Handover Parameter Optimisation of a Cellular Network The Kenyan Case

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Abstract

Handover, also known as Handoff is a key procedure that ensures that the cellular users move freely through the network while still being connected and being offered quality services. It is an event taking place whenever a mobile node moves from one wireless cell to another, abandoning the connection with the first base station and getting attached to the second one. Since its success rate is a key indicator of user satisfaction, it is vital that this procedure happens as fast and as seamlessly as possible.

This paper aims to optimize the handover decision process of a cellular radio network for an in-vehicle mobile station.

This is first by determining the optimal handover parameters then developing an algorithm that determines the best time to handover using the fuzzy logic system.

Keywords: Handover, Fuzzy Logic, Handover Decision.

1. Introduction

In general, when a target cell is perceived to provide a better service than the current serving cell, the mobile station (MS) sends a measurement report to the network which decides whether or not to perform a handover. Cellular handover is a core element performed by all cellular telecommunication networks.

Most problems associated with handover failures or sub-optimal system performance could be categorized as either too early or too late triggering of the handover.

Kenya is mainly served by both the 2G and 3G networks as much as the 4G has been introduced in the network.2G is cheaper than the 3 and 4G in that the tariff, licensing and maintenance cost of the latter is higher. For a number of users, the main function of the 2G technology is the transmission of information via voice signals while that of 3 and 4G technologies is data transfer. As much as data usage is increasing in Kenya, voice communication is still with us and thus, the GSM network cannot be just wished away. The motivation of this paper is the overall network performance and user QoS improvement. The main targets are: reducing the number of handovers that are initiated but not carried out to completion (HO failures), repeated back and forth handovers between two base stations ('Ping-Pong' HOs) and calls being dropped (CDP). In [7], network operators insist on the optimisation of handover since it is related to the dropped calls, network overloads and subsequent criticisms by the users. Most of the handover algorithms applied today are based only on one input value, such as Received Signal Strength (RSS), bandwidth, cost or distance, which does not provide proper information for handover decision making. During deployment, operators tend to use standard parameter templates, as there are many GSM parameters. However, due to the differences between cells (propagation and interference environment), it is necessary to fine-tune some parameters on a cell-by-cell or adjacency-by-adjacency basis in order to get optimum performance. The essential idea behind optimisation is how to find the correct value for a specific parameter applied to a specific cell.

Radio resources, such as power and frequency spectrum, are valuable, hence, they should be used efficiently so as to boost the users' experience for the better. In order to realise this, efficient algorithms and advanced technologies are critical thus is the need for intelligent systems.

An *Intelligent* system is one that is able to modify its action in the light of on-going events. Such systems are *adaptive* and give the appearance of being *intelligent* as they change their behaviour without the intervention of a user.

These two uses of the term *intelligent* are important as they describe systems in common use. The first usage includes all rule-based methods such as the fuzzy logic. The second usage includes techniques which aim to perceive and comprehend the significance of the data with which they are trained; such as the neural networks.

The fuzzy logic forms a basis for fuzzy controlling where linguistic terms, such as "medium", "high", "low" etc are mapped to the whole interval of [0 1] by using membership functions. It is based on the if–then rules, which express the relationship between the input and the output variables. The rules are derived from statements that are formulated in natural language.

The major advantages of the fuzzy logic are:

1. It is conceptually easy to understand.
2. The mathematical concepts behind fuzzy reasoning are simple.
3. Fuzzy logic is flexible.
4. With any given system, it is easy to add more functionality without starting again from scratch.
5. Can model arbitrary complex nonlinear functions.
6. It is possible to create a fuzzy system to match any set of input-output data.
7. Tolerates imprecise data. Most things are imprecise even on careful inspection. Fuzzy reasoning builds on this understanding.

Due to these advantages, the Fuzzy Logic can be applied to optimize the QoS of the mobile phone networks. Since handover is dependent on fading and other environmental factors, a fuzzy logic system will give good results as it works with imprecise data [8].

