Analysis of the Impact of Fuzzy Logic Algorithm on Handover Decision in a Cellular Network

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Abstract

Fuzzy logic is one of the intelligent systems that can be used to develop algorithms for handover. For success in handing over, the decision-making process is crucial and thus should be highly considered. The performance of fixed parameters is not okay in the changing cellular system environments. The work done on this paper aims to analyse the impact of utilising the fuzzy logic system for handover decision making considering the Global System for Mobile communication (GSM) network. The results from the different simulations show that the need to handover varies depending on the input(s) to the Fuzzy Inference System (FIS). By increasing the number of data, thus the criteria parameters used in the algorithm, an Optimised Handover Decision (OHOD) is realised.

Keywords: Optimised Handover Decision, Received Signal level (RxLev), Received Signal Quality (RxQual), Fuzzy Inference System

INTRODUCTION

Most of the existing handover algorithms have not exploited the benefits of multi-criteria handover, which provides better performance than the single criterion algorithms. The primary decision-making sequence includes: identifying the need then to find the possible candidates which are then evaluated and lastly choosing the target cell. Selection of a network segment using one criterion (traditional network selection methods) is not intelligent enough as it does not consider other relevant parameters [7].Key Performance Indicators (KPIs) outline the success or failure rates of the most important events such as call blocking, call dropping and handovers. Conventional methods used only the Received Signal Strength Indicator (RSSI) for handover initiation but with time, this metric has been combined with many other parameters to enhance the performance evaluation. The key issues which have led to the addition of more parameters to RSSI are of the Ping-Pong problem, corner effect, and multipath fading which resulted in unnecessary handovers, call drops and forced termination [12], [10].

Using fuzzy logic is viable as the nature of network parameters is imprecise. The conversation time of the GSM subscribers, their movement, and environmental conditions rely on parameters that are not adequately defined and change with time [15]. Fuzzy logic can best handle this imprecise data as a tool for the wireless network algorithms [1].

2. RELATED WORK

The degree of mobility influences the quality of communication link such that a high-speed mobile station (MS) moving away from a serving base station(BS), experiences signal degradation faster than a low-speed MS[15]. Therefore, it is important to consider the velocity of the mobile user when studying handover related issues. Handover algorithms based on artificial intelligence such as the neural networks have been proposed by various authors [20], [8]. It is better to work with an intelligent system than the traditional methods. A fuzzy logic based vertical handover technique has been proposed where weights have been assigned to the performance metrics and defined the scale and range for different networks taken [13]. [10] Proposed a hard handover algorithm based on the fuzzy inference system. In this case, the distance between a mobile station (MS) and a base station (BS) and the signal strength that a mobile station receives from a base station are used as inputs, while the output is the handover decision value. An intelligent Vertical handover (VHO) uses Fuzzy Logic to estimate the necessity of handing over and finding the new point of attachment. Depending upon the traffic type, different Fuzzy Logic Controllers (FLC) is used for traffic to improve the overall performance of proposed system in [2]. A Fuzzy Multi-attribute Decision Making (MADM) access network selection is to assign weights to each parameter in heterogeneous environments. An approach proposes a vertical handover decision algorithm using fuzzy logic multiple attributes with aware context strategy that enables the mobile terminal to make a proactive decision based on the quality of service and user preferences parameters [15]. The output of the simulation shows that the proposed approach fulfils quality of service requirements of audio, video and data regarding packet loss. The Sugeno Fuzzy Inference system has been used to find the decision for vertical handover where the available bandwidth, network load, and signal strength are the input parameters to inference system [3]. The level of the candidacy of the related BS decides the handover initialization process [4]. The parameters used for the FIS input are the data rate, mobile speed and received signal strength indicator. Fuzzy logic based decision-making handover controller is designed to achieve a decision for the mobile networks: consider in figure 1. In proposed controller, MS measures the Received Signal Strength (RSS) from the current BS. Here, the fuzzy logic system is used to adjust the threshold value using RSS, so that threshold level is kept at the desired level to prevent call dropping. The MS reports the threshold measures to the BS.

From the proposed model, a transfer function is used to specify the BS. Lower threshold level indicates weak signal strength at MS, so the chances of call-dropping are more. Hence, lower value of threshold designated to pass the control to another BS. For optimal handover decision, RSS threshold value should be accurate. Therefore, the feedback control is used for the better and correct decision. On the previous threshold value from the BS and RSS, the controller generates new threshold value using fuzzy logic control algorithm. By this new threshold value handover decision is taken by the BS [18].This model is a motivation behind this paper. Now that the handover decision is made considering only the new threshold value of the received signal strength, it would be possible to have more than one parameter to affect the decision. Vertical handover has been considered in most of the cases mentioned so the need to study how the GSM system responds to a fuzzy system that has three inputs. The interface to access the network changes in the case of a vertical handover but does not change in the horizontal handover.

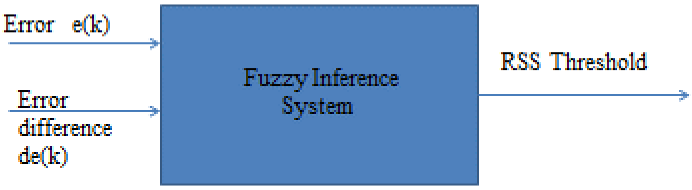

Figure 1: Fuzzy Inference System to vary the RSS Threshold [18]

3. THEORETICAL FRAMEWORK

RxLev and RxQual are key parameters in the evaluation of handover [13]. The Received Signal Level (RxLev) determines how high a received signal is. The mobile station continuously monitors the available base stations' RxLev values and can also use this information as a basis for changing its currently active connection.

RxLev	dBm Range
0	<-110
1 to 62	- 110 to -48
63	> -48

Table 1: Signal strength mapping to RxLev [6]

The RxLev is defined as a number from 0 to 63 that corresponds to a decibel referenced to one mill Watt (dBm) value range. 0 represents the weakest signal, while 63 is the strongest as shown in Table 1. RSSI below -110 dBm are considered unreadable in GSM while that near -50 dBm are rarely seen, and this would mean that the MS is next to the BS.

RxQual	BER
RxQual_0	Less than 0.1 %
RxQual_1	0.26% to 0.30%
RxQual_2	0.51% to 0.64%
RxQual_3	1.0% to 1.3%
RxQual_4	1.9% to 2.7%
RxQual_5	3.8% to 5.4%
RxQual_6	7.6% to 11.0%
RxQual_7	Greater than 15.0%

Table 2: BER mapping to RxQual [6]

The Received Signal Quality (RxQual) describes the signal quality. It reflects the average bit error rate (BER) over a period of 0.5s. As much as the listeners' speech quality is affected by other factors, the RxQual is still an important measurement. There are eight RxQual categories: 0 to 7 (best to worst). The DL quality is measured according to BER; it is averaged and mapped to RxQual values as defined in the GSM specifications as shown in Table 2.

Back in 1965, Lotfi A. Zadeh realised that conventional computer logic was not able to manipulate data that represented vague ideas. Therefore, he created fuzzy logic to allow computers to determine the distinctions among data with shades of gray, similar to the human reasoning process.

The tabular and formula-based methods can sometimes be rendered impractical as it may be difficult or impossible to derive a workable mathematical model. Fuzzy Logic overcomes this disadvantage since it has neither heavy number-crunching demands of formula-based solutions nor substantial memory requirements of look-up tables.

Classical logical statements are black or white, true or false, on or off but in fuzzy logic, a statement can assume any real value between 0 and 1, representing the degree to which an element belongs to a given set [21].

