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# Analysis of the impact of Adaptive Neuro Fuzzy Inference System (ANFIS) Algorithm on Handover Decisions

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## Abstract

Many traditional handover algorithms such as Fuzzy logic based and hysteresis have short comings. The fuzzy handover algorithm is not optimized thus needs attention from human experts. Fuzzy logic and neural networks are two complementary technologies. This is so because the neural networks have learning ability that can learn knowledge using the training examples, while FIS deduces knowledge from given fuzzy rules. The combination of the two outperforms either fuzzy logic or neural network method used exclusively. Most of existing ANFIS handover algorithms have not taken into consideration how the number of the inputs to ANFIS affects performance of the algorithm. This work aims at analyzing impact of using the adaptive neuro fuzzy inference system for the handover decision making. The number of inputs that were considered for this case were five and they were signal quality, signal level, available bandwidth, mobile station velocity and traffic load of the BTS. The results from the different simulations have shown that, need to handover vary depending on number of inputs to the ANFIS. As the number of inputs to the ANFIS is increased, the handover decision is optimized. The data used in training the ANFIS was obtained from the developed fuzzy logic system and Safaricom LTD, Kenya.

**Keywords:** ANFIS, Handover decisions, iterations, Signal level, signal quality

## I. INTRODUCTION

Fundamentally the ANFIS is all about taking the FIS and tuning it with the ANN algorithm using some collection of the input-output data. With the given input and output data set, toolbox function ANFIS will construct the FIS whose MF parameters are adjusted (tuned) using back-propagation algorithm alone or the combination with the least squares type. The adjustment will allow the fuzzy systems to learn from data they are modeling [8] [10]. Parameters associated with MFs changes through learning process. The adjustment of these parameters (or their computation) is facilitated by the gradient vector. The gradient vector will provide the measure of how well FIS is modeling input and output data for the given set of parameters. Any of the several optimization routines will be applied to adjust parameters and reduce measure of error when gradient vector is obtained. The measure of the error is the sum of squared difference between the actual and the desired outputs [9] [11]. The process is known as the supervised learning in the neural network terms. Fuzzy logic and neural networks are two complementary technologies. This is so because the neural networks have learning ability that can learn knowledge using the training examples, while FIS deduces knowledge from given fuzzy rules. The combination of the two outperforms either fuzzy logic or neural network method used exclusively [9].

Most of existing ANFIS handover algorithms have not taken into consideration how the number of the inputs to ANFIS affects performance of the algorithm. The proposed method consist of a five layer ANFIS, that takes in five inputs that is signal level, signal quality, available bandwidth, MS velocity and traffic load of the BTS. This method investigates how number of inputs to ANFIS affects the performance of the algorithm. As number of the inputs to ANFIS is increased, performance of algorithm improves.

## II. RELATED WORK.

Adaptive Neuro-Fuzzy Inference System (ANFIS), method used as the teaching method for the Sugeno-type fuzzy system was proposed by Jang in 1993 [6]. ANFIS will construct an input-output mapping based on human knowledge and generated input output data pair using either hybrid algorithm or back propagation algorithm. When applying the ANFIS, the user has to specify number and the type of the fuzzy system (MFs), membership function. It is efficient in that it combines advantages of Fuzzy Logic Controller (FLC) and Neural network (NN) in constructing the nonlinear self-tuning controller. Intermediate results are interpreted and analyzed easily because the rules takes the linguistic format. Checking data sets, number of the data pairs and training data sets are some of design parameters that are required for ANFIS controller. For training to commence, number of epochs are to be specified. The default minimum number of epochs is three. ANFIS is viewed as a hybrid method by researchers. It consists of gradient method used in calculation of MFs for input parameters and least square method used in calculating the output function parameter [7]

