Abstract— It is commonly accepted that the problem of network congestion control remains a critical issue and a high priority, especially given the growing size, demand, and speed of the increasingly integrated services networks. This is where the need for an intelligent multi criteria handoff algorithm becomes apparent. Efficient load balancing algorithm is important to serve more mobile stations in the diverse wireless networks.

This paper presents the design and implementation of a fuzzy multi-criteria handoff algorithm based on signal strength, path-loss and traffic load of base stations and the received signal to interference ratio as to balance traffic in all the neighboring sites at any time. This can be achieved by using Fuzzy Logic. The algorithm would balance traffic between neighboring sites and improve the performance of the overall network.

Keywords— Congestion, Fuzzy Logic, Handoff, Path loss, Received Signal Strength

I. INTRODUCTION

A. Cellular Telephone Systems

Cellular systems are extremely popular: these are the systems that ignited the wireless revolution [1]. Cellular systems provide duplex voice and data communication with regional and national coverage. The basic premise behind cellular system design is frequency re-use pattern, which exploits the fact that signal power falls off with distance to re-use the same frequency spectrum at spatially separated locations. The coverage area of a cellular system is divided into non overlapping cells theatrically where a set of channels is assigned to each cell according to density of subscriber [1]. This same channel set is used in another cell after some distance away, as shown figure 1.

Operation within a single cell is controlled by a centralized base station. The interference caused by mobile users in different cells operating on the same frequency set is called inter-cell interference. The re-use factor of cells that use the same channel set should be as small as possible so that frequencies are re-used as often as possible, thereby increasing spectral efficiency. However, as the re-use distance decreases, the inter cell interference increases, because of the smaller propagation distance between those interfering cells.

Since inter-cell interference must remain below a given margin for tolerable system performance, re-use distance cannot be reduced below some minimum threshold margin. In practice it is difficult to determine this minimum value since both the transmitting and interfering signals experience arbitrary power variations due to the characteristics of wireless signal propagation. So as to get the best re-use distance, an accurate characterization of signal propagation within the cell is needed [1].

The wireless radio channel possesses a harsh challenge as a medium for reliable communication. Wireless radio channel is not only exposed to noise and interference but these impediments change with time in random ways due to user movement [1]. The ultimate goal of any wireless networks is to provide global connectivity with efficient ubiquitous computing to these mobile stations (MSs) based on the always best connected principle [2].

Mobile Station (MS), in the presence of these random networks with overlapping cellular coverage, can connect to any of these wireless access technologies. When a mobile terminal moves away from a base station, the signal level drops and there is a need to switch the communications channel to another base station. That time there is a need for a handoff to be executed [3]. Handoff is the process of changing the communications channel associated with the current ongoing connection while a call is in progress [3].

Many metrics have been used to support handoff decisions, including received signal strength (RSS), signal to noise ratio (SIR), power budget, and distance between the mobile station and base station, traffic load, mobile velocity and among others [4]. The single criteria handoff decision compares one of the metric from the serving base station with that from one of the neighboring base stations, using a...
constant handoff threshold value [5]. The selection of the threshold is important to handoff performance. If the threshold is too small, many unnecessary handoffs may be take place. On the contrary, the quality of service could be low and calls could be dropped if the threshold is too large [4]. A multi-criteria handoff algorithm can provide better performance than a single criterion handoff algorithm due to the extra number of evaluation parameters and the greater potential for achieving the desired balance among different system characteristics. This multi-criteria nature of the algorithm allows simultaneous consideration of several significant aspects of the handoff procedure in order to enhance the system performance [3].

Despite of many years’ research hard work, the problem of network congestion control remains a serious issue and need attention, given the growing size, demand, and speed of the networks. Network congestion is becoming a real threat to the growth of existing real time networks and of the future deployment of communication networks. This has stimulated strong research activity in the field of Self-optimizing Networks (SON) [4], [6] - [9], [11]. A major issue addressed by Self-optimizing network is the uneven allocation of cellular traffic.

B. Load balancing

Load balancing can be used to explain any mechanism whereby loaded base station (BTS) distribute some of their traffic to less loaded neighbors BTS in order to make the use of the radio resource more efficient across the whole cluster network [12].