Fuzzy combinations, also known as "T-norms," are used to construct the rules. A fuzzy rule is made using the concept of "and," "or," and sometimes "not." The ''and'' operator has been utilized in this case. Linguistic rules define the relation between the input and the output. Linguistic rules define the relation between the input and the output. A fuzzy set is used to admit the possibility of partial membership; describing the vague concepts like the speed was high.

A membership function (MF) is a curve showing how each point in the input space, sometimes referred to as the universe of discourse, is mapped to a membership value (degree of membership) between 0 and 1. Gaussian membership functions are preferred methods for specifying fuzzy sets because of their smoothness and concise notation.

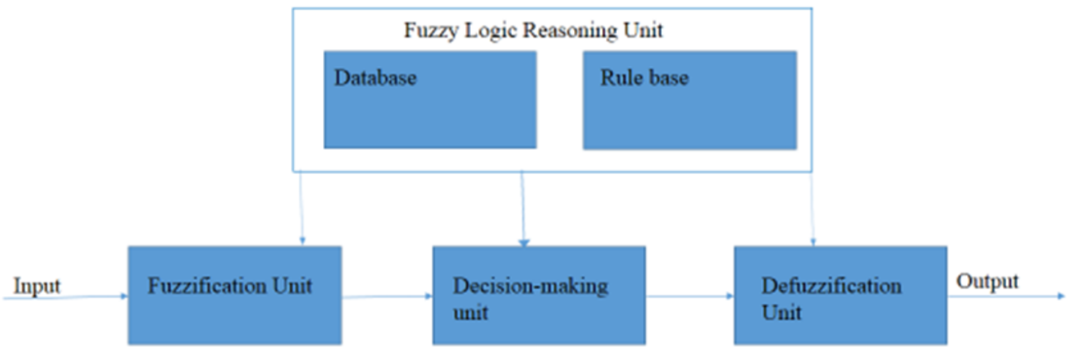

Figure 2: The Basic Structure of a Fuzzy Inference System [17]

The fuzzy logic reasoning unit is an essential element of the fuzzy inference system. It contains the database and the rule base. The database defines the number, labels, and types of the membership function the fuzzy sets used as values for each system variable (input and output variables). The universe of discourse of the variable is formed from the fuzzy sets of each variable.

The rule base maps fuzzy values of the inputs to fuzzy values of the outputs. The fuzzy rules incorporated in the rule base express the control relationships usually in an IF-THEN format. The if-part of the rule is the condition also called premise or antecedent, and the then-part is the action or consequence.
The actual input and output values are usually crisp; therefore fuzzification and defuzzification operations are needed to map them to and from the fuzzy values used internally by the fuzzy inference system. The input and output of the decision-making unit (inference unit) are fuzzy figures [14]. Defuzzification is a method that produces a number that best represents, and consistently represents the fuzzy set.
The Sugeno output is a crisp (well-defined) number that is that is found by multiplying each input value by a constant figure and then adding up the results. There is no output distribution, in this case, just the weighted average of the outputs from the computational paradigm that is based on how humans think. The advantages of the Sugeno Method that makes it more suitable for this work, is that it works well with adaptive techniques and optimization and is well suited for mathematical analysis [17]. Zero-order Sugeno Fuzzy inference system works best in forming the logical rules and decision making [11].

4. SIMULATION WORK

The simulation work was done on Matlab.

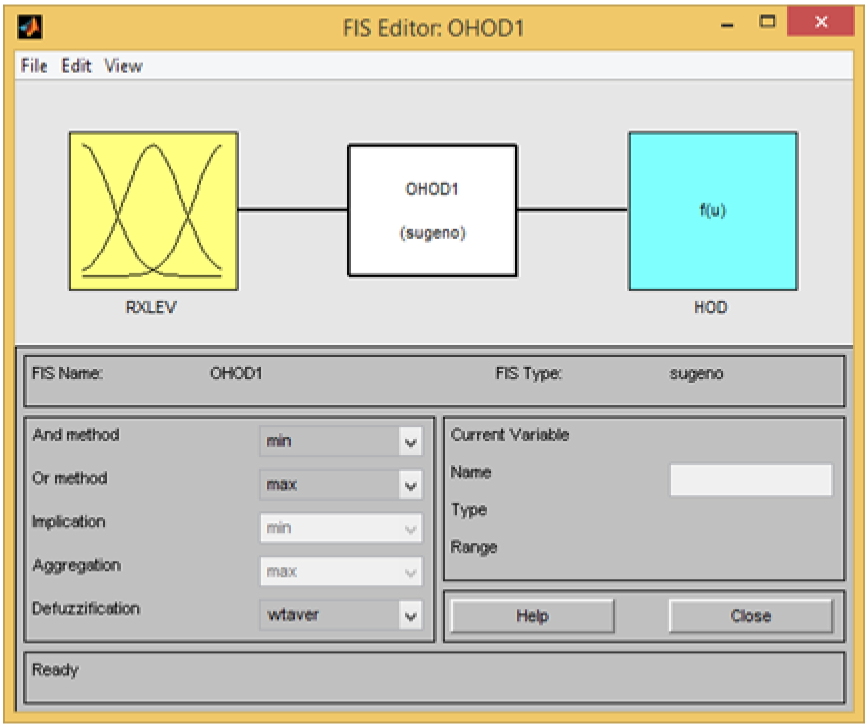

Figure 2a: One input FIS

The RxLev is the input parameter to the FIS in this first case. The output is called Handover Decision (HOD).

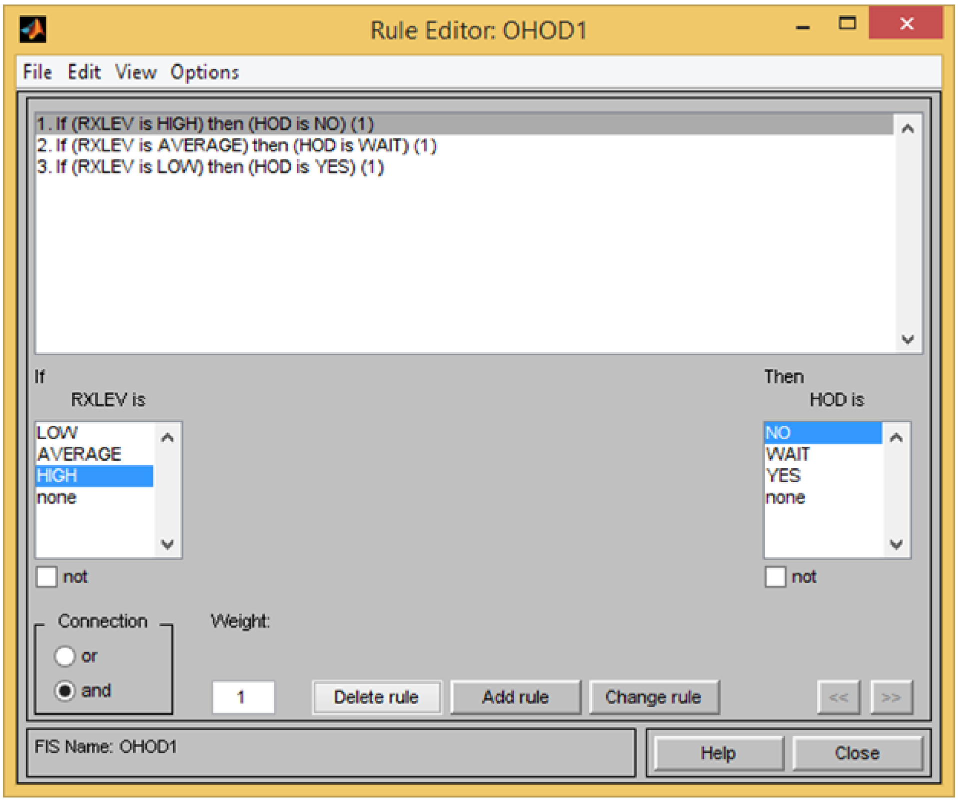

Figure 2b: RxLev Membership Functions

RxLev 0-31.5 is regarded as ‘Low', 0-63 is ‘Average' and 31.5-63 is ‘High'.