Authors in [1], proposed vertical handover decision algorithm for the wireless heterogeneous networks basing on adaptive neuro fuzzy inference. Parameters that were considered were data rate, RSSI and monetary cost. From their results they concluded that ANFIS algorithm provided enhanced outcomes for the network and the user. According to their results ANFIS reduced number of handovers as opposed to pure Fuzzy logic. Authors in [2], proposed the novel vertical handover algorithm basing on ANFIS. They considered parameters such as subscriber speed, jitter, initial delay, and bandwidth and received signal strength. Their results showed that the ANFIS in design is simpler and has less time delay. Authors in [3], proposed an ANFIS handover algorithm. Two input parameters were considered (RSSI and BER). Their aim was to introduce a training element to existing fuzzy handover algorithm. With the use of ANFIS, number of rules was reduced to only three reducing complexity of system and speed of training convergence. Authors in [4], proposed the ANFIS for the dynamic load balancing for 3GPP LTE. Three input parameters were considered (fairness index, hysteresis and satisfied users). Authors in [5], proposed adaptive netwok basing on fuzzy inference system model for minimizing handover failure in mobile networks. They considered three inputs (signal to interference ratio, speed of the mobile phone users and distance. They concluded that rate of handover failure in the mobile wireless network was effectively controlled by ANFIS. Also the effectiveness of their algorithm was determined by the amount of data set used to train ANFIS.

From the above it is evident that none of the authors have considered how number of inputs affects the performance of ANFIS handover algorithm. In this paper, an investigation of how increase in number of the inputs to ANFIS affects the handover decision is carried out.

## III. PROPOSED ALGORITHM

In this research work, an ANFIS handover algorithm is presented with aim of investigating the performance of algorithm with increase in number of the input parameters. Five input parameters were considered which are, signal quality, signal level, available bandwidth, MS velocity and traffic load of the BTS. In this research, after introduction of the training element by ANFIS, an investigation of how increase in number of the inputs to ANFIS affects the handover decision was carried out. The comparison was made based on number of the iterations and time it takes for convergence to take place. A threshold of 0.5 is used in order to reduce unnecessary handovers. Any threshold above 0.5 triggers handover while that below 0.5 does not trigger handover. Gauss membership function, (MF) was used as MFs due to its capability in achieving better handover performance. Number of membership functions used was three and the MF type was constant.

