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Fuzzy Logic Simulation of Key Performance Index in Telecommunication Activities

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Abstract: Fuzzy logic system has been a success in deployment in high and sensitive areas such as automatic controls, robotic, aerospace and telecommunication. In telecoms, global demand for high-speed, large data transmission services, such as internet access via a mobile terminal, voice and video conferencing with mobile phones, are gaining popularity and growing faster than the required infrastructure in place or deployed already. This paper presents a fuzzy based simulation on key performance index in telecommunication activities to meet the requirement of the QoS. The analysis and simulation results show that fuzzy scheme has a better robust performance in channel utilization.

I. INTRODUCTION

A cellular network is a radio network comprising cells, which are interconnected usually over coverage area of a given geographical area (Singh and Ashtana, 2012). The tremendous advances in data communications and telecommunication can be equally conclude perhaps that the most revolutionary is the development of cellular networks based on the exponential increase in number of subscribers of 11 million in 1990s to billions in 2005 (Williant, 2005). That shown the universal usage, spread use of mobile phone service, internet services and other related services are the sign of general and public acceptance of mobile cellular technologies. The related foundation books are found in Nishith and Reed (2014), Ajay (2007) and recent literature review are in Gawas (2015), Sathiya *et al*. (2015), Said *et al*. (2013) taken from the different scholars and researchers. Ideally, an operator likes to totally maximize the radio resource utilization and also accommodate as many subscribers with their varied resource requirements as possible without increasing investment. This calls for efficient user roaming and management of the limited radio resources available has become important for grade of service (GoS) and quality of service (QoS) provisioning and network stability and effective radio resource management (RRM) to manage or optimize the existing infrastructure using soft computing techniques such as fuzzy system (FS), neural network (NN), evolutionary computation (EC) and others.

Ironically in the late 1930s, the concept of multi-valued sets was developed and formalized by Max Black but fizzled out slowly because of little or no attention by positivists and technological communities (Kosko, 1993). In 1960s, Prof. L. A. Zadeh coined the name "fuzzy" to describe multivalued set theory and applied it to solve system problems but received no immediate interest as at that time in western hemisphere by researchers and highly rated scholars (Kosko, 1993). The acceptance of interest slowly grew in Japan and China in the late 70s and mid 80s where companies were rolling out products that inculcate fuzzy logic techniques. This singular interest acts as an impetus for explosion of fuzzy logic techniques, general acceptance and usage in the whole technological communities in the world (Kosko, 1993).

II. LITERATURE REVIEW

Over the years, several scholars and researchers have provided informative discussions, cited different examples, identified trends and proposed great numbers of different resource allocation techniques that seek to proffer solutions that will address the need for adequate provision and allocation of network resources and reduce wastages. The resources in question are power, bandwidth, channels and frequency (Mundada *et al*., 2011; Moradi, 2011). Some of the tremendous works done based on allocation of frequency are showcased in the following literature of scholars (Jongchan and Moonho, 2015; Narayan *et al*., 2014). Some of the research works by researchers and scholars that are based on allocation of channels are (Mishra and Saxena, 2012; Kishana and Balakrishnan, 2013). Some of the research work done on bandwidth allocation includes: (Avinash *et al*., 2014, Akashdeep *et al*., 2014). Power requirements for communication are reviewed in (Mishra and Saxena, 2012).

Discussions on allocation algorithm classification act as a useful guide and future direction to the selection of an approach or technique to solve complex problems more efficiently than using a brute force alternative. Some related foundation materials in (Claus *et al*., 2014). Sumathi *et al*. (2008) provides an informative discussion on theoretical advances and applications in evolutionary intelligence and other problem-solving strategies are found in (Mehboob *et al*., 2014), neural networks (Bhattacharya *et al*., 2013), optimization (Sheng *et al*., 2014), Particle swarm (Amin and Mottar, 2014), fuzzy logic (Atayero and Luka, 2012).