The work in this paper is divided into six sections: (1) Introduction, (2) Related Work (3) Theoretical Framework, (4) Simulation Work, (5) Results and Discussion then lastly (6) Conclusion.

2. RELATED WORK

Work that has been done on this topic has focused on the LTE network for instance in [1], [2] and [3]. A vertical handover decision algorithm is developed based on artificial neural networks (ANN) [4]. The mobile device collects features of available wireless networks and sends them to a middleware called vertical handover manager through the existing links. A fuzzy logic based algorithm [5] is developed which is used to handle handovers between WLAN and UMTS. Work done in the paper [6] includes two parameters: - a Received Signal Strength Indicator and the relative direction of a Mobile Node toward an access point, which are the inputs to the fuzzy logic system to facilitate the handover decision process and choose the best preferable access point around this MN. Traffic analysis and bandwidth have been left for future work. The main goal of the research in [8] is to investigate the several schemes that can handle handover. This research also studies the different handover mechanisms that reduce the resources utilizations of the GSM network while reducing the dropping possibilities of the user calls. Both the prioritized and the non-prioritized handover scheme are presented. [9] Says that the auto-tuning functionalities should be merged with the network elements whether a long term or short term auto-tuning is required. Fuzzy Logic Controlling has been found particularly well suited for parameter auto-tuning in radio access networks

3. THEORETICAL FRAMEWORK

Some of the parameters that are considered when a handover decision is to be made include:

i. Measurements are taken by the mobile station such as the downlink reception level of the serving cell and the transmission quality.
ii. Measurements made by the base station such as the timing advance
iii. Static parameters such as the maximum transmit power of the mobile station and that of the serving base station
iv. Traffic such as the cell capacity.

During the process of making a handover decision, the BSS will process, store and compare certain parameters from the measurements made and the predefined thresholds. For every slow associated control channel (SACCH) multi-frame, the BSS compares each of the processed measurements with the relevant thresholds. The radio link measurements, the reported RXLEV, and RXQUAL values are needed when performing handover.

The Received Signal Level (RxLev) is used to determine how strong a received signal is. The mobile station constantly monitors the available base stations' RxLev values and will use this information as a basis for changing its currently active connection.

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 [16].

Three types of handover can be distinguished depending on the network structure:

i. Intra-BSC Handover – This is where the mobile station changes between two cells that belong to the same BSC. In this case, the BSC has full control over the handover.
ii. Inter-BSC Handover – where a mobile station changes between two cells belonging to different BSCs under the same MSC/VLR. In this case, the "old" BSC will take the decision and initiate the handover.

iii. Inter-MSC Handover – The mobile station changes between two cells belonging to different BSCs under different MSC/VLRs. In this case, the "old" BSC will take the decision and initiate the handover.

[12] Encourages that the handover process in wireless networks should allow users to move without dropping their communication.

4. SIMULATION WORK

To develop the algorithm, the fuzzy logic system is considered [20] and this comprises a series of steps as below:

1. Choice of the Input Parameters

The network performance in terms of quality, capacity and operability may be improved should the characteristics of the cells and the changing environment are considered [11]. It is at this point that this case considers three input parameters: The signal level (RXLEV) the signal quality (RXQUAL) in the current serving cell and also the Velocity of the mobile station.