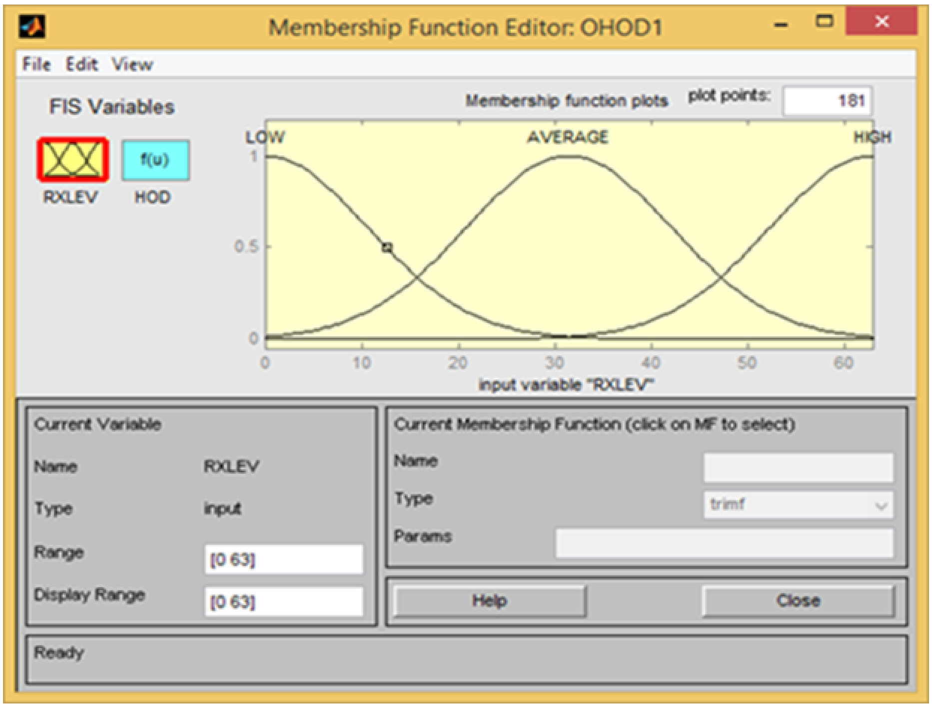

Figure 2c: Rules for one input

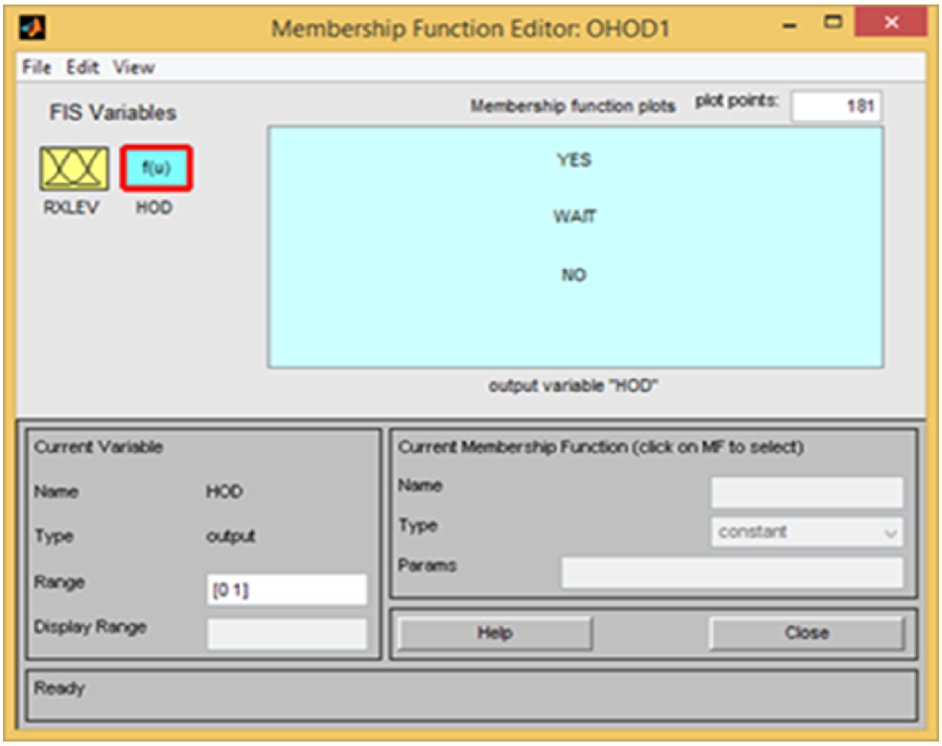

Figure 2d: Output for one input

The output of the fuzzy system in this work is called the Optimal Handover Decision (OHOD). It is the range of 0 to 1. The possible outputs are 'Yes' at 1, 'Wait' at 0.5 and 'No' at 0.

