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Design & Development of Fuzzy Inference System for Hand-off in Cellular System

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***Abstract*: This study is founded on a brief examination of the handoff process and how it benefits cellular systems in wireless communication. How fuzzy Inference System (FIS) can increase handoff efficacy and efficiency. Additionally, a fuzzy inference system is being developed for the cellular system's multi-criteria handoff procedure. As input matrices and the output of the fuzzy system, we used Receive Signal Strength (RSS), Signal to Noise Ratio (SNR), Path-loss, and Traffic Load. Different advantages of such an optimization over the conventional handoff process.**

Keywords – Cellular Handoff Process, Handoff Decision Issue, Fuzzy Logic, Fuzzy Inference System.

1. INTRODUCTION

When a single big coverage area cell is divided into numerous small cells, each with its own low power base station, this is referred to as the cellular system. Which enable signal transmission. These tiny cells attach to one another to create clusters, which are small groups. Without omissions or overlaps, in order to completely cover a vast region.

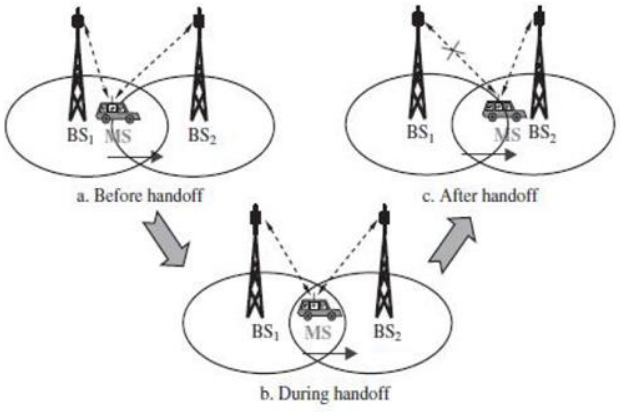

Fig.1. Handoff process in cellular system [6]

When a mobile user switches from one cell to another, then they hand-off signal from one cell to another cell. The hand-off method switches the active call from one base station to another base station for mobile users. In order to stop calls from dropping. Users can move around thanks to hand-off, which gives the network constant access to signal transmission.

When using cellular technology, the handoff process is crucial for maximising spectrum usage. To ensure greater frequency reuse as users migrate, more handover processes are necessary due to shrinking cell sizes. If the right handoff procedure is not employed, the Ping-Pong effect may occur more frequently at the cell boundary. Or Ping-Pong matches happen because of fading. Unnecessary handover will occur if matrices are improperly balanced. This will put more strain on the system and lead to unethical handover choices. QoS will be interrupted as a result. Every call drop is possible [3].

Handover algorithms for cellular communication systems have been the subject of numerous studies. Making a decision about a handover while taking into account many factors is quite tough. Occasionally, the trade-off of some criteria should be considered. Therefore, heuristic perspective based on Neural Networks, Genetic Algorithms (GA) and Fuzzy logic (FL) can prove to be efficient for wireless networks.

RSS, SNR, Path-loss, and Traffic-load are the handoff matrices. Due to the additional evaluation criteria and possibilities for attaining the necessary balance between the various system features, a multiple handoff algorithm can perform better than a single criteria handoff algorithm [1].

In this study, we develop a new handoff system that can prevent the Ping-Pong effect and makes effective handover decisions using fuzzy logic. In section 2, where the paper's structure is laid out, we discuss the handover decision Issue. We provide a quick overview of fuzzy logic in Section 3. Mention hand-off decision process using fuzzy logic in section 4. We describe the fuzzy inference system for hand-off in Section 5. We talk about the simulation findings in Section 6. In section 7, there are some conclusions.

2. HANDOVER DECISION ISSUE

Link Quality upkeep, interference reduction, and minimising the numbers of handoffs are the primary goals of handoff. Additionally, a handoff should only be initiated by a handover algorithm if and when it is absolutely essential. A handover algorithm's purity depends on how it starts the handover procedure. Another important factor is the moment the Handoff is initiated. If the beginning is too early or too late, it could have negative impacts on the link quality and interference. A timely handoff algorithm is one that doesn't start the handoff too soon or too late [2].

Large- and small-scale fades are a common occurrence in a mobile environment. Making an accurate and timely judgement is quite difficult for the handover algorithm to perform. It should be emphasised that some information about handover criteria may be innately imperfect or that obtaining the right information may be challenging. This is why we provide a fuzzy logic-based technique that can work

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with obscure data and model non-linear functions of any complexity.