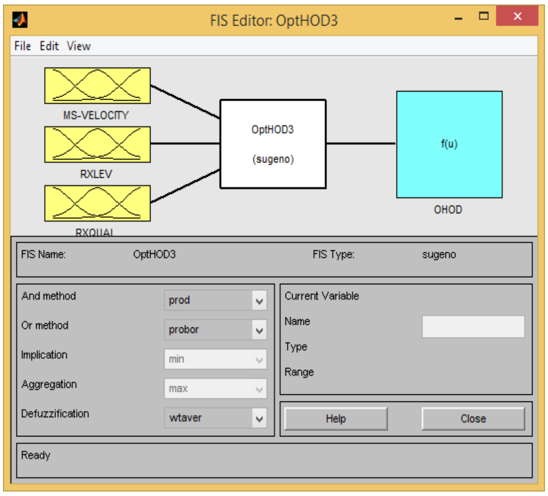


Figure 1: Fuzzy Logic System used

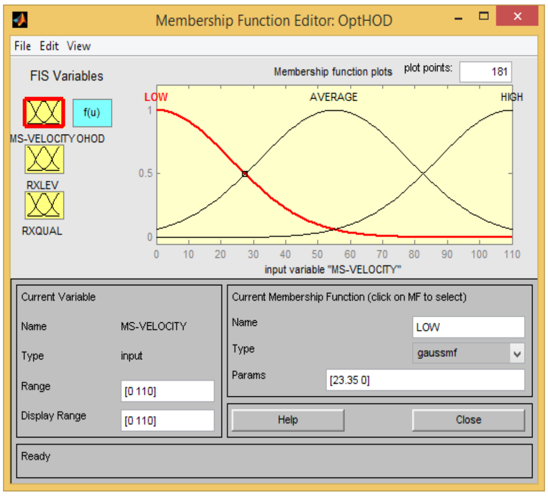


Figure 2: Membership functions

2. Fuzzification

Fuzzification step converts the real input values into fuzzy sets. The membership degree of the measured input values to the considered properties is determined by means of the corresponding membership functions and is in the interval [0 1]. In this paper, Gaussian membership functions are used. The properties, which are also called linguistic regions, describe the measured values of the input parameters. One membership function is associated with one linguistic region. The input parameters in this work are described by three linguistic regions: "Low", "average", and "high" and for the output parameter, "Yes", "Be Ready", "Wait" and "No".

3. Inference Engine and Rule Base

The inference engine applies the rules in the rule base and outputs a fuzzy value. The rules in the rule base are designed based on experience and knowledge [10].Their number depends on the number of the input variables and on the number of the distinguished linguistic regions per input variable. Now, in this case, there are 3 input variables each with 3 properties thus resulting to 27 rules. A section of the rules has been displayed below.

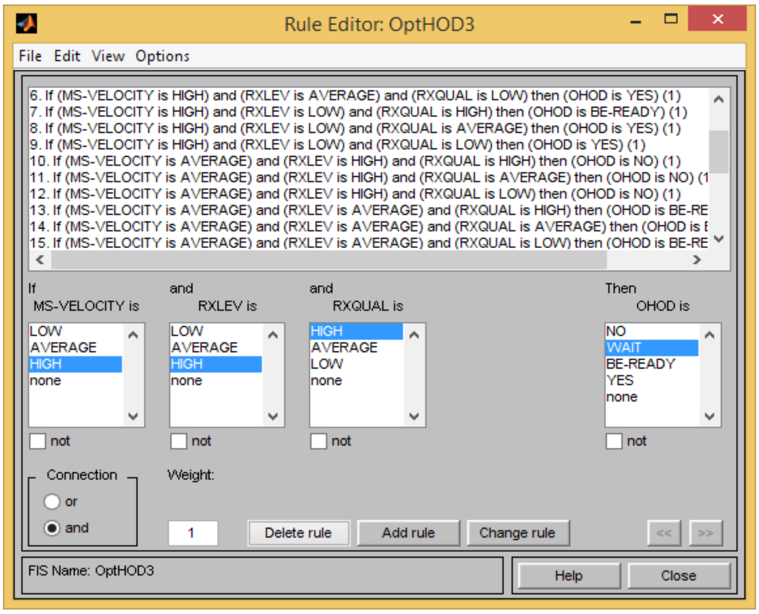


Figure 3: Sample set of rules

4. Defuzzification

The output membership degrees for each linguistic region of the output parameter are then used as an input for the defuzzification step. In this step, the fuzzy output values are converted into real numbers.

5. RESULTS AND DISCUSSION

The output of the fuzzy system in this work is called the Optimal Handover Decision (OHOD). It is the range of 0 to 1. There are 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 1for Yes.

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

The figures below show the results of the various sets of inputs giving their different outputs.