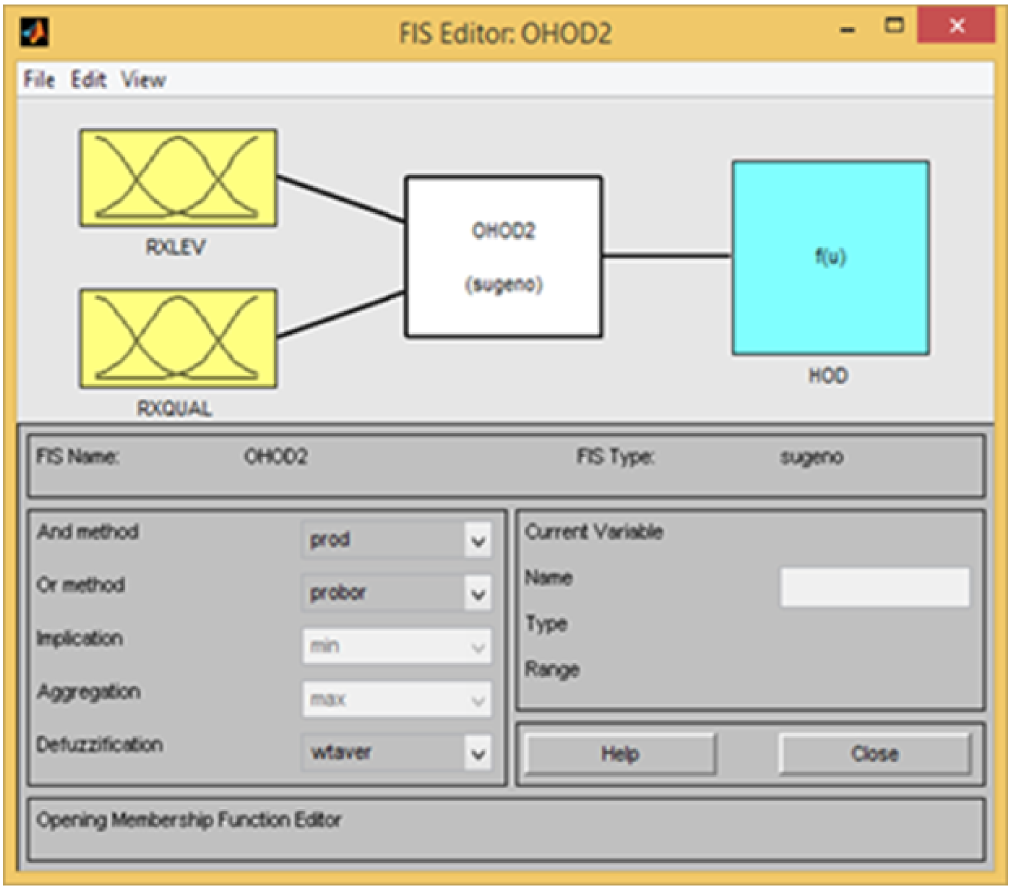

Figure 3a: Two input FIS

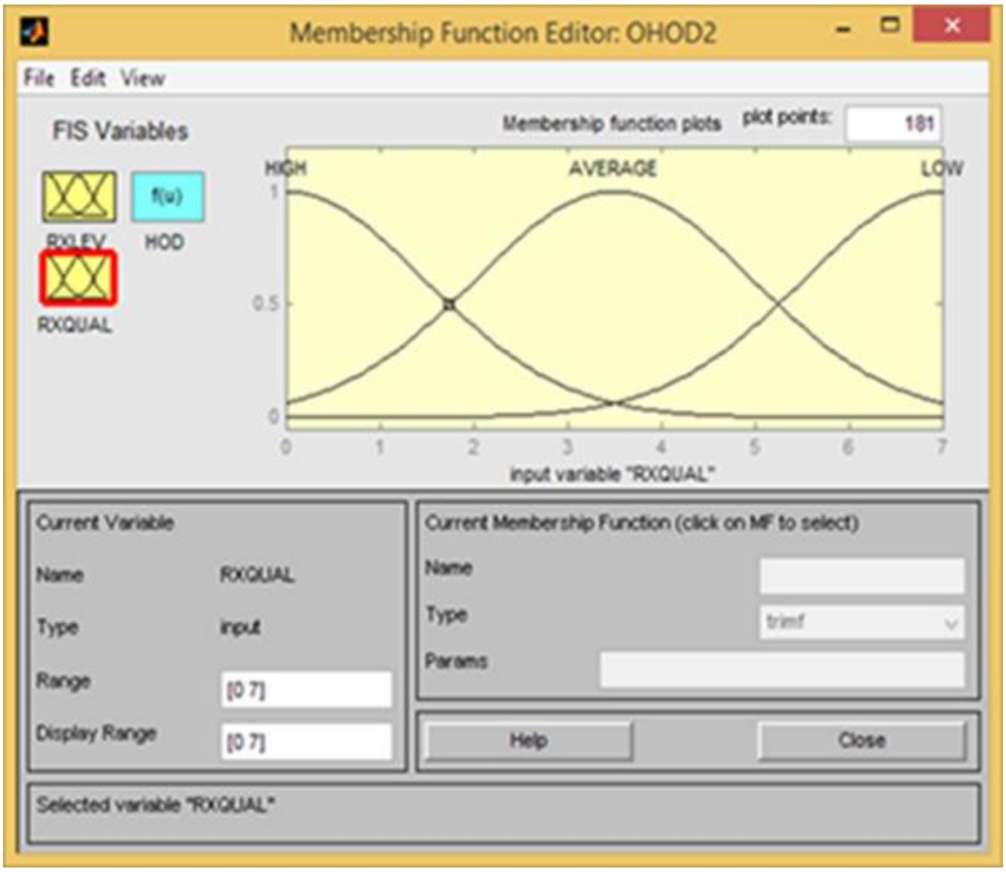

Figure 3b: MFs for RxQual

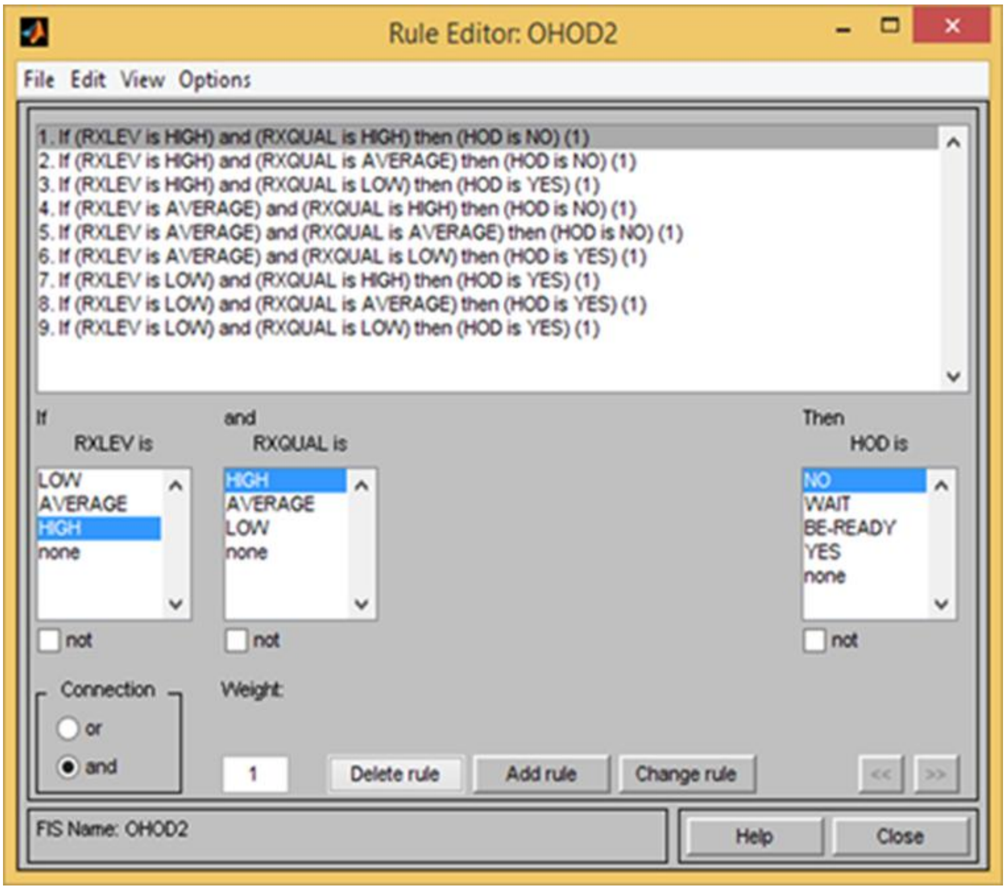

Figure 3c: Rules for the 2-input FIS

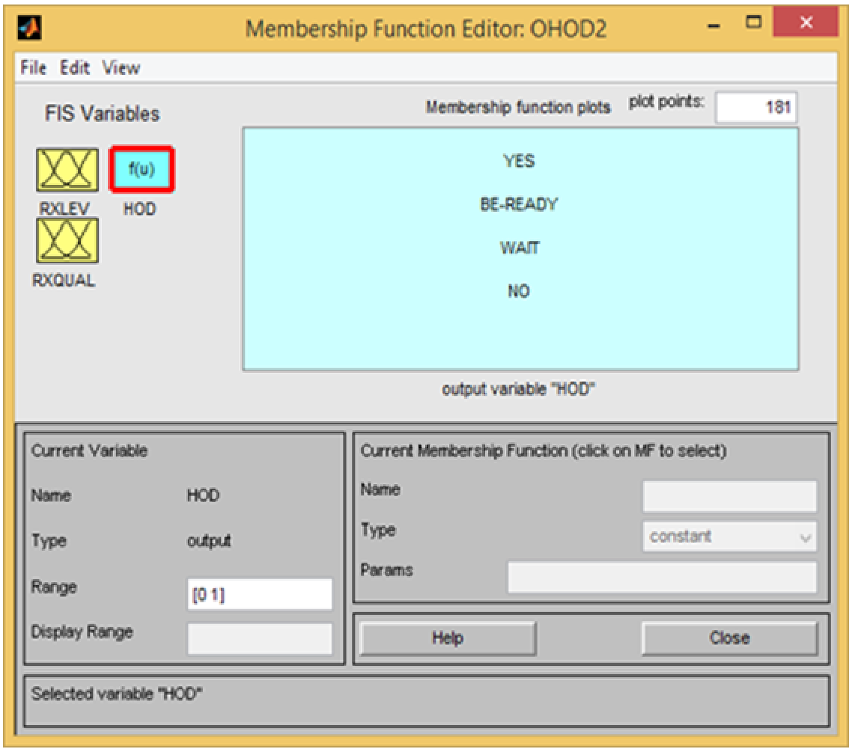

Figure 3d: Output for 2-input FIS

This case provides four possible outputs and thus membership functions for a given set of inputs: 0 to