Quality of Service plays a key role in cellular networks. The network based services QoS depend on factors such as throughput, Packet error rate, reliability, delay, packet loss rate. It is for these reasons that providing QoS has been a great challenge in the past and it continues to be a hot topic as there is still a lot of scope to provide better service standards. The performance of cellular networks can be measured using different major indices called key performance indicators (KPIs) which can be ranked or grouped according to their weights because they are closely associated with each other. Isabona (2014) stated that the most important component of the KPIs used by the telecommunication operators include frame erasure rate (FER), bit error rate (BER), mean opinion score (MOS) and bit error probability (BEP).However, the major KPIs used by Nigeria Communication Commission (NCC) in Nigeria for rating the quality of service of cellular networks are standalone dedicated, channel blocking rate (*SDCCHBLK*), standalone dedicated channel loss rate (*SDCCH LOSS*), handover success rate (*HOSR*), call setup blocking rate (*CALLSETBLK*), traffic channel blocking rate (*TCHBLK*) and traffic channel mean traffic (*TCHMEAN*) (Ozovehe and Usman, 2015).

In this paper, fuzzy based solution was reviewed and discussed extensively. Sabra and Alam (2004) proposed a fuzzy logic feedback controller for traffic management in asynchronous transfer mode (ATM) networks which monitors the traffic on the links, switches and sends back explicit cell rate to the sources. Malarkkan and Ravichandran (2006) have analyzed Fuzzy based (CAC) scheme in which the mobility information of the new user requesting connection were considered. The existing users type of service request and the load factor are formulated and calculated from the intra-cell interference at the base station with a view of using the QoS requirement to accommodate more number of real time traffic users. Mallapur *et al*. (2008) gave the underlying design and developed a buffer allocation and call dropping scheme for wireless multimedia networks using fuzzy logic in which the buffers are allocated based on some fuzzy parameters, rate of flow, priority, and packet size which shows that the fuzzy based buffer allocation scheme performs better than static buffer allocation. Bacciu *et al*. (2008) developed admission control strategy for voice-over-internet-protocol (VoIP) over wireless local area network based on Fuzzy set theory and evaluation of the technique shows substantial advantages over traditional crisp approach. Ravichandran *et al*. (2009) identified and used fuzzy logic to provide a wonderful solution plan to the issue of call admission control (CAC) and also increase bandwidth utilization by considering call drop probability and call blocking probability. Sun *et al*. (2010) got efficient result when a fuzzy controller based QoS routing algorithm in mobile ad hoc networks was developed with primary view of measuring the performance of the scheme in terms of packet delivery, path success and average delay using Network Simulator.

III. MOTIVATION

What makes FS so unique and powerful in telecommunication system is the simple fact that most of human reasoning and concept formation are heavily linked to the use of fuzzy rules which provides a systematic framework for computing with fuzzy clauses that greatly amplifies the power of human reasoning in two remarkable human capabilities. First, the areas of the capability to converse, reason and make rational decisions in an environment of imperfect information such as conflicting and incompleteness of information, imprecision and uncertainty of information, partiality of possibility and truth or false to achieve robustness, tractability and low solution cost. Secondly, the capability to provide an inference mechanism to perform a wide variety of tasks without any measurements and enables approximate human reasoning capabilities to be applied to knowledge-based systems.

IV. FUZZY LOGIC (FL)

The research works on the Fuzzy systems have been underway for over 50 years which is difficult to cover all development aspects. A detailed treatment of the scholars and researchers are found in (Zadeh, 1965; 1973) and (Zimmermann, 2001). Fuzzy logic (FL) mimics the reasoning of a human expert, preserving information through the use of continuous “interest” or “membership” values until the output is produced. One distinct feature to be noted is that fuzzy logic is not probability despite employing values {0, 1} to represent an event or symbol. Probability functions in the likelihood of an event's occurrence while fuzzy logic values represent a truth value or the extent to which a situation is true. FL has the ability to handle complex decisions by verbalizing the whole approaches and operations with potential algorithm that not just in verbalizing but achieve the tremendous results using processing the inputs of a series of if-then directives and usage of several thresholds. The FL systems use information efficiently from robust to uncertain, missing or corrupted data to propagate till final “defuzzification”. It is capable to encode human expert knowledge/heuristics with common-sense, easily interpreted and constraints naturally enforced with relatively straightforward design and implementation. FL systems are relatively cheap because in most case, trainings of data are not usually needed except

