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Cellular System Handoff optimization using Fuzzy Logic implementation

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***Abstract*—This paper aims at optimizing the hand off decisions of a cellular communication system in order to reduce the burden on the mobile switching centre by curbing the unnecessary handoffs as well as forced call terminations due to insufficient time to perform handoffs by utilizing the principles of fuzzy logic. The variations in the minimum usable power for acceptable voice quality and the handoff power threshold are manipulated using fuzzy logic principles in order to obtain an optimum handoff result for uninterrupted wireless call services.**

Keywords—Mobile Switching Center,Handoff,Fuzzy Logic

I. INTRODUCTION

In the recent times, due to the increased usage of wireless cellular services, it is essential for the terrestrial telecommunication carrier operators to allocate different frequencies for individual users in order to eliminate interference of signals. In order to overcome the frequency constraints to serve a large pool of users, modern telecommunication carrier providers have adapted a powerful technique called frequency reuse in order to use the same frequency at different spatial locations. Each area is hypothetically divided into a cell and the mobile devices within a particular cell have a unique base station serving different frequencies. As the communicating devices are not stationary, it is mandatory that calls have to be transferred to the new channel belonging to a new base station automatically. This phenomenon is called as handoff and it is carried out by a Mobile Switching Center(MSC). In order to effectively carry out the process of handoff, the principles of fuzzy logic can be adapted. The fuzzy decisions tend to select the right signal power for handoff , thereby yielding optimal results by reducing the burden on the MSC.

II. HANDOFF STRATEGIES

In wireless cellular communications, a mobile may move among different cells and respective frequencies have to be allotted for uninterrupted communication. Mobile Switching Center automatically transfers the call to the new base station using a principle called handoff. Generally, the handoff value is determined by the minimum usable power of the current cell. In order to effectively perform handoff operations, the base station periodically tracks the average value of the signal strength. The length of the time needed to decide whether handoff is required depends on the speed at which mobile device is moving. The time over which a call may be maintained within a particular cell region is called as dwell time [2]. Fault handoff decision made by the MSC may result in the drop of signal strength of the communication and eventually leads to forced termination of the call. In modern telecommunication equipment, the guard channel concept is utilized in order to reserve certain frequencies within a cell for handoff situations. However, this method is disadvantageous as it reduces the total carrier traffic and adapting queuing strategies may result in call termination due to large delays in serving a particular subscriber [3]. A threshold margin value is required in order to decide the ideal time for handoff.

The margin $\Delta = P_{r\ handoff} - P_{r\ min}$

$$P_{r\ handoff} = \Delta + P_{r\ min}$$

Here $P_{r\ handoff}$ is Handoff power signal level

$P_{r\ min}$ is Minimum power at which the call can be maintained in a particular cell before handoff

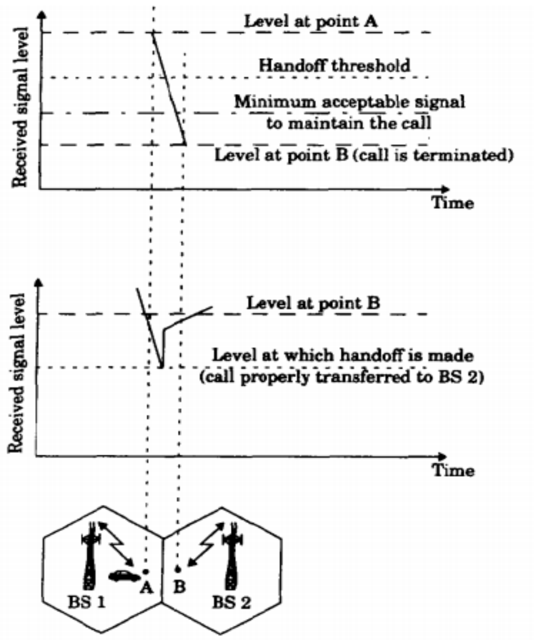

Fig. 1 Illustration of handoff at cell boundary

In order to determine the optimized handoff value, the margin value (**Δ**) has to be manipulated using fuzzy based decisions.

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III. FUZZY LOGIC

Fuzzy logic is a computational logical principle in which the truth values of variables can be any values between 0 and 1 contrasting with the Boolean principles which have crisp values as output. This logic can be used in order to handle the partial truth scenarios [4]. It is effective in combating complex situations like the one involved in selecting the optimal handoff signal range for unperturbed and undisturbed communication. Using the fuzzy principles, the power of the signal required to perform handoff is determined in accordance with the change in the values of the margin and the minimum power maintenance before handoff.