mean No, 0.3333 meaning Wait, 0.6667 to mean Be Ready and 1 for Yes.

Therefore, a higher value of the OHOD will indicate a higher recommendation for handover and vice versa.

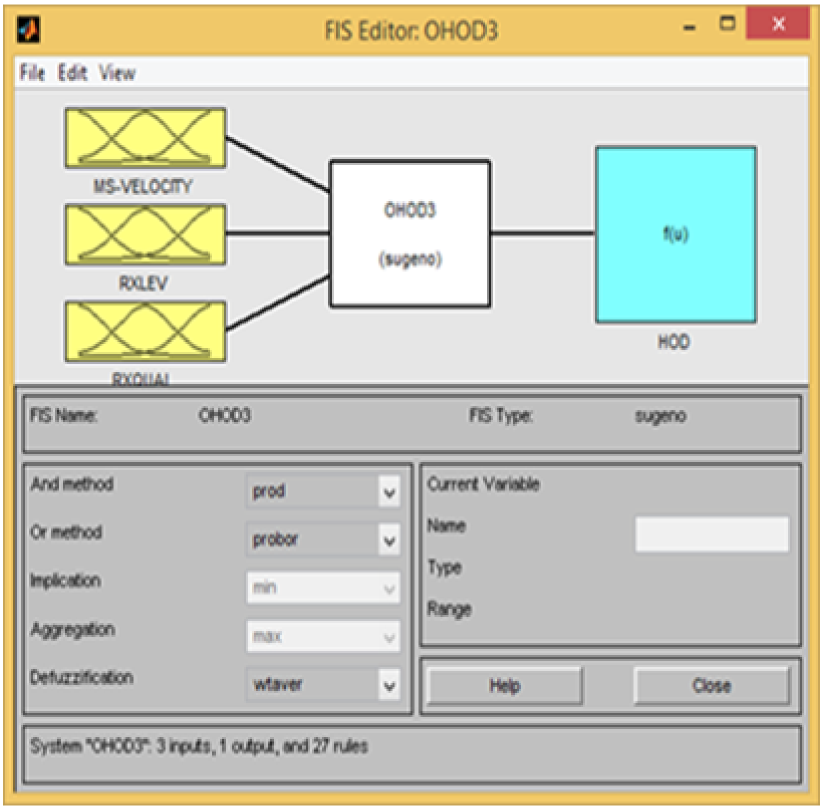

Figure 4a:3-input FIS

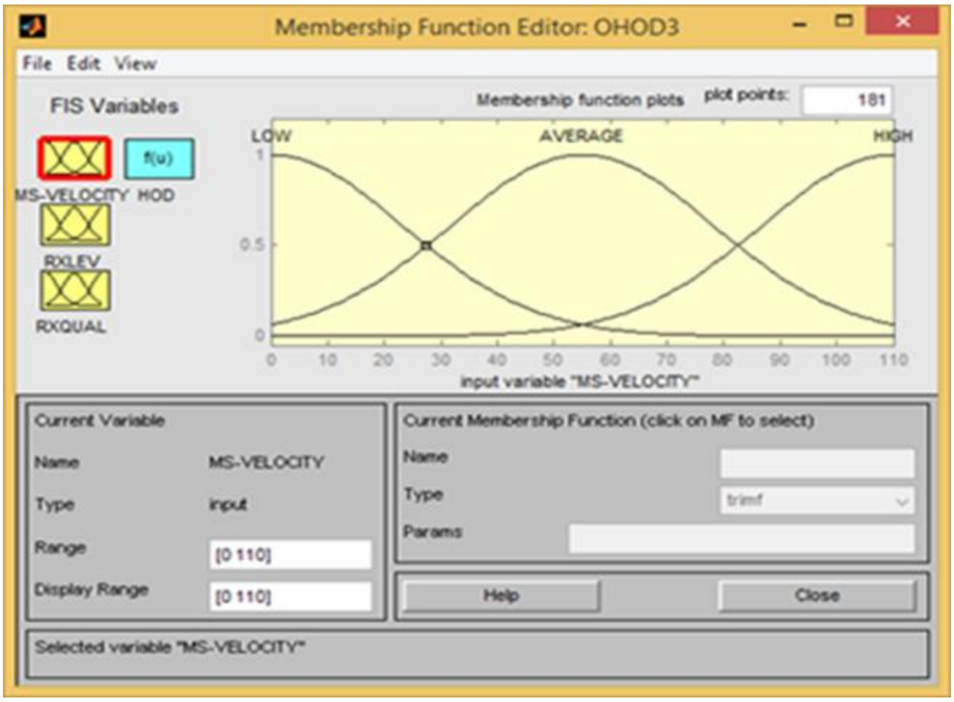

Figure 4b: MFs for MS Velocity

The MS Velocity is in the range of 0 to 110 km/hr. for low, average and high levels.