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used to tune system and also joint or conditional probability distributions are not required. The general structure of a fuzzy inference system (FLS) with three component parts is depicted in Fig. 1

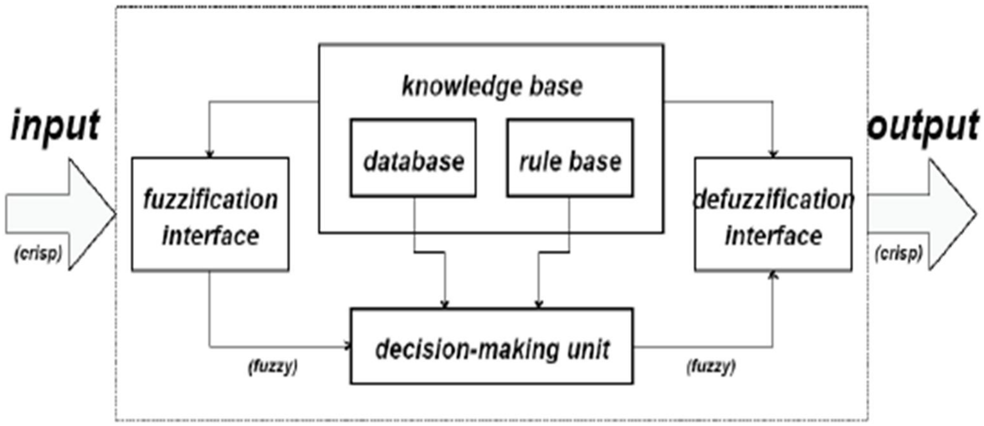

Fig. 1: General structure of a fuzzy logic system (FLS)

The idea of fuzzy sets is introduced by way of examples which are sets with imprecise amplitudes. Zadeh (1965) stated that that the "membership" in a fuzzy set is not a matter of affirmation or denial, but rather a matter of degree. Therefore, a membership function,μ, (also called universe) shows the extent to which a value from a domain is included in a fuzzy concept. Membership values represent the degree to which an object belongs to a fuzzy set. It is used to define a set and can be represented mathematically as (Ahmad 2004):

$$\mu_A(x) = 1 \qquad if\, x \in A, \text{ and}$$

$$\mu_A(x) = 0 \qquad if\, x$$

A for all values of x.

The most commonly used in practice and described mathematically and graphically in this paper are bell-shaped MF, triangular MF, Gaussian MF, two-sided Gaussian MF, pi-shaped MF, product of two sigmoidal MFs, difference between two sigmoidal MFs, and trapezoidal MF. The triangular MF as shown in fig 2, which is specified with three parameters (a, b, c) is expressed as:

$$f(x\colon a,b,c) = \mu(x) = \begin{cases} 0 & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ \frac{x-a}{b-a} & b \le x \le c \\ 0 & c \le a \end{cases}$$

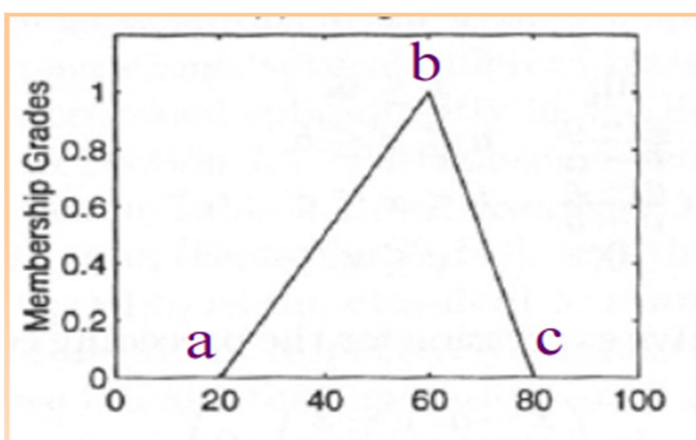

Fig. 2: The triangular MF

where the parameters *a*, *b* and *c* describe the shape of the triangular MF.