There are a number of methods to balance traffic load among BTS. One of the most important methods is based on antenna down tilting [13]. With the down tilt, one directs the antenna radiation further down to the ground. The down tilt is advisable when one wishes to decrease interference and coverage in some specific areas, having each BTS to meet only its designed area. When selecting the optimum tilt angle, the goal is to have as high signal strength as possible in the area where the BTS should be serving traffic [13]. Beyond the serving area of the BTS, the signal strength should be as low as possible. A too aggressive down tilt strategy will however lead to an overall loss of coverage and would create coverage holes which eventually lead for call drop.

The second method is to adjust the BTS coverage by varying transmitter power [14]. A minimal transmitter power effectively disallows more distant mobiles to access the BTS, thereby decreasing the coverage area and prohibit distant mobile users to access the BTS. Hence, reducing BTS coverage area runs at the danger of creating coverage holes. Having the coverage holes on the cellular system adversely affect the performance of cellular system leading to call drop. Conversely maximum transmitter power allow mobile at distance to access the BTS, at the cost of producing interference on those BTS using the same frequency.

The antenna height is the fundamental of BTS coverage area. If the antenna height is increased path-loss is reduced and decreasing the antenna height path-loss increases. The relation between antenna height and coverage area is stated on two ray model [1]. If antenna height is doubled, then coverage would be increased by 6db [1].To prohibits the distant mobile user from accessing BTS, reducing the height of antenna is good alternative.

Another way to balance the load is to adjust the handoff regions between neighboring BTS. Such an approach is referred to as mobility load balancing. The theory behind mobility load balancing is to adjust the handoff regions by biasing the handoff measurements, causing cell edge users in highly loaded cells to migrate to less loaded neighbor cells, thereby increasing the efficiency of resource utilization [15].

However, all the above techniques of load balancing are not self adaptive, due to complex process of mobility and load distribution can change any time. The problem of network congestion control remains a critical issue and a high priority, mainly given the growing size, demand, and speed of the networks. Therefore, Network congestion is becoming a real threat to the growth of existing real time networks (circuit switching). It is a problem that cannot be ignored.

C. Conventional Handoff Algorithms

Normally received signal strength (RSS) based on the measurements are considered for its simplicity. The conventional handoff decision compares the received signal strength from the serving base station with that from the one or more of the neighboring base stations, using a constant handoff threshold [11]. However the fluctuation of the signal strength result in ‘ping pong’ [4].

With conventional algorithm, looking at the variation of signal strength from either base station it is possible to tell X3 optimum area where handoff can take place. However, the conventional algorithm with hysteresis allows a Mobile Terminal to make handoff decision only if the RSS received from the neighboring base stations is sufficiently stronger than the current one by the specified hysteresis margin. With the later, one can set the constant hysteresis value to vary the handoff region between X3 and X4.

D. Proposed multi criteria handoff algorithm based on fuzzy logic

Fuzzy logic reasoning scheme is applied for mapping of non-linear data set to scalar output figure. When the problems are with doubt and ambiguity, then to anticipate the correct value among all uncertainties, then fuzzy logic is selected. Fuzzy logic develops computational techniques that can carry out reasoning and problem solving tasks that requires human intelligence [10]. Thus, fuzzy logic is used to choose the optimal serving base station amongst given neighboring base stations for handoff decision founded on
the multiple parameters as crisp inputs and give the best possible answer to choose the best base station.

The four input parameters considered are: Received Signal Strength (RSS), power budget, received signal to noise ratio (SNR) and traffic load of the base station.

The only output parameter of the fuzzy inference system is handoff decision. In the proposed algorithm the range of received signal is taken to be -50dbm to -100dbm, the path loss varies from 20db to 80db, the SNR ranges from the lowest 10db to highest 30db. The range of the base station traffic load range from 0 to 100%.

1) Fuzzification

In the first step of the handoff process, the model would collect the parameters like received signal strength, path loss, the received signal to noise ratio and traffic load of the base station and feed into a fuzzifier. The fuzzifier transforms real time measurements into fuzzy sets. In order to improve the reliability and robustness of the system, Gaussian membership functions (MFs) are used as an alternative to triangular MFS. For instance, if RSS is considered in crisp set, it can only be weak or strong. It cannot be both at a time. However, in a fuzzy set the signal can be considered as weak signal and medium at same time with graded membership. The membership values are obtained by mapping the values obtained for particular parameter into a membership function.