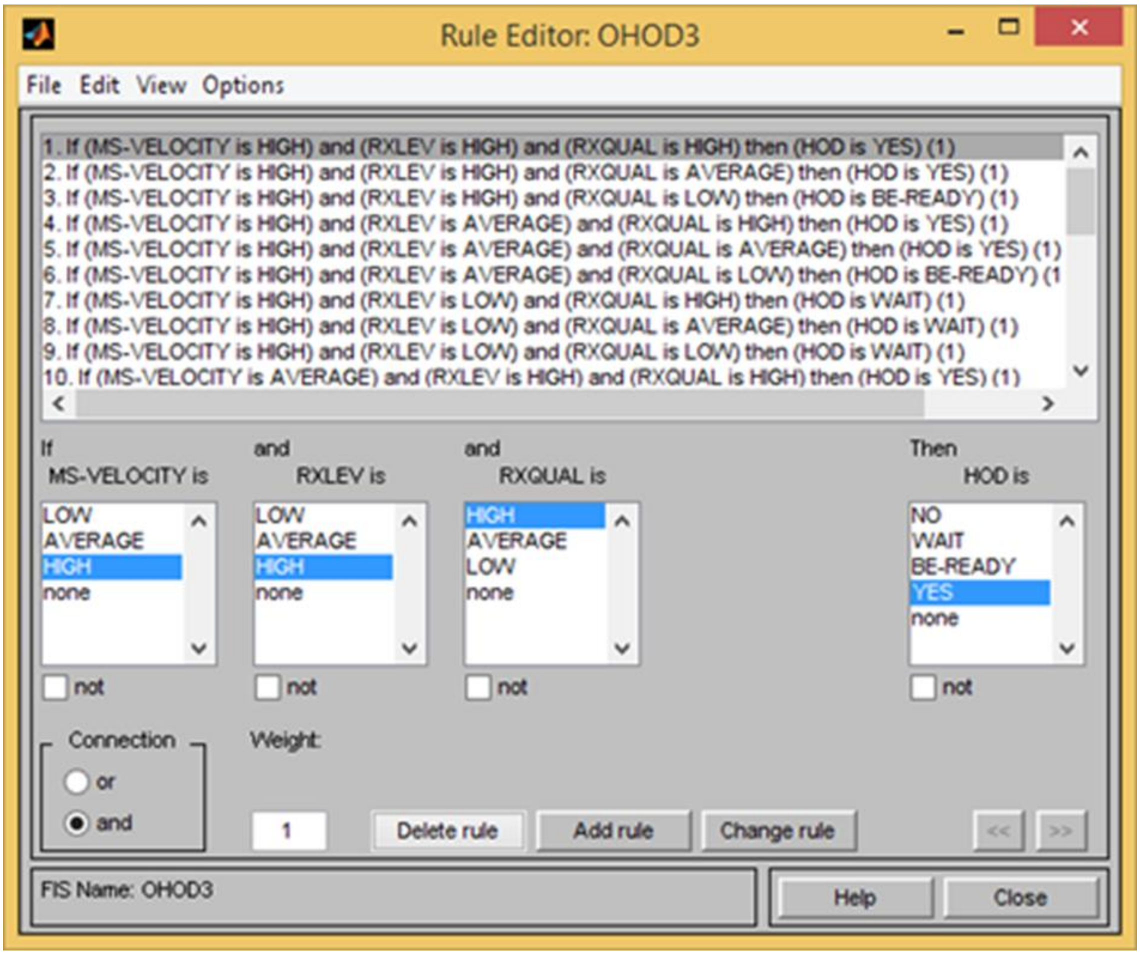

Figure 4c: Some Rules for 3-input FIS

5. RESULTS AND DISCUSSION

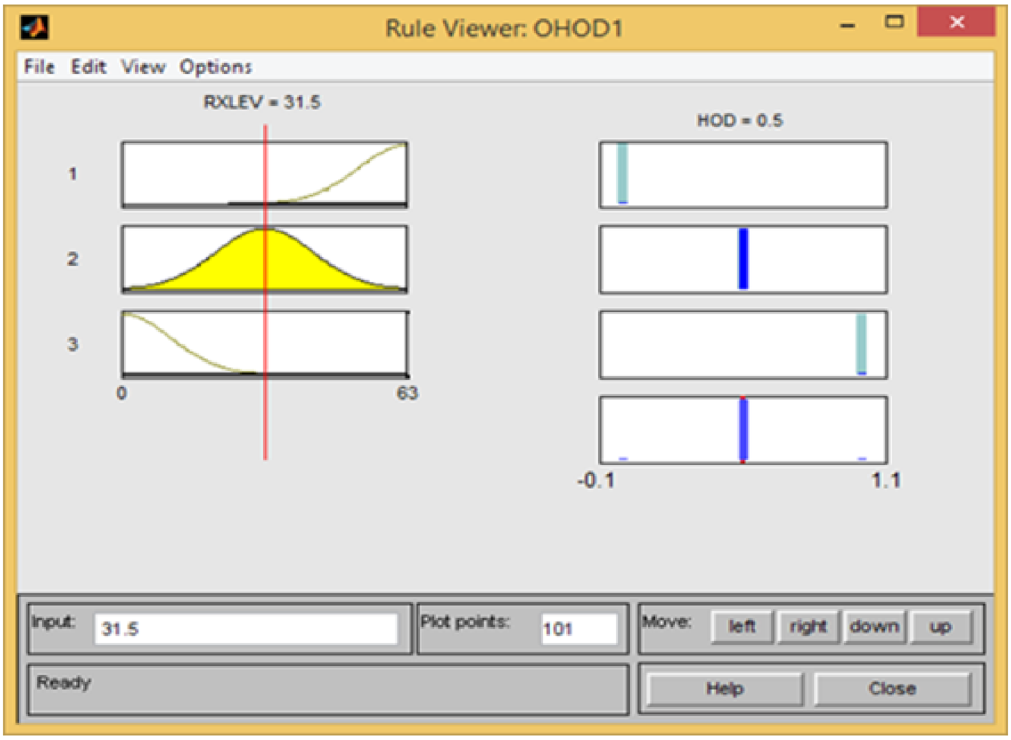

Figure 5a: Output at mean 1-input level

The output means that the MS should wait for handing over to the next BS.

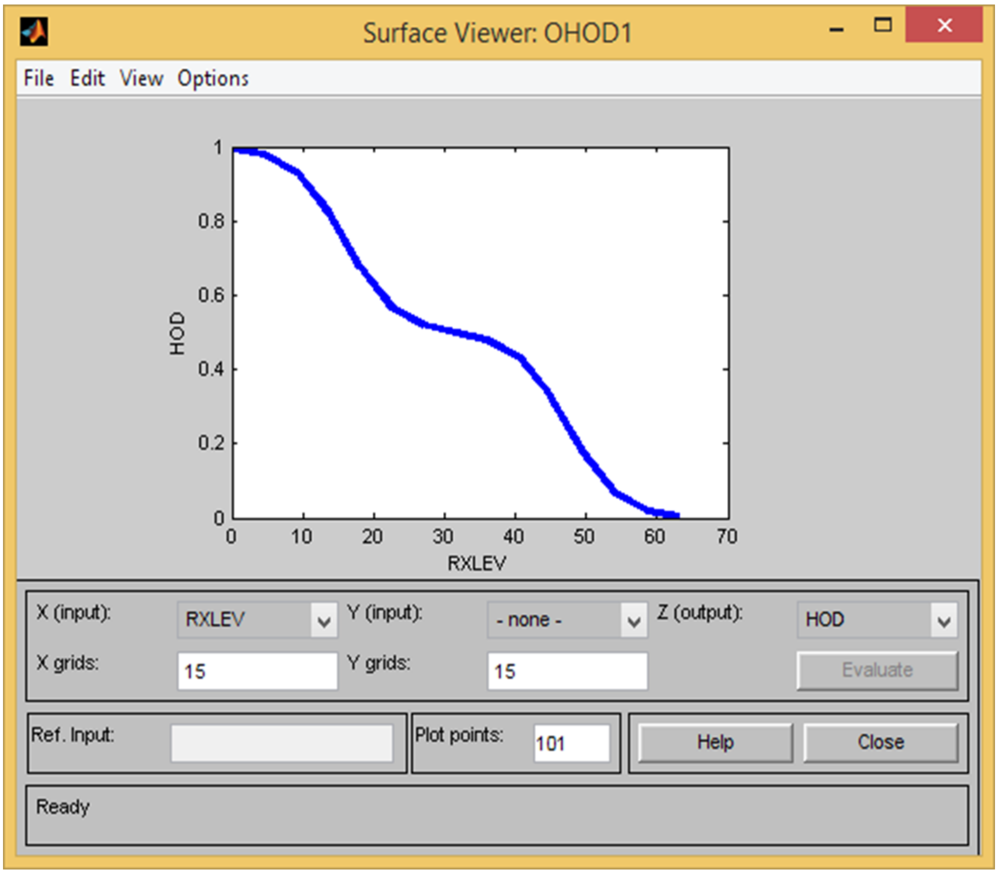

Figure 5b: Output at varied RxLev

At high RxLev, there is no need to handover as the conditions are favorable to sustain the current communication. At an average level, the MS should wait to be handed over as the signal level may change. If the RxLev becomes weak, there is need to handover to the next more appropriate BS.