The trapezoidal MF as shown in fig. 3, which specified by four parameters (a, b, c, d) is expressed as:

$$f(x;a,b,c,d) = \begin{cases} 0 & x \le a \\ \frac{x-a}{b-a} & a \le x \le b \\ 1 & b \le x \le c \\ \frac{d-x}{d-c} & c \le x \le d \\ 0 & d \le x \end{cases}$$

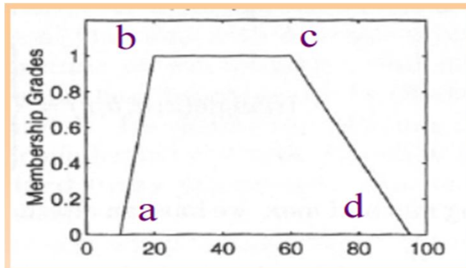

Fig. 3: The trapezoidal MF

where the shape of the trapezoidal MF is decided by the parameters *a*, *b*, *c* and *d.*

For the Gaussian MF as shown in fig. 4, specified by two parameters {m,σ }, the expression is:

$$f(x;m,\sigma) = e^{-\frac{(x-m)^2}{2\sigma^2}}$$

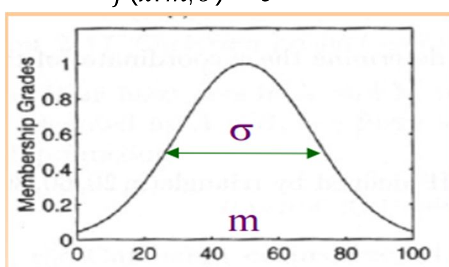

Fig. 4: Gaussian MF

where the parameters *m* and σdecide the shape of the Gaussian MF in which the m and σ denote the center and width of the function respectively. A small σ will generate a "thin" MF, while a big σ will lead to a "flat" MF. The two-sided Gaussian MF is expressed as:

$$f(x;c_1,c_2,\sigma_1,\sigma_2) = \begin{cases} e^{-\frac{(x-c_1)^2}{2\sigma_1^2}} & x \le c_1 \\ 1 & c_1 < x < c_2 \\ e^{-\frac{(x-c_2)^2}{2\sigma_2^2}} & c_2 \le x \end{cases}$$

where the shape is decided by the parameters σ_1, c_1 andσ_2, c_2which correspond to the widths and centers of the left and right half Gaussian functions. The bell-shaped MF as shown in fig 5, is expressed as:

$$f(x;a,b,c) = \frac{1}{1 + \left|\frac{x-c}{a}\right|^{2b}}$$

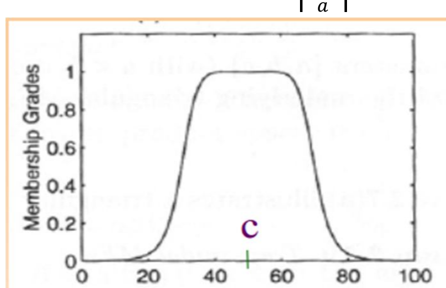

Fig. 5: The bell-shaped MF

where the parameters *a*, *b*, and *c* describe the shape of bell-shaped MF in which the parameter "b" is usually positive and can adjusted. The parameter "b" is used to vary and control the slopes of "c" (vary the center) and "a" (width of the function).