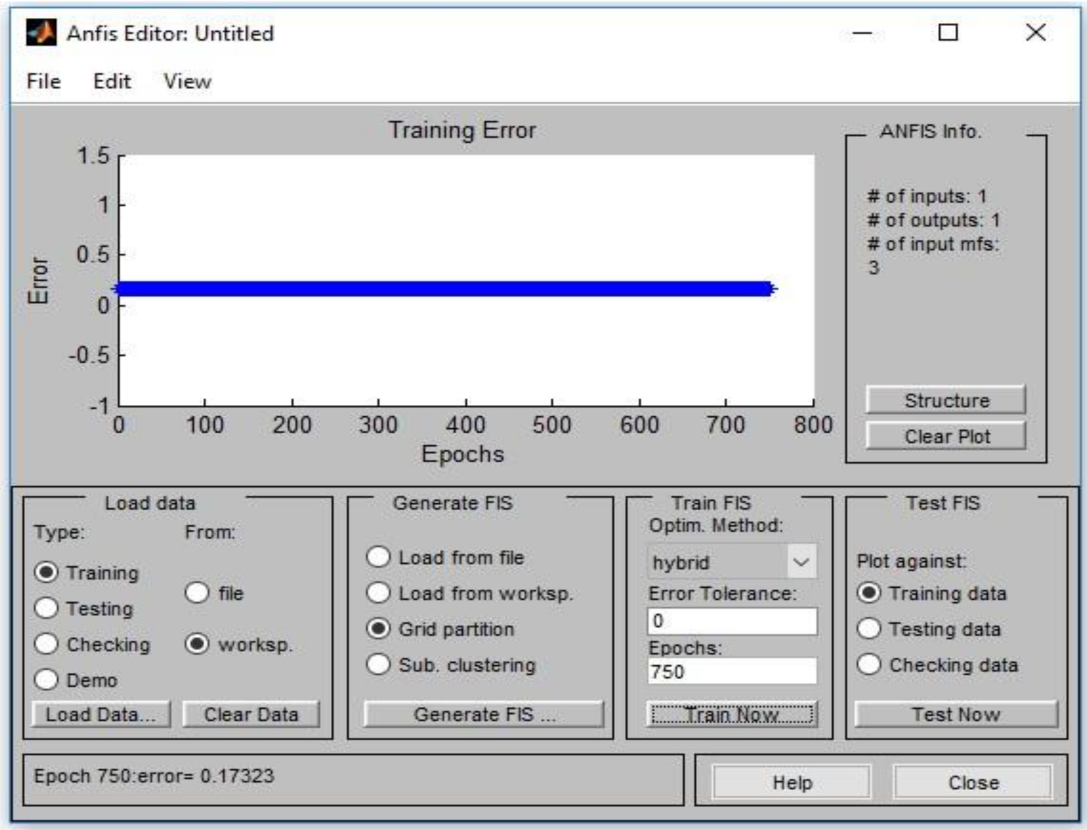


**Fig. 1a.** Training error and number of the epochs for one input.

As shown in figure 1a, when number of the inputs to ANFIS is one (signal quality), the training error is high (0.17323) and it takes large number of the epochs for convergence to take place.

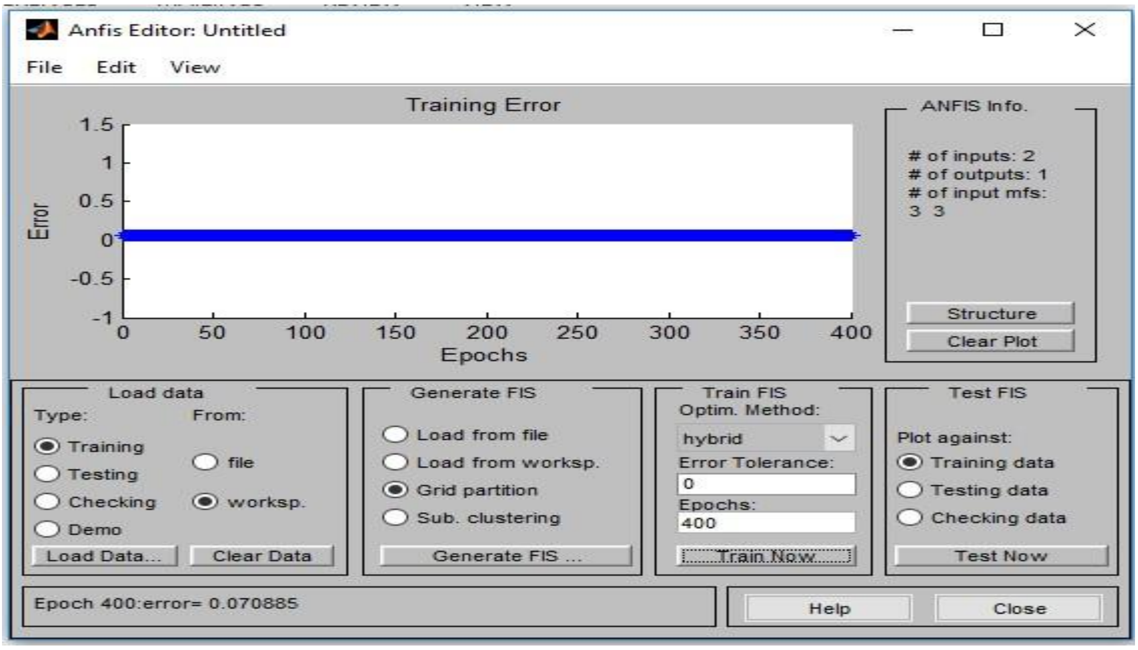

**Fig. 1b.** Training error and number of the epochs for the two inputs.

As shown in figure 1b, when number of the inputs to ANFIS is two (signal quality and signal level), the training error reduces further (0.070885), as compared to previous case of only one input. It also takes a short time for convergence to take place (only 400 epochs) when compared to the case of one input.