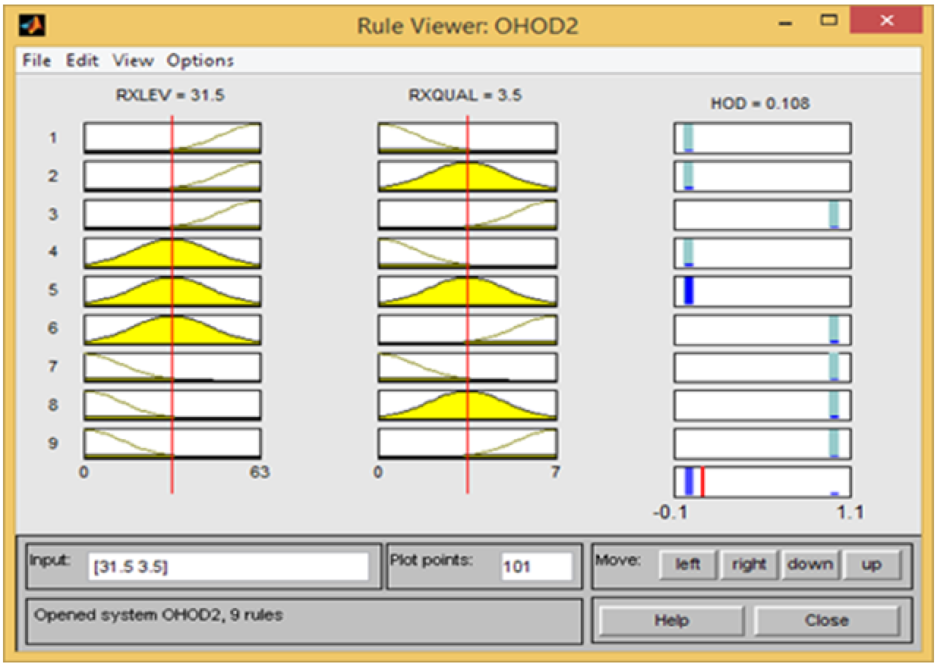

Figure 5c: Output at mean levels for two inputs

The input parameters at their average position, in this case, imply that there is no need to handover. Compare this output of 0.108 versus the previous output of 0.5 where RxLev is the only input: implying that there's more optimal network resource utilisation in this case. The need to handover has been optimised to suit the given situation.

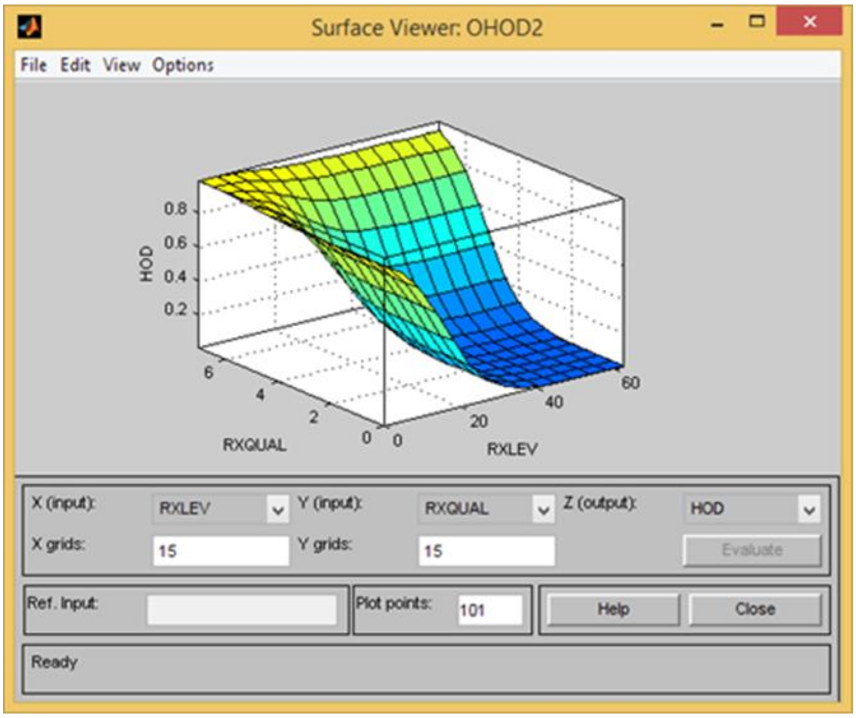

Figure 5d: Output at varied RxQual and RxLev

The OHOD is high when the RxLev and the RxQual are low and vice versa. The need to handover decreases as the signal level increases. The OHOD increases as the RxQual becomes poorer at around the 4th level.

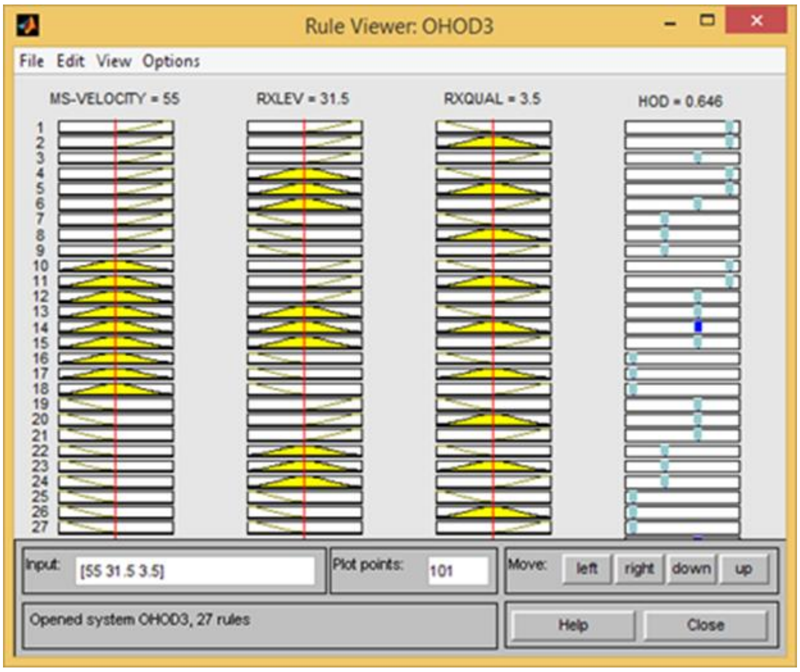

Figure 5e: Output for 3-input system

When all the input parameters are at their average positions, then the user will be ready for handover. This output of 0.646 is different from the previous two cases of 0.5 and 0.108 due to the aspect of the MS Velocity.