Sigmoidal MF as shown in fig. 6, specified by two parameters (a, c) is expressed as:

$$f(x{:}\,a,c) = \frac{1}{1+e^{-a(x-c)}}$$

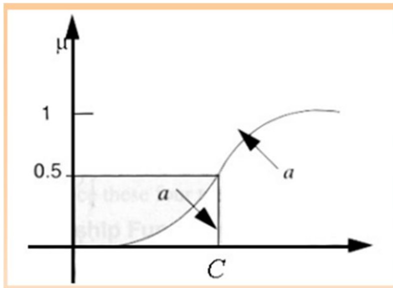

Fig. 6: Sigmoidal MF

where "c" is the center of the function and "a" control the slope.

The product of two sigmoidal MFs is expressed as:

$$f(x{:}\,a_1,c_1,a_2,c_2) = \frac{1}{(1+e^{-a_1(x-c_1)})(1+e^{-a_2(x-c_2)})}$$

where the parameters $a_1, c_1, a_2 and c_2$describe the shapes of two sigmoid MFs.

The pi-shaped MF is the product of Z shape and S shape functions. It is expressed as:

$$f(x{:}\,a,c) = \begin{cases} S(x;c-a,c), & x \le c \\ Z(x;c,c+a), & x > c \end{cases}$$

where *c* is the centre and *a* (>0) is the spread on each side of the MF.

The difference between two sigmoidal MFs is expressed as:

$$f = \left|\frac{1}{(1+e^{-a_1(x-c_1)})} - \frac{1}{(1+e^{-a_2(x-c_2)})}\right|$$

note: $f = f(x{:}\,a_1,c_1,a_2,c_2)$

where the parameters $a_1, c_1, a_2 and c_2$describe the shapes of two sigmoid MFs.

A fuzzy set is hence characterized by its membership function, $\mu_A(x)$ as:

$$\mu_A(x){:}\,X \to [0,1]$$

In the meantime, it indicates the membership grade of these elements in fuzzy set *A*. There are two major prevalent techniques of inference using fuzzy rule based system, the Mamdani and the Sugeno systems. Both begins with fuzzification of the input data and the antecedent evaluation of *if-then* rule [(rule weight) If (antecedent) Then (consequent)] is still the same but the difference lies in consequent structure techniques in such a way that rule consequents in Sugeno systems are singletons, moving with the inputs while in Mamdani technique, the inputs are fixed general fuzzy sets.

Mamdani general format of IF-THEN rule

$(w_i = n)$

$$If(A_x is P_{xj})(AND/OR\ rule)(A_y is P_{yj})$$
$$Then\ (A_z is P_{zL})$$

Sugeno first order general format of IF-THEN rule

$(w_i = n)$

$$If(A_x is P_{xj})(AND/OR\ rule)(A_y is P_{yj})$$
$$Then(A_z = k_x * A_x + k_y * A_y + k_z)$$

The scale of the rule's output is as the result of the evaluation of logical expression of both systems in the antecedent to determine a resultant membership function value (rule activation level).Because of its multidisciplinary and widely acceptance nature, the fuzzy inference system is known by numerous other names, such as fuzzy model, fuzzy expert system, fuzzy associative memory and

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simply fuzzy system. The fuzzy inference system (FIS) comprises the knowledge and experience of an expert, widely used and popular computing framework based on the concepts of sets of fuzzy control rules, fuzzy if-then rules, and fuzzy reasoning. Fuzzy inference system can be classified into three types based on the types of fuzzy reasoning and fuzzy if-then rules employed.

V. IMPLEMENTATION

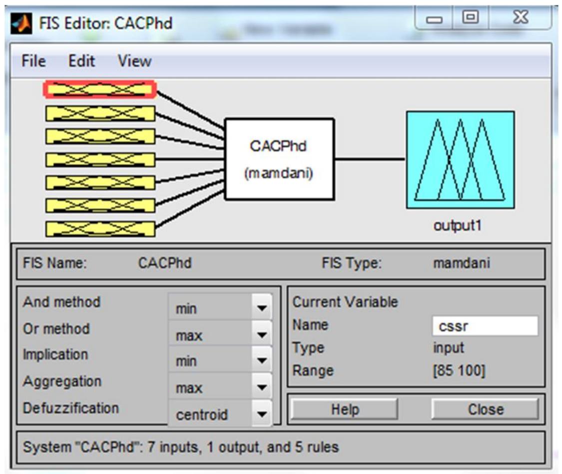

Fig 7: FIS Editor for CAC

Name='CACPhd'
Type='mamdani'
Version=2.0
NumInputs=7
NumOutputs=1
NumRules=5
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