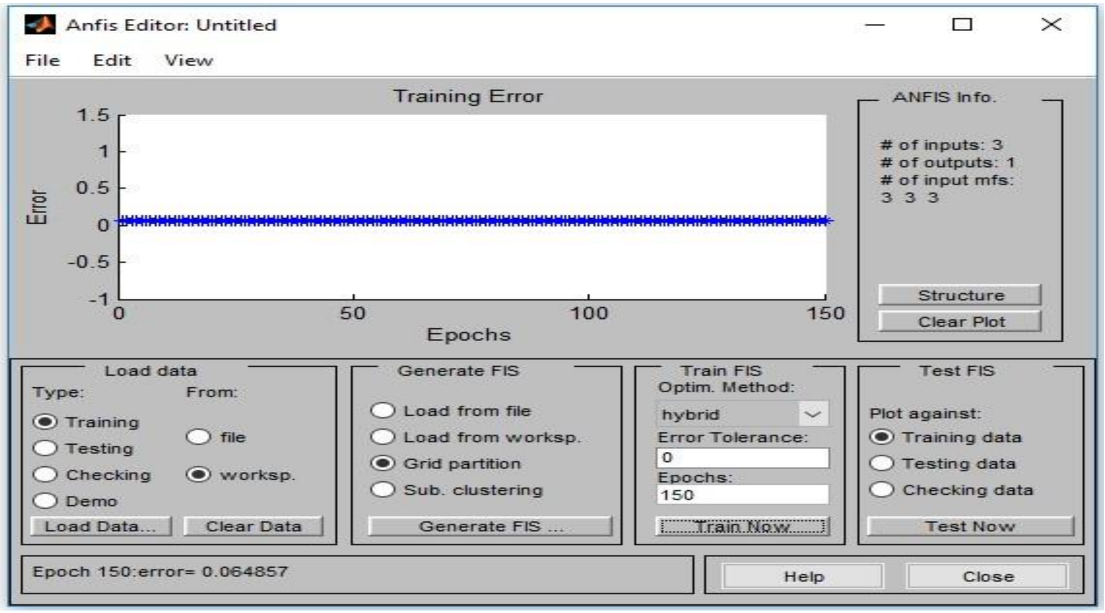

**Fig.1c.** Training error and number of the epochs for the three inputs.

As shown in figure 1c, when number of inputs to ANFIS is three (signal quality, signal level and available bandwidth), the training error reduces further (0.064857), as compared to previous case of only two inputs. It also takes a short time for convergence to take place (only 150 epochs) when compared to the case of two inputs.