2) Fuzzy Inference

The second step of handoff process involves feeding the fuzzy sets into an inference engine, where a set of fuzzy IF-THEN rules are applied to obtain fuzzy decision sets. These set are mapped to the corresponding Gaussian membership functions. Since there are four fuzzy inputs and each of them has three subsets so there are \(3^4=81\) rules. Fuzzy rules can be defined as a set of possible scenarios. For simple understanding, the set (No Handoff, Wait, Be Careful, Handoff) are used to represent the fuzzy set of output handoff decision, the range of the decision matrix is from 0 to 1, where 0 is no handoff and 1 is exactly handoff.

3) Defuzzification

Finally, the output fuzzy decision sets are aggregated into a single fuzzy set and passed to the defuzzifier to be converted into a precise quantity during the last stage of the handoff decision. The centroid of area method is elected to defuzzify for changing the fuzzy value into the crisp set [10].

II. SIMULATION USING MATLAB

For system simulation Mam-dani Fuzzy Inference system is proposed due to fact that Mam-dani method is well suited to human input and the nature of wireless is non-linear. Fuzzy inference gather the input values of received signal strength, path loss of the received signal, signal to noise ratio (SNR) of the received signal and the load of the base station from event collector as crisp inputs and then evaluates them according to the fuzzy interference rules base. The composed and aggregated output of rules evaluation is defuzzified using the centroid of area method and crisp output is obtained [10].

Figure 3 to 6 show the fuzzy input variable for RSS, path loss, the load of the base station and SNR respectively. Each of the fuzzy input variables has three subsets. These sets are mapped to the corresponding Gaussian membership functions. Since there are four fuzzy inputs and each of them has three subsets so there are \(3^4=81\) rules. The fuzzy IF-THEN rules provide knowledge to the system and decide a handoff is necessary or not.

II. SIMULATION USING MATLAB

The fuzzy set values for the output decision variable handoff decisions are no handoff, wait handoff, be careful handoff and handoff. The universe of discourse for the variable handoff is defined from 0 to 1. Where 0 is no handoff and 1 is definite handoff.

III. RESULT AND DISCUSSION

Figure 7 shows the received signal strength from base station \(i\) decrease as MS moves from the base station \(i\) to
ward base station $j$, while the received signal strength from base station $j$ increases. In the middle between these base stations, MS gets an ideal boundary where the received signal strength is equal. This is handover region where conventional handoff takes place to keep the connection. The conventional handoff algorithm cannot handoff the mobile station from base station $i$ to base station $j$ unless on the ideal boundary, even if the base station $i$ is fully congested and base station $j$ has no users on the entire coverage area.

However, with the proposed algorithm, it is possible to handoff from base station $i$ to base station $j$ when the load of base station $i$ has high load and base station $j$ has medium load or low load.

![Signal Strength](image)

**Figure 7** Received signal strength from base station $i$ and $j$

For example from Figure 7, when a MS receives signal strength of -70dbm from base station $i$, it will receive -90dbm from base station $j$. The path loss will be 40db and 60 db respectively for base station $i$ and $j$, for transmission of -30dbm transmitter power. At any particular time, it is assumed, a MS receives SNR of 20db for both base stations.

For the handoff threshold of 0.5, MS can handoff from base station $i$ to $j$ for traffic load of above 75% on base station $i$ only when the traffic load of base station $j$ is less than 75% (Figure 8), though there is 20db difference between the received signal from base station $i$ and $j$.

![Figure 8 comparison of handoff for varying load between base station $i$ and $j$](image)

On the ideal boundary, when a MS receives signal strength of -80dbm from either side, the path loss will be 50db for base stations for -30dbm transmitter power. As shown on Figure 9, a MS can handoff from base station $i$ to $j$ for traffic load of above 75% on base station $i$ if and only if base station $j$ has less than 75% of traffic load.

This shows how the algorithm distribute traffic among all the neighboring sites make better resource utilization and improve the performance of the overall network.

![Figure 9 comparison of handoff for varying load between base station $i$ and $j$](image)
REFERENCES