Table 1: [Rules]

1	3	3	1	1	1	1(1)	:1
2	2	2	2	2	2	1(1)	:1
3	2	2	2	2	2	1(1)	:1
1	1	3	1	1	1	1(1)	:1
4	3	1	1	1	3	1(1)	:1

VI. RESULTS AND DISCUSSIONS

Under this premise, we present and discuss the obtained results of the proposed fuzzy system based technique in which the general structure of a Mamdani of fuzzy inference system was employed to model and simulate the system with 7 inputs, 1 output and 5 fuzzy rules, as depicted in fig. 7. The membership scheme was neatly constructed and calibrated as well as the rule base as shown in table 1, so as to obtain reasonable results.

The simplified MATLAB simulation scenario of each input variables with different membership function were depicted through fig. 8 to 14 whereas the output variable depicted in fig. 15 with membership function to match. The fig. 16 shows the rule viewer of the proposed system in which, the reading of some key parameters was considered and recorded. The fig. 17 shows the three-dimensional surface curve between CDR, CSSR and the output variable. Upon opening the Surface Viewer, the three-dimensional curve represents the mapping with special capability that is very helpful in cases with two (or more) inputs and one output

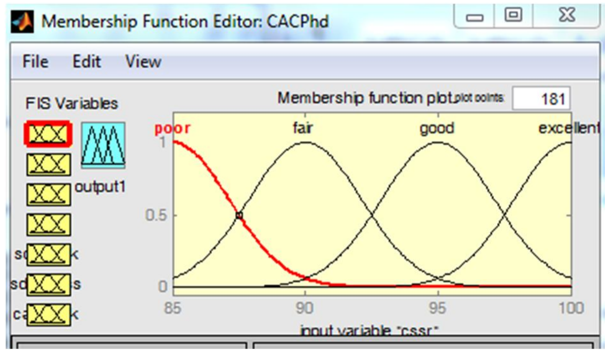

Figure 8: Membership function plot of input variable 1 “CSSR” (gaussmf)

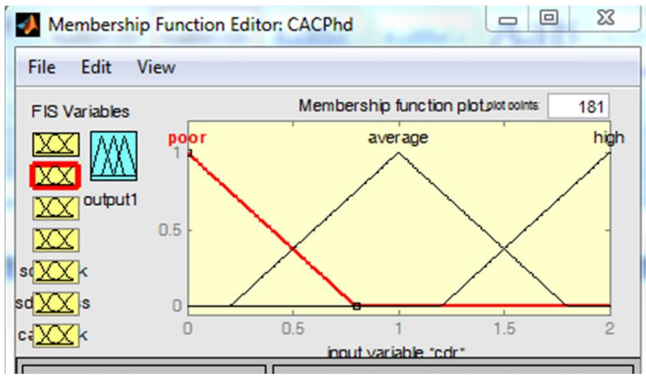

Figure 9: Membership function plot of input variable 2 “CDR” (trimf)

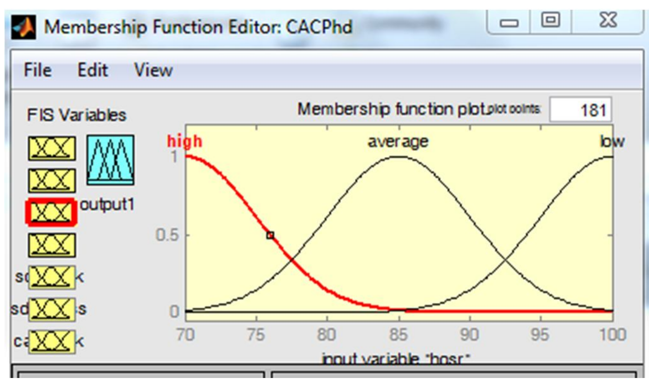

Figure 10: Membership function plot of input variable 3 “HOSR” (gaussmf)