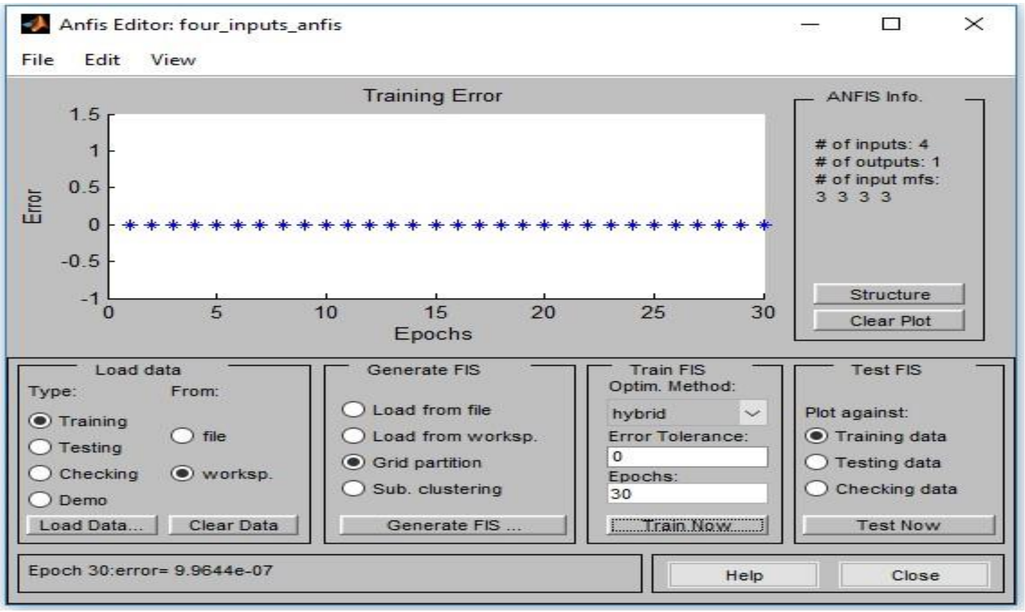


**Fig.1d.** Training error and number of the epochs for the four inputs.

As shown in figure 1d, when number of inputs to ANFIS is four (signal quality, signal level, available bandwidth and MS velocity), the training error reduces further (9.9644e-07) as compared to previous case. It also takes a short time for convergence to take place (only 30 epochs) when compared to the case of three inputs.

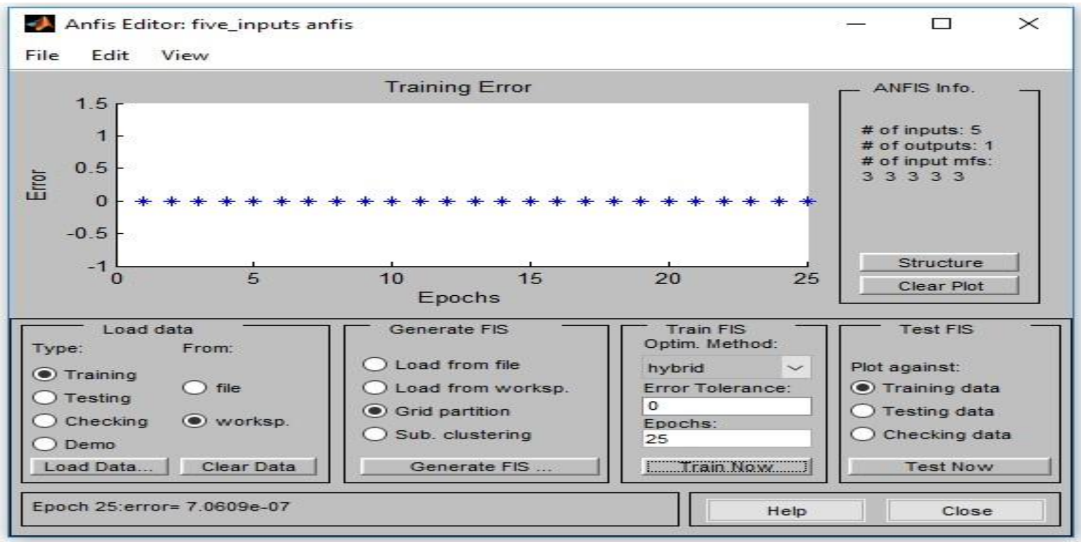


**Fig. 1e.** Training error and number of the epochs for the five inputs.

As shown in figure 1e, when number of inputs to ANFIS is five (signal quality, signal level, available bandwidth, MS velocity and BTS traffic load), the training error reduces further (7.0609e-07). It also takes a short time for convergence to take place (only 25 epochs)

Table 1, shows the relationship between number of iterations required in order to get a constant error and number of inputs.

Figure 2, is the representation of table 1 graphically.