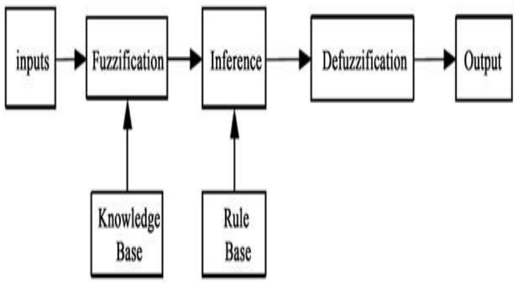

Fig. 2 Fuzzy logic block diagram

The process of fuzzification adapts a predetermined knowledge based rules and involves in decision making accordingly. The process of defuzzification is performed at the end in order to obtain a crisp value as in Boolean logic.

IV. HANDOFF OPTIMIZATION

It tends to be cumbersome in order to select a proper handoff power value. This is mainly due to the fact that there is no optimal way to fix the marginal value of power. If the marginal value is too large, it will result in unnecessary handoff situations thereby complicating the mobile switching center decisions. On the contrary, if the marginal value is too small, hand off cannot be performed thereby increasing the chances of call termination rather than smooth transition to the neighboring cell.

A. FUZZY LOGIC IMPLEMENTATION

In order to overcome the marginal value selection problem at the MSC, the fuzzy logic principles can be utilized for obtaining an optimized power value for handoff. First, the fuzzy rules have to be framed [5].

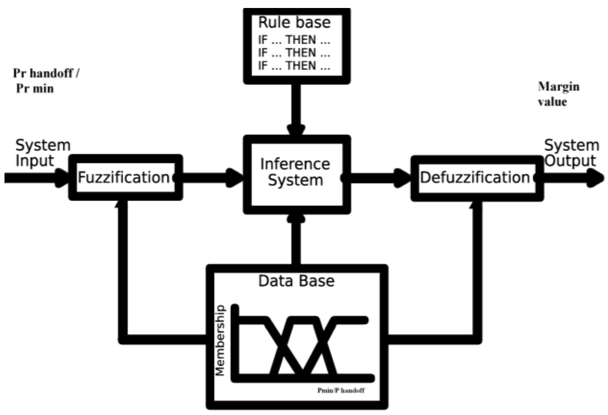

Fig.3 Functional Block Diagram of the proposed system

B. METHODOLOGY

I. The input values of $P_{r\ handoff}$ and $P_{r\ min}$ are fuzzified into fuzzy membership functions.

II. All the applicable rules available in the rule base are executed in order to obtain the margin values (Δ) accordingly.

III. The fuzzified output function (margin value) is defuzzified using one of the defuzzification methods in order to obtain the crisp value for Δ.

C. FUZZY LOGIC RULES

- IF $P_{r\ handoff}$ is very low and $P_{r\ min}$ is very high, THEN the margin value is decreased greatly.
- IF $P_{r\ handoff}$ is low and $P_{r\ min}$ is high, THEN the margin value is decreased slightly.
- IF $P_{r\ handoff}$ is high and $P_{r\ min}$ is low, THEN the margin value is increased slightly.
- IF $P_{r\ handoff}$ is very high and $P_{r\ min}$ is very low, THEN the margin value is increased greatly. IF $P_{r\ handoff}$ is very low and $P_{r\ min}$ is very high, THEN the margin value is increased greatly.

According to these rules, the margin value is manipulated in order to get the desired handoff value.