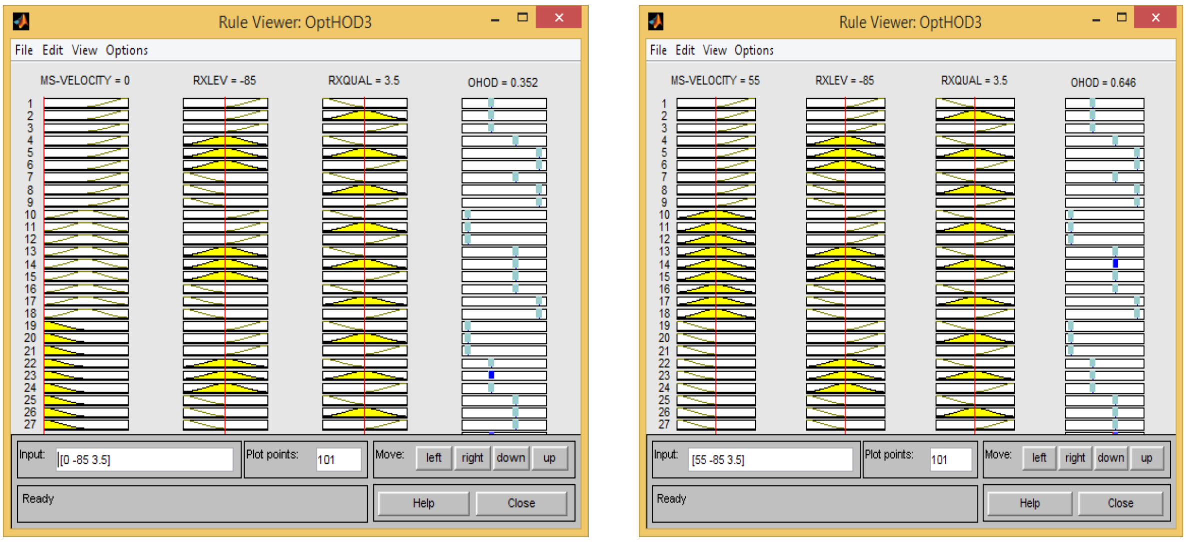
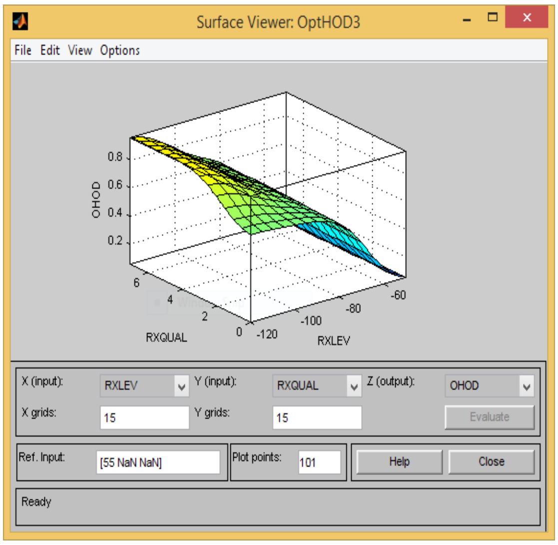
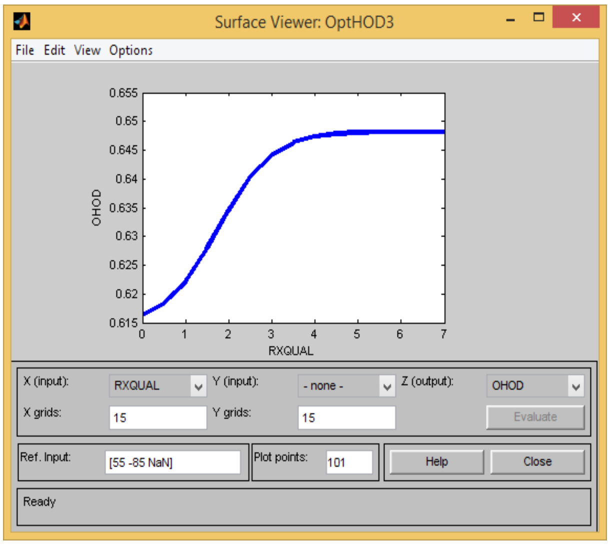