**Table1:** Relationship between number of inputs and number of iterations needed for convergence to occur.

| | | | | | |
|---|---|---|---|---|---|
| **No of inputs** | **1** | **2** | **3** | **4** | **5** |
| **No of iterations** | **650** | **400** | **150** | **30** | **25** |

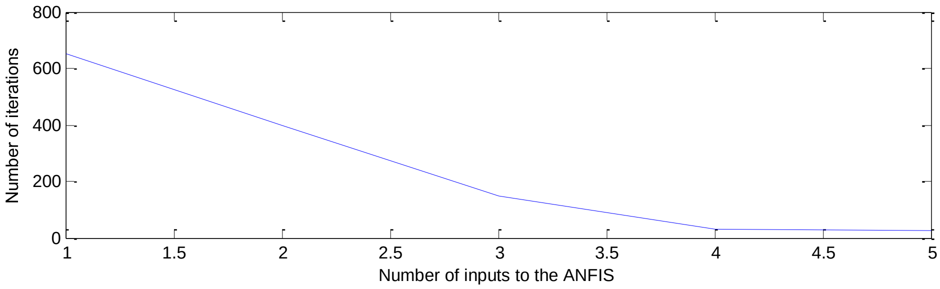


**Fig. 2.** Relationship between number of inputs and iterations.

## IV. RESULTS AND DISCUSSION

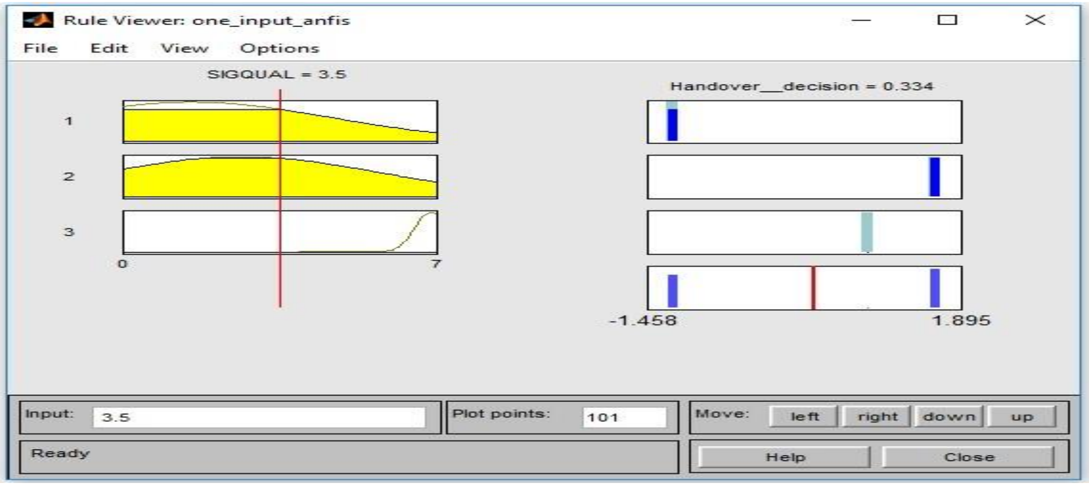


**Fig. 3a.** Output of ANFIS at mean – one input (signal quality)

The output of figure 3a means that Mobile station has to wait before handing over to the next BTS.