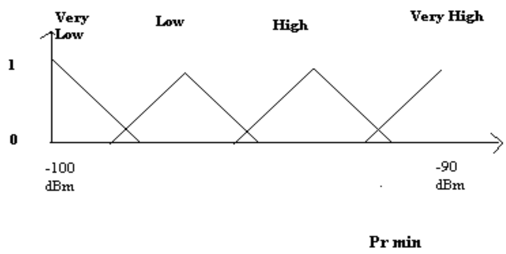

Fig. 4 Graphical fuzzy representation of $P_{r\ min}$

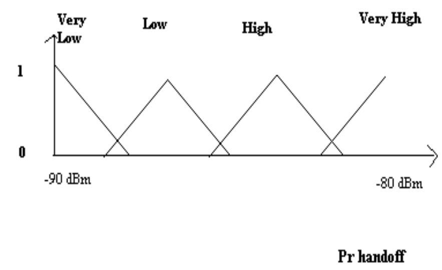

Fig.5 Graphical fuzzy representation of $P_{r\ handoff}$

The general acceptable voice quality at the base station receiver is normally taken between -90 dBm and -100 dBm. Therefore, the threshold handoff value is chosen slightly greater than the minimum acceptable value (greater than 5dBm but less than 10dBm) and later fixed and optimized by fuzzy logic by varying the margin value.

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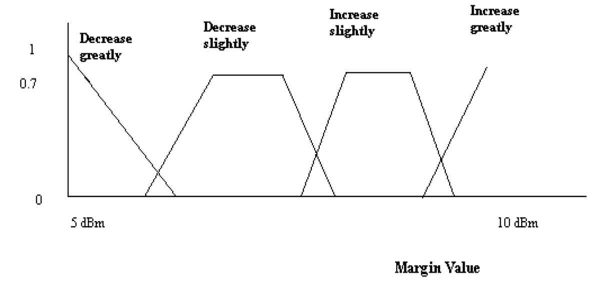

Fig. 6 Graphical fuzzy representation of output margin value

The margin values range obtained in the fuzzy output function has to be converted back into a crisp value for MSC to fix the optimized handoff power level.

D. DEFUZZIFICATION

Defuzzification is the process of converting the complex fuzzy sets and the corresponding member degrees into a crisp logic analogous to a Boolean binary output [6]. There are several methods like constraint decision defuzzification, center of area, weighted average, center of gravity, extended center of area, extended quality method, fuzzy clustering defuzzification, fuzzy mean, first of maximum, generalized level set defuzzification.

E. ILLUSTRATION OF DEFUZZIFICATION

The defuzzification involved in selecting the proper margin value can be illustrated with the example of weighted average defuzzification methodology [7]. After performing the defuzzification process, the crisp value of the margin Δ is obtained and it is added with the minimum power value $P_{r\,min}$ in order to get the optimized handoff value. The weighted average methodology is based on weighting each function in output with its respective maximum membership value.

The crisp value $z^* = \dfrac{\sum \mu (z')*(z')}{\sum \mu (z')}$

Here $\mu (z')$ is the maximum membership value
z' is the mean of the output function.

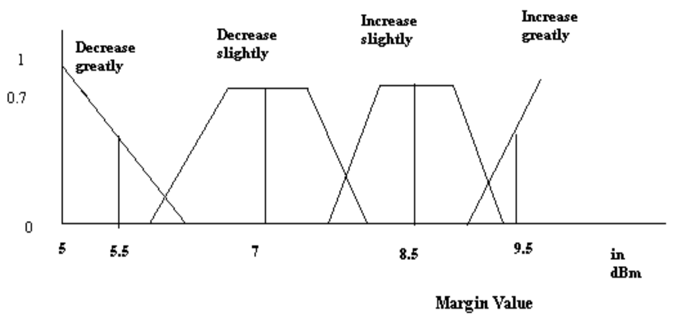

Fig. 7 Defuzzification by the weighted average method

$$z^* = \frac{(5.5*1) + (7*0.7) + (8.5*0.7) + (9.5*1)}{1+0.7+0.7+1}$$

$$z^* = \frac{5.5+4.9+5.95+9.5}{3.4}$$

z^* =7.60 dBm

In case the value of $P_{r\,min}$ is -95 dBm, the optimum handoff value can be determined by the formula $\mathbf{P_{r\,handoff} = \Delta + P_{r\,min}}$.
Here, $P_{r\,handoff}$ = -95+7.60 = -87.4 dBm

V. CONCLUSION

It is essential for the cellular communication system to select the proper handoff value in order to serve the mobile subscribers effectively. The proposed idea of incorporating the fuzzy principles for determining the handoff values is useful in order to ease the complex decision making that involves various power levels of minimum acceptable signal strength of a particular cell. The fuzzy algorithm has to be included in the decision circuits of the Mobile Switching Center. This method will prove to be beneficial in providing smooth transition during shifting of the mobile devices from one cell to its neighboring the cell without termination or loss of quality of the ongoing call.

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