3. FUZZY LOGIC

Instead of using the standard "true or false (0 or 1)" Boolean logic on which the current computer is based, fuzzy logic bases computation on the "degree of truth." By using "degree of truth," it aims to use reasoning more in line with everyday life. **Dr. Latfi Zadeh** of the University of California first proposed the concept of fuzzy logic in 1965. Fuzzy logic takes into account both the extreme cases of truth—0 and 1—as well as the numerous intermediate states of truth. The term "fuzzy" alludes to things that are not clear, and fuzzy logic looks to work more like how human brains operate. In the actual world, we occasionally encounter situations that are impossible to predict. Whether the statement is accurate or not [9].

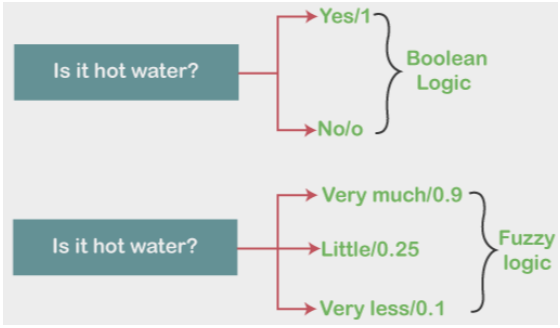

Fig 2. Representation of Uncertain Environment [7]

Function "μA(x)" also known as the **membership function** of set "A," defines the fuzzy set A of the universe x.
μA(x): x ⟶ [0,1]

Where,

μA(x) = 1 if all of x is contained in A.

If x is not in A, μA(x) equals 0.

If x is partially contained in A, the expression 0<μA(x)<1 applies.

A **membership function** determines the degree to which an input belongs to a set.

3.1 Degree of Membership Function

The Degree of Membership, also known as the membership value of element X in set A, is expressed as a number between 0 and 1 and is the result of the membership function. Membership function can be defined as a technique to solve practical problem by experience rather than by Knowledge (degree of truth). A fuzzy logic system's fuzzification and defuzzification use membership functions [9].

3.2 Feature of Membership Function

(i) Core: A membership function's core for a fuzzy set A. Is characterised as the area of the universe that has full and complete membership in the set.

(ii) Support: This area of the universe is known as the support of a membership function for some fuzzy set A. That is distinguished by non-zero set membership.

(iii) Boundary: The area of the universe is the definition of the boundary of a membership function for some fuzzy set A. containing element that is not completely a member but has no zero membership.

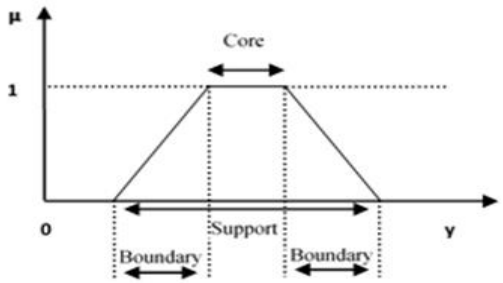

Fig.3 Feature of membership function [8]

4. HAND-OFF DECISION PROCESS USING FUZZY LOGIC

Fig. 4 depicts the fundamental Fuzzy system that is used for handover. Different matrix combinations have been utilised to improve handover decisions.

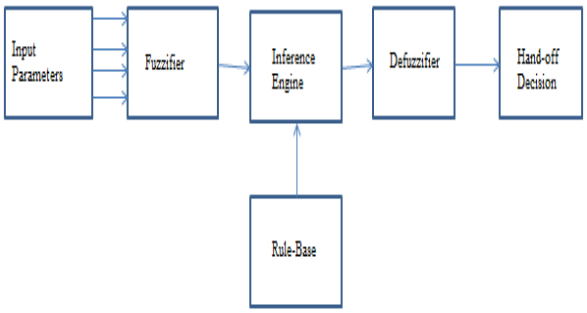

Fig.4. Fuzzy Inference system for Handover [3]

A) Matrices for Handover

The handover probabilities of each cell are calculated using four matrices, and the best neighbouring cell is then selected to serve as the MS. Below are the metrics.

1) Received Signal Strength (dbm)
2) Signal to Noise Ratio (dB)
3) Path-Loss (dB)
4) Traffic- Load (%)

We take into account a GSM cellular network with 100 traffic channels and omnidirectional cells that are all served by a single central BTS. The distribution of mobile users inside a BTS's service area is thought to be log-normal. A single BSC (Base Station Controller) is connected to the

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BTS. From the currently serving BTS and all the nearby BTS, a mobile station measures the received signal strength, Signal to Noise ratio, Path-Loss, and Traffic load. Every half second, mobile stations take measurements and communicate them to the BTS via the common control channel, where the BTS processes the information and makes decisions.