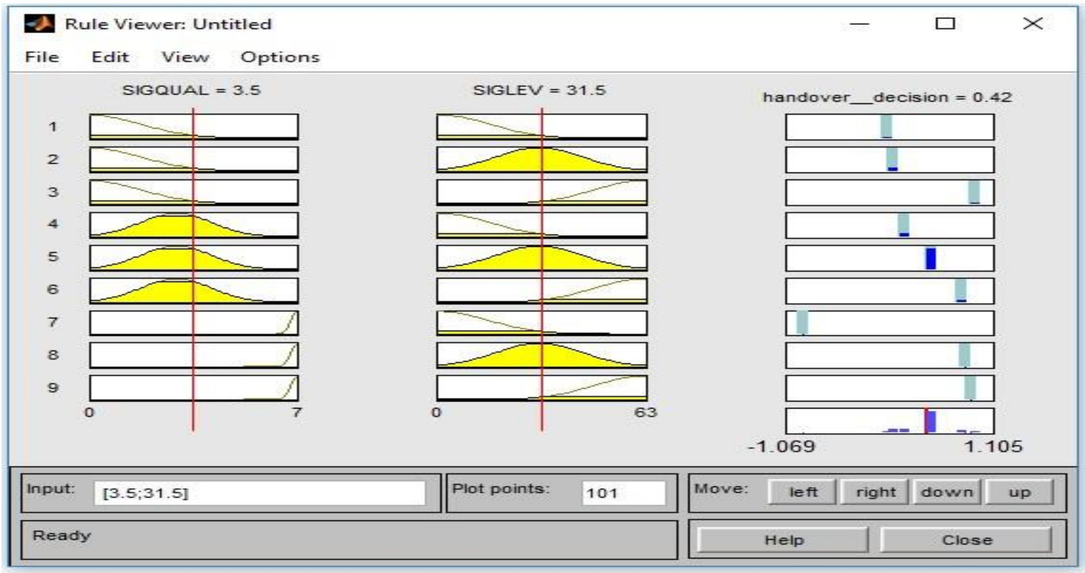


**Fig. 3b.** Output of ANFIS at mean – two inputs (signal quality and signal level)

In figure 3b, two input parameters, that is signal quality and signal level are at their mean position giving an output of 0.42. Comparing this output with threshold value of 0.5, it shows that there is no necessity of handing over to the next BTS since the current one can still offer best services.

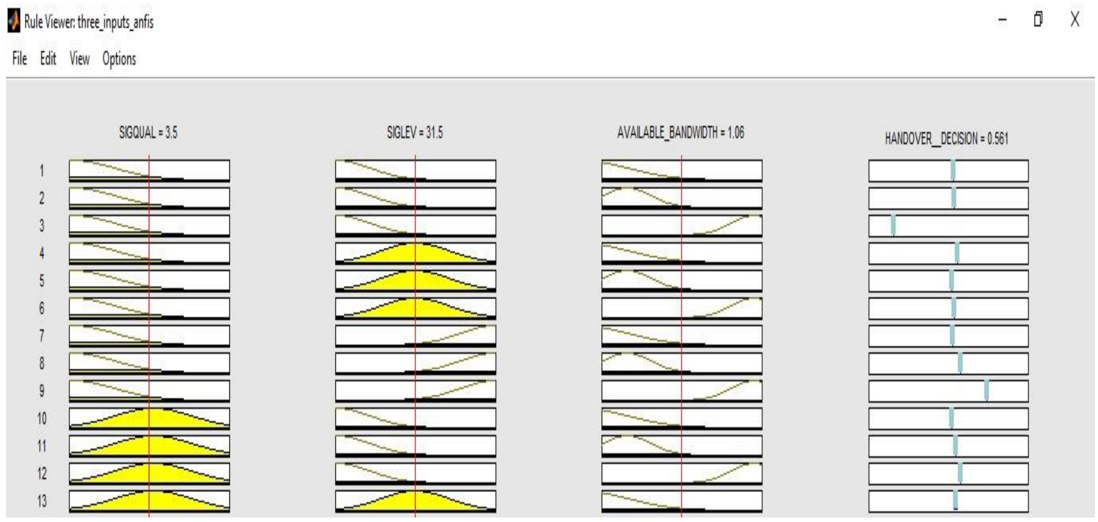


**Fig. 3c.** Output of ANFIS at mean – three inputs

In figure 3c, three input parameters, that is the signal quality, signal level and available bandwidth are at their mean position giving an output of 0.561. Comparing this to the threshold value implies that the current BTS can no longer support the service, hence the need to handover to the next BTS.


**Fig. 3d.** Output of ANFIS at mean – four inputs

In figure 3d, four input parameters, that is the signal quality, signal level, available bandwidth and MS velocity are at their mean position giving an output of 0.607. Comparing this to the threshold value implies that the current BTS can no longer support the service, hence the need to handover to the next BTS. This value is higher than the one in the previous case due to the effects of parameter “available bandwidth”