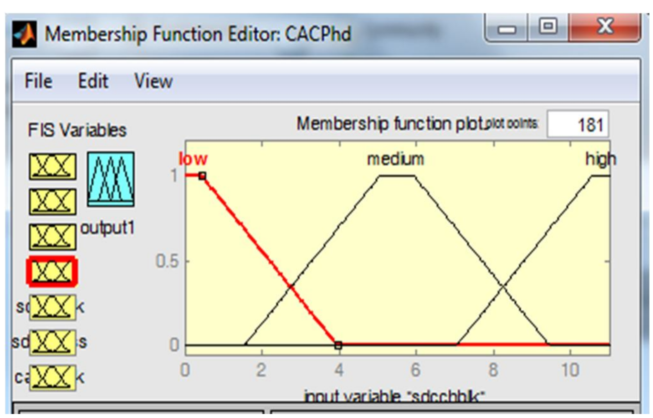

Figure 11: Membership function plot of input variable 4 “SDCCBBLK” (trapmf)

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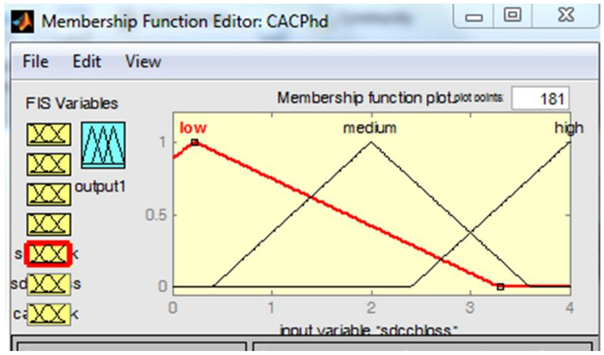

Figure 12: Membership function plot of input variable 5 “SDCCHLOSS” (trimf)

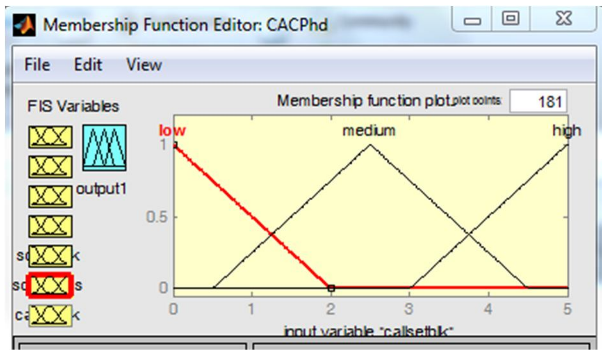

Figure 13: Membership function plot of input variable 6 “CALLSETBLK” (trimf)

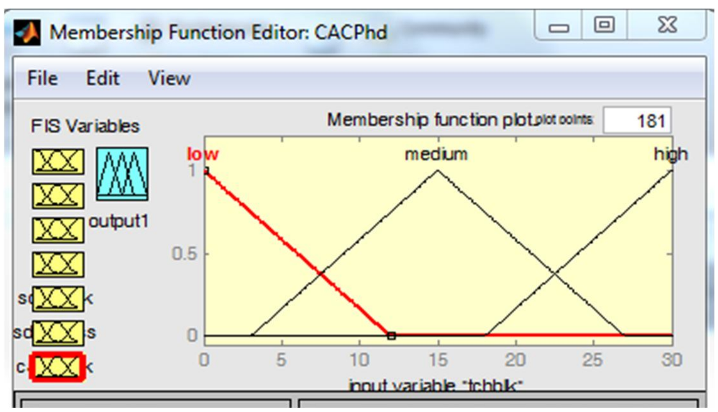

Figure 14: Membership function plot of input variable 7 “TCHBLK” (trimf)