Received Signal Strength: When a single ground reflection predominates the multipath effect, the two-ray model is employed. The broadcast signal, which is just travelling through free space, and the ground's reflection make up the two components of the received signal [1]. Equation (1) shows that regardless of wavelength, received power falls by inversely the fourth power of d.

Pr dbm= Pt dbm + 20log (hthr) - 40logd+Gr+Gt Equation (1)

Where,
Pr denotes the received power in dbm.
Pt represents transmission power in dbm. Gr stands for received antenna gain in db. Gt stands for transmit antenna gain in db. ht stands for transmitter antenna height and hr is the antenna height measured in metres.

Handoff process is take place when Received Signal Strength less than -90dbm to -100dbm.

A mobile station (MS) can only decide to switch to a neighbouring BTS using the usual algorithm with hysteresis if the RSS it receives from the neighbouring BTS is sufficiently stronger than the present one, as long as a minimum signal level is guaranteed [1].

Signal to Noise Ratio: Instead of the overall in band noise in the system, cochannel interference in cellular systems is what's limiting their effectiveness and performance. This is due to the fact that the system's overall power of in-band noise (thermal, man-made) is significantly lower than the power of the unwelcome signal. So, it is possible to ignore the noise [1].

Mathematically,
SNR = RSS /I + Ns, or signal-to-noise ratio
For I>> Ns, the Signal to Interference Ratio, C/I = RSS/I

Where the desired RSS Signal strength, I is the undesirable cochannel. Power of the interfering signal and Ns, the overall power of in-band noise in the system. The signal to interference ratio is a useful indicator of the modulation technique's effectiveness in the cellular system and can really affect its spectral efficiency.

Cellular networks use the C/I from two nearby BTS, and the Process is in charge of making sure that only MS is always connected to the BTS with the Better C/I. Therefore, interference-related handoff occurs when the C/I ratio is between 16 and 15 db or below. It is also possible to include constant hysteresis in an interference-based handoff method.

Path-loss: Under typical circumstances, any MS is supplied by a BTS that offers a minimum path-loss, and handoffs due to path-loss occur when losses exceeded 118 dB. A mobile station (MS) can only decide to hand off if the path-loss obtained from the neighbouring BTS is better than the present BTS by a specified hysteresis margin, according to the usual algorithm with hysteresis [1].

Traffic Load: A specified set of voice channels is allotted to each cell under a fixed channel assignment scheme. Any call attempt inside the cell can only be accommodated by the channels that aren't in use there. The call is terminated if every channel in that cell is already in use. to prevent call severing. Call from an edge user in one cell is transferred to a neighbouring cell. By which available channel for processing calls. MSC is in charge of this process.

5. FUZZY INFERENCE SYSTEM FOR HANDOFF

Using the 4 matrices as input, a FIS (Fuzzy Inference System) is created to provide fuzzy hand-off decisions. The FIS tool in MATLAB R2014a is used to design the system. To create the FIS, the membership function needs to be created. A total of 5 linguistic variables, including "Hand-off" as an outcome, have been employed. Triangular functions were employed. Based on investigative experience, the membership functions of a fuzzy system are taken into consideration.

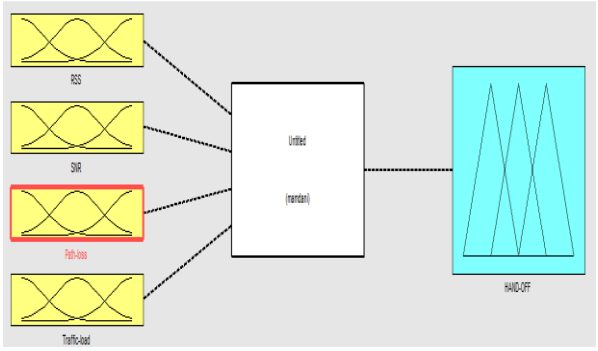

Fig.5. Fuzzy Inference System (FIS)

Below are the membership functions for the phonological variables:

1) Received Signal Strength (RSS) = {Weak, Medium, Strong}

The cellular system considers received signal strength of -100 dbm to be weak.