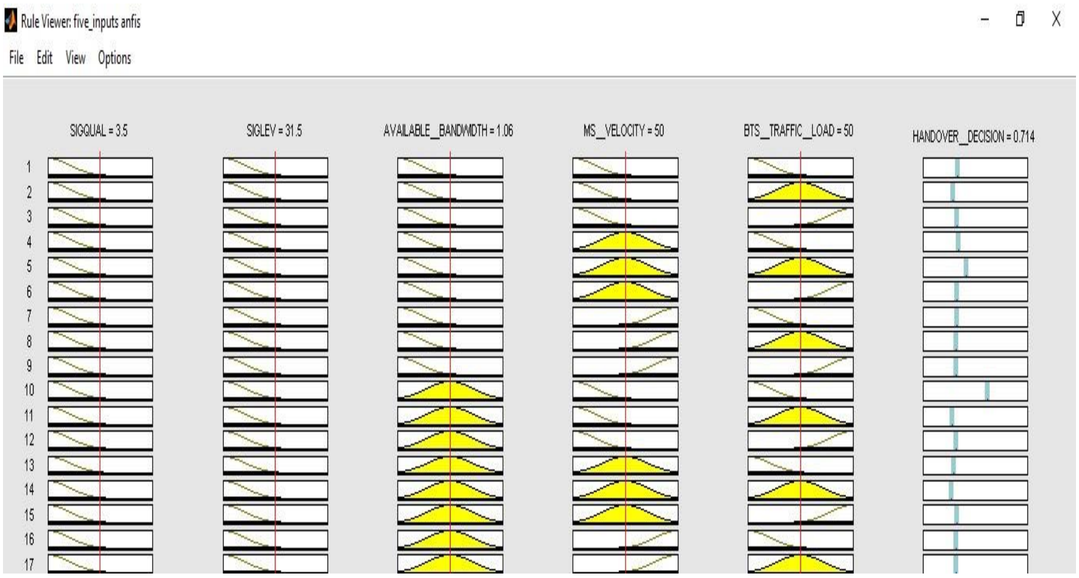


**Fig. 3e.** Output of ANFIS at mean – five inputs

In figure 3e when all the input parameters(signal quality, signal level, available bandwidth, MS velocity and BTS traffic load) are at their mean value gives an output of 0.714 implying that there is a high need to handover to the next BTS.

**Table 2:** Relationship between output of ANFIS and number of inputs

| No of inputs | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Output of ANFIS | 0.334 | 0.42 | 0.561 | 0.607 | 0.714 |

Table 2, shows the relationship between number of inputs and the output of ANFIS

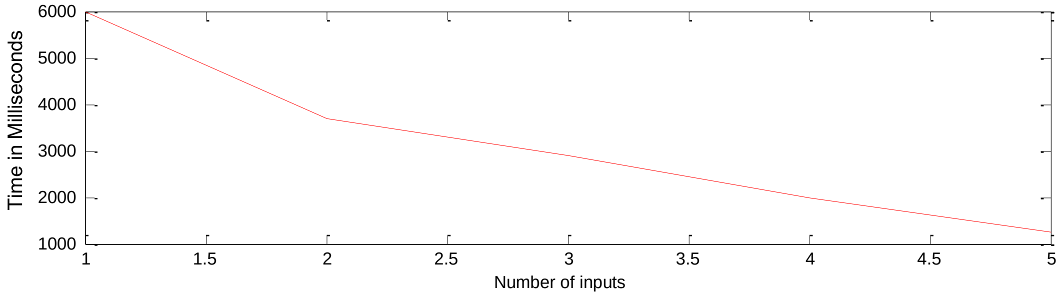


**Fig. 4.** Relationship between number of inputs and time.

Figure 4 shows the relationship between time taken for convergence to take place and the number of inputs to ANFIS.

## V. CONCLUSION AND FUTURE WORK

As number of the inputs to ANFIS is increased, performance of algorithm improves. The output is 0.334 when number of inputs is one, and 0.561 when number of inputs is three and 0.714 when number of inputs is maximum (five). Thus increase in number of the inputs to ANFIS will increase performance of handover process.

For future work, an investigation should be carried out to find the maximum number of inputs to the ANFIS that increases performance of handover algorithm and above which no improvement will take place.

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