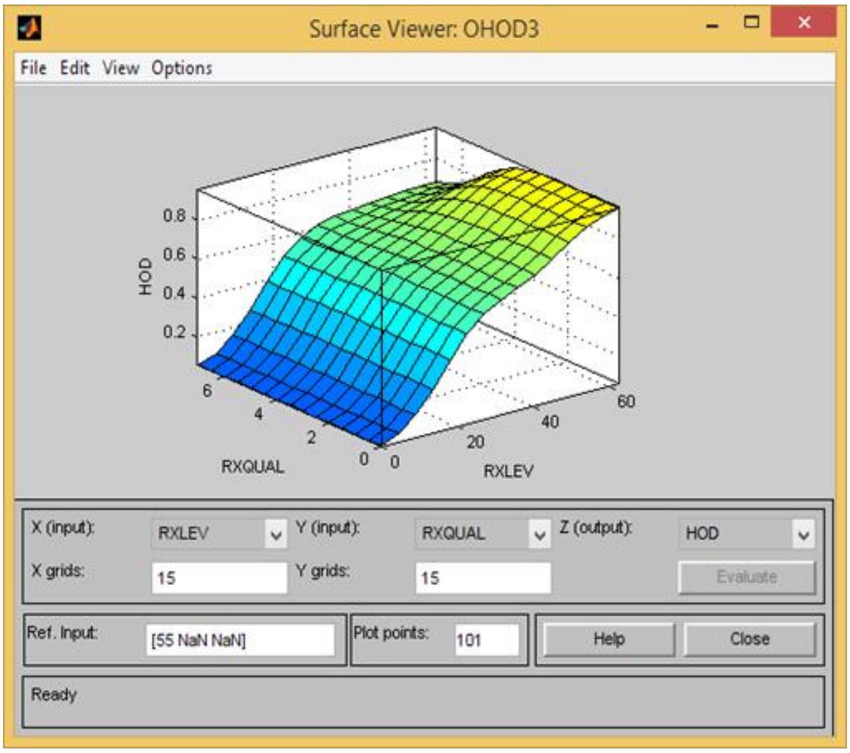

Figure 5f: Output at varied RxQual and RxLev

The RxQual and RxLev vary, but the MS Velocity is held constant at 55km/hr. At low RxLev say level

10, and high RxQual says level 3, the output of the handover decision is small due to the average MS Velocity and the good signal quality thus a lower need. The need to handover increases when the signal level and the signal quality decrease. At the average MS Velocity, low RxQual and low RxLev, execution of handover will await as the MS will cross the cell boundary shortly.

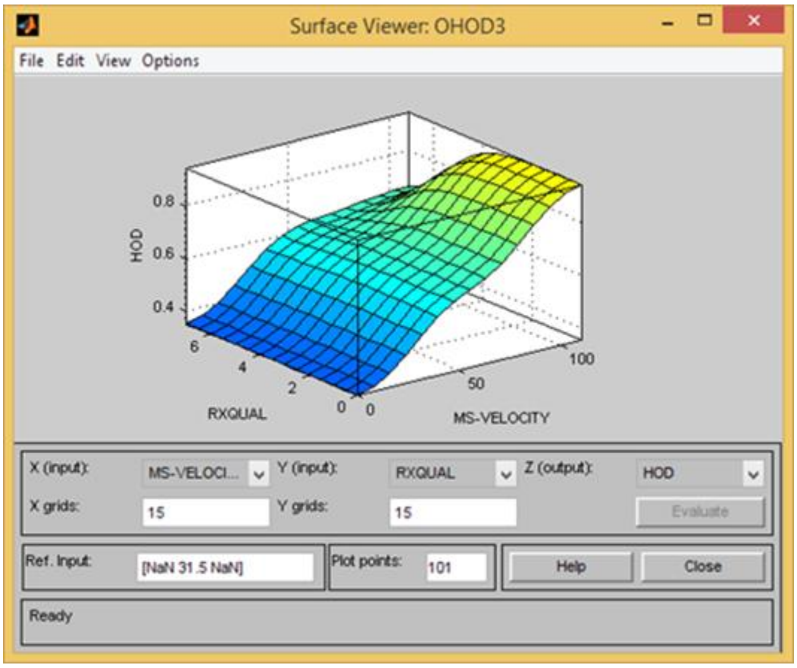

Figure 5g: Output at varied RxQual and MS Velocity

The RxLev is constant at level 31.5 while the RxQual and the MS Velocity vary. Say the roads are clear, the mobile station is at 110Km/hr., and the RxQual is high say at level 2, the handover decision will be a yes due to the large relative decrease in the signal quality with respect to time.

Taking a case when there is no relative movements of the mobile station say at 0 km/hr. and the quality being at its best, then there's no need for a handover. When the MS velocity is at 0Km/hr., for instance when the user is in a traffic jam that's at a stop, and the RxQual is poor, then the decision made is that the process should wait. The optimal handover decision for the different RxQual is constant at around 0.6 and then drops at around RxQual 4 as the signal quality becomes poorer thereby complementing the RxLev.

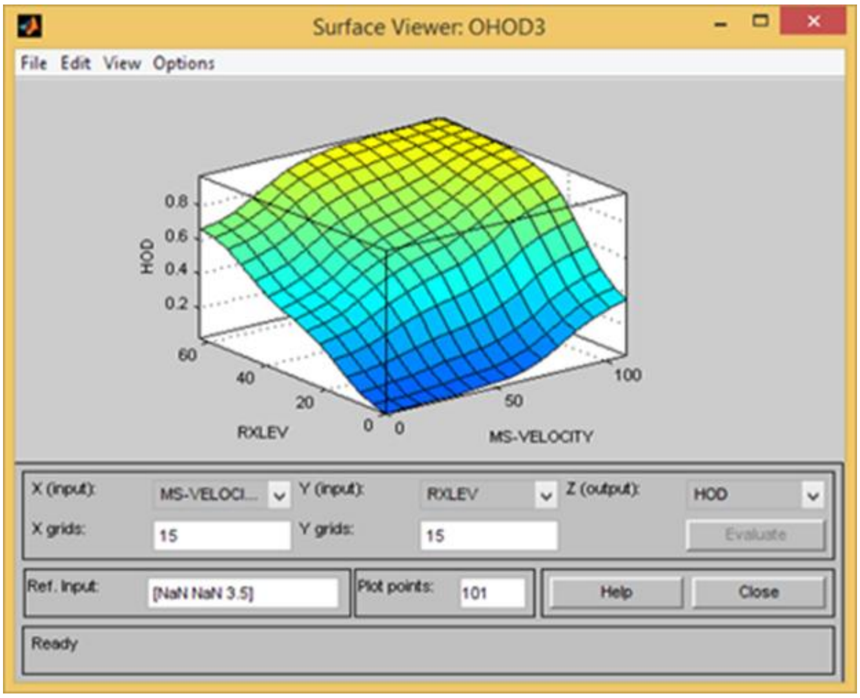

Figure 5h: Output at varied RxLev and MS Velocity

The RxQual is at a constant of level 3.5 with the RxLev and the MS Velocity varying. The OHOD increases as the MS Velocity increases and the RxLev decreases. At low signal levels, the decision to handover has to be made so as not to drop the communication and thus increased OHOD values.

Consider when the mobile station is at 110Km/hr., and the RxLev is great to say at level 20, the handover decision will be a yes due to the large relative decrease of the signal level with respect to time. Taking a case when there is no relative movement of the mobile station for instance at 0 km/hr. and the signal level being at its best, and then there is no need for a handover. When the MS velocity of the mobile station is at 0Km/hr., and the RxLev is weak say at level 60, then the decision made is that the handover should wait.

6. CONCLUSION

An analysis of using the fuzzy logic system for handover decision making has been done in this paper considering the GSM network. From the various simulations, it has been shown that the need to handover varies depending on the input(s) to the FIS (Fuzzy Inference System).The more the number of data and thus the criteria parameters used in the algorithm, the more optimised the handover decision is (optimal OHOD). Further work that could be done may be to validate the actual level of improvement on the handover success rate.

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