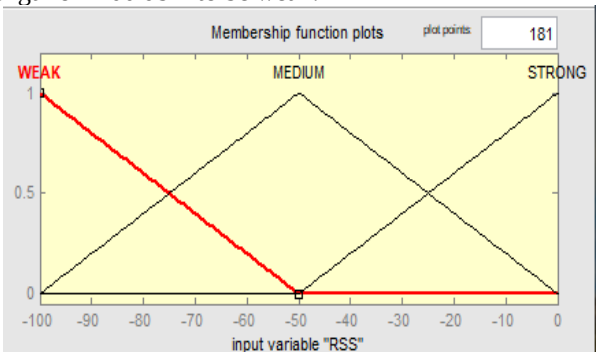

Fig.6. Membership Function of Received Signal Strength

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2) Signal to Noise Ratio (SNR) = {Low, Medium, High}

According to the GSM approval, a minimum operational SNR of "0" dB is considered low.

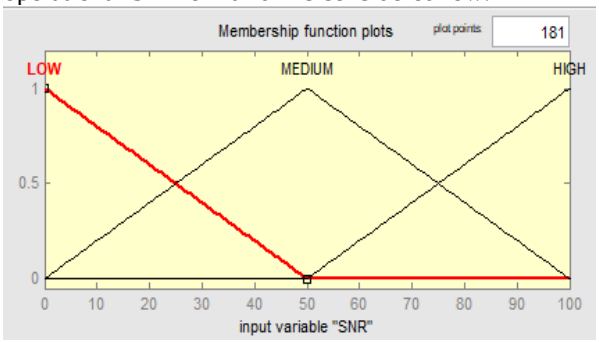

Fig.7. Membership Function of SNR

3) Path-Loss = {Small, Medium, Large}

Path-Loss of 120 db is deliberated as Large in cellular System.

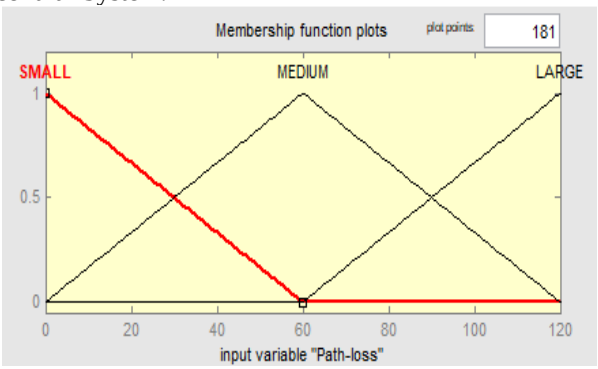

Fig.8. Membership Function of Path-Loss

4) Traffic-Load = {Low, Medium, High}

50% traffic load is considered to be medium in terms of traffic load.

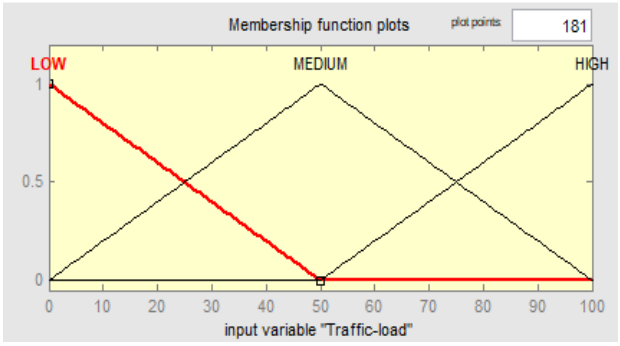

Fig.9. Membership Function of Traffic-Load

5) Hand-off = {No Hand-off, Wait, Be- Careful, Hand-off}

- If probility is “0” , then No- Hand-off
- If probility is “1”, then Hand-off.

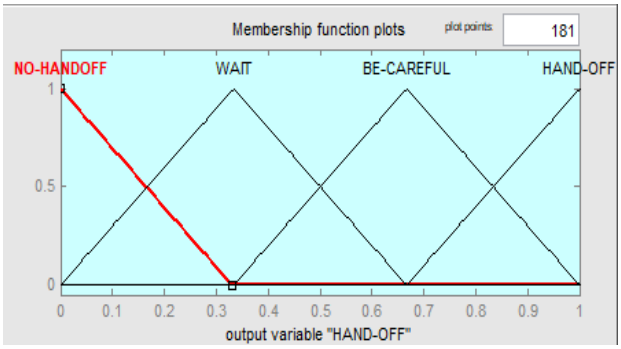

Fig.9. Membership Function of Hand-Off

The Fuzzy Inference engine is a set of guidelines created from expert information. Based on an attentive comprehension of the perspective underlying the handover performances, we have calculated the awareness-based rules that link the inputs and outputs. There are four ambiguous concepts, and each one has three subcategories. There are **81 rules**, or 3^4. For instance, there is no hand-off if RSS is strong, SNR is high, path loss is moderate, and load is low [1].

