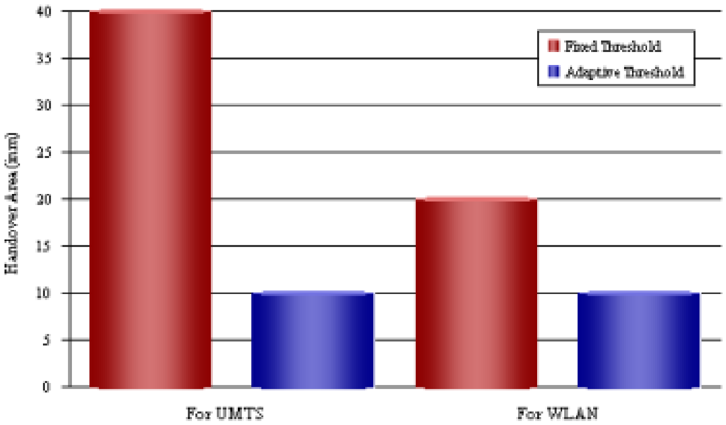
Fig. 8 shows the handover area for fixed and adaptive threshold for both the networks respectively. Clearly, the mobile stations cover more area to handover to adjacent cell in case of fixed threshold than adaptive threshold in case of both the networks. A large handover area can cause a high ping pong effect. In case of UMTS network, the adaptive threshold algorithm takes around one-fourth the area of the fixed threshold algorithm whereas in case of WLAN it takes half the area.



Outage Probability Vs Number Of Hosts



Adaptive Threshold Vs Number Of Hosts



Handover Area for UMTS and WLAN using Fixed and Adptive threshold algorithms

Looking at the above results, we can easily infer that the adaptive threshold algorithm works much better than the fixed threshold algorithm. The algorithm also includes load balancing which is a problem faced by most of the network providers nowadays. The algorithm enables a cell to adapt its coverage area according to its load. Heavy load causes the cell to shrink whereas the cell serves normally during low load conditions. The work here lays road for the future generation networks to coordinate with each other to share their load.

IV. ACKNOWLEDGMENT

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