Figure 4 (a) MS Velocity at 0Km/hr. (b) Inputs at mean values

(d) At maximum velocity (e) No need of handover

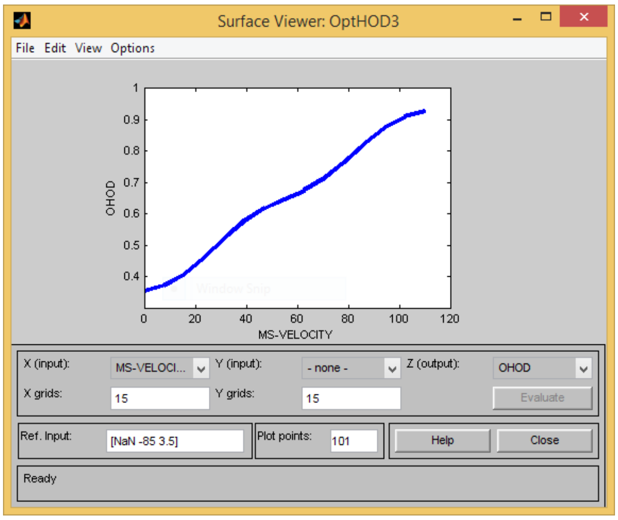
When the velocity of the mobile station is at 0Km/hr.,(a) for instance when the user is in a traffic jam that's at a stop, and the other two parameters are still appropriate for handover, then the decision made is that the process should wait. Given a time when all the input factors are at their mean positions, (b) then the user will be ready for handover. Say the roads are clear and the mobile station is at 110Km/hr., (c) the handover decision will be a yes. Taking a case when there is no relative movement of the mobile station, (d) the signal level and quality being at their best, then there's no need for a handover.

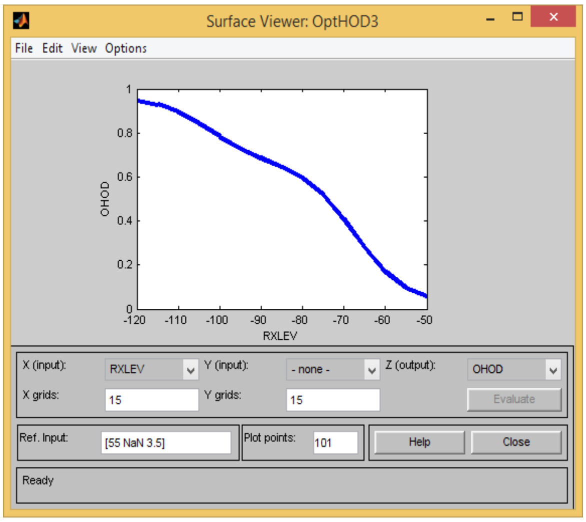




(f)Output at various the RXQUAL and RXLEV (g) Varying RXQUAL

The need to handover increases when signal level and/or the signal quality decrease (f). By the time the signal quality is at the 4th level, the decision is that the user should be ready for handover (g).





(h) Varying MS Velocity (i) Varying RXLEV

From figure (h), an increase in the velocity of the mobile station will require the need for a handover decision as there's limited time in a given serving cell at increased velocity. The optimal handover decision, when the signal level is being varied (i), decreases as the RXLEV increases. At low signal levels, the decision to handover has to be made so as not to drop the communication and thus increased OHOD values.

6. CONCLUSION

From the work above, it can be inferred that the probability of handover can vary depending on the various factors-RXQUAL, RXLEV, and the MS Velocity.

In this case, the optimised handover decision process has been realised. With this proposal, there will be better decisions made concerning the best time to handover to a given cell thus reduced handover dropping probabilities. This paper is based on the GSM network but the idea could be extended to the other networks.

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