Table 1.FRB

Rule	RSS	SNR	PATH-LOSS	TRAFFIC-LOAD	HAND-OFF	RULE	RSS	SNR	PATH-LOSS	TRAFFIC-LOAD	HAND-OFF
1	W	L	SM	L	BC	42	M	M	H		BC
2	W	L	SM	M	BC	43	M	M	LG	L	BC
3	W	L	SM	H	H	44	M	M	LG	M	BC
4	W	L	M	L	BC	45	M	M	LG	H	BC
5	W	L	M	M	BC	46	M	H	SM	L	W
6	W	L	M	H	H	47	M	H	SM	M	W
7	W	L	LG	L	H	48	M	H	SM	H	W
8	W	L	LG	M	H	49	M	H	M	L	W
9	W	L	LG	H	H	50	M	H	M	M	W
10	W	M	SM	L	W	51	M	H	M	H	W
11	W	M	SM	M	W	52	M	H	LG	L	BC
12	W	M	SM	H	BC	53	M	H	LG	M	BC
13	W	M	M	L	W	54	M	H	LG	H	BC
14	W	M	M	M	W	55	S	L	SM	L	W
15	W	M	M	H	BC	56	S	L	SM	M	W
16	W	M	LG	L	BC	57	S	L	SM	H	BC
17	W	M	LG	M	BC	58	S	L	M	L	W
18	W	M	LG	H	H	59	S	L	M	M	W
19	W	H	SM	L	W	60	S	L	M	H	BC
20	W	H	SM	M	W	61	S	L	LG	L	BC
21	W	H	SM	H	BC	62	S	L	LG	M	BC
22	W	H	M	L	W	63	S	L	LG	H	H
23	W	H	M	M	W	64	S	M	SM	L	W
24	W	H	M	H	W	65	S	M	SM	M	W
25	W	H	LG	L	BC	66	S	M	SM	H	BC
26	W	H	LG	M	BC	67	S	M	M	L	BC
27	W	H	LG	H	H	68	S	M	M	M	BC
28	M	L	SM	L	W	69	S	M	M	H	W
29	M	L	SM	M	BC	70	S	M	LG	L	W
30	M	L	SM	H	BC	71	S	M	LG	M	BC
31	M	L	M	L	BC	72	S	M	LG	H	H
32	M	L	M	M	W	73	S	H	SM	L	NH
33	M	L	M	H	BC	74	S	H	SM	M	W
34	M	L	LG	L	BC	75	S	H	SM	H	W
35	M	L	LG	M	BC	76	S	H	M	L	W
36	M	L	LG	H	H	77	S	H	M	M	BC
37	M	M	SM	L	W	78	S	H	M	H	BC
38	M	M	SM	M	W	79	S	H	LG	L	W
39	M	M	SM	H	W	80	S	H	LG	M	W
40	M	M	M	L	W	81	S	H	LG	H	BC
41	M	M	M	M	BC						

Following are the definitions for the terms set, RSS, SNR, Path-loss, and Traffic-load:

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T (RSS) = {Weak, Medium, Strong}
= {W, M, S}
T (SNR) = {Low, Medium, High}
= {L, M, H}
T (Path-Loss) = {Small, Medium, Large}
= {SM, M, LG}
T (Traffic-Load) = {Low, Medium, High}
= {L, M, H}

6. SIMULATION RESULT AND DISCUSSION

The output at input1 (RSS) is -**50**, input2 (SNR) is **50**, input3 (Path-loss) is **60,** and input4 (Traffic-Load) is **50** in Figure 10. As a result**, 0.667** represents the output Probability of Handover.

Fig.10. The result of FIS

7. CONCLUSION

Given a number of parameters, the hand-off judgement procedure in cellular communication systems is particularly challenging. Because both large- and small-scale fades frequently occur in the mobile environment, it is exceedingly difficult for the handover algorithm to make accurate and timely decisions. Some information used as handover criterion may be innately wrong, or accurate information may be difficult to get. We devised a fuzzy logic-based method that can handle fuzziness data for this purpose. In this study, fuzzy logic was used to plan a hand-off system. The intended system has the potential to evade call closure, interfere, and improve system performance.

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