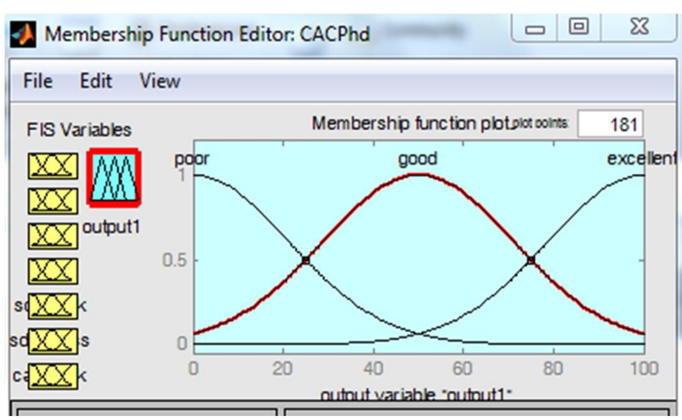

Figure 15: Membership function plot of output variable “OUTPUT” (gaussmf)

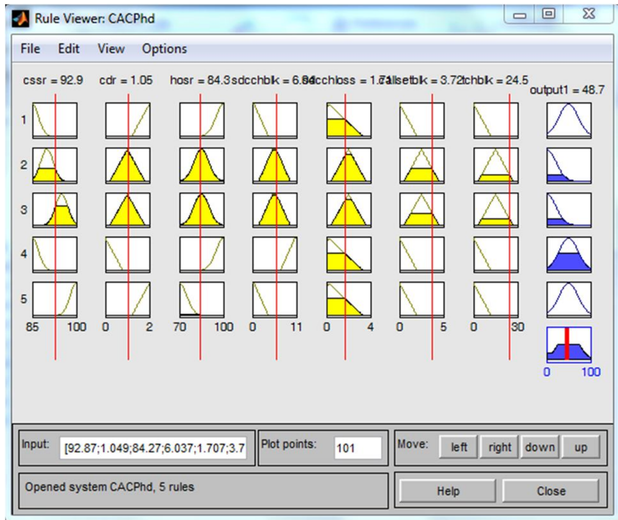

Figure 16: Rule Viewer for the proposed system

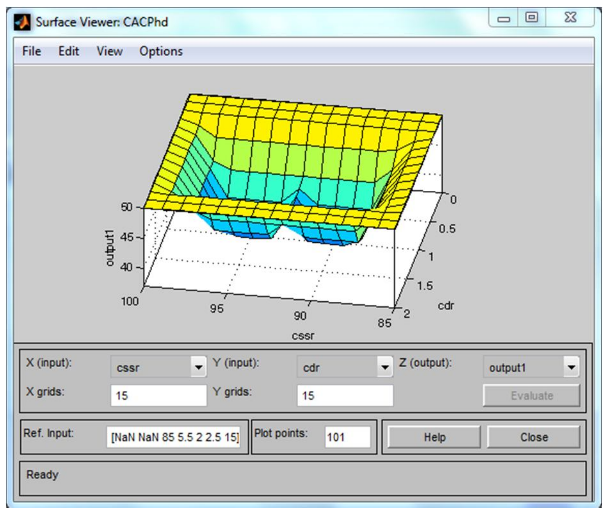

Figure 17: 3-D surface view relating changes in CSSR and CDR with the output

VII. CONCLUSIONS

In this paper, a Fuzzy logic based approach *if-then* clause was presented which shows the effectiveness of the algorithm in a simulation scenario. The proposed algorithm provides an intelligent system for optimization where all the 7 input variables were evaluated and feed to the fuzzy inference system. The authors have demonstrated the high performance and effectiveness of the algorithm in a simple simulation scenario. Fuzzy logic based prove very effective both in its ability to form high quality, faster than some standard algorithm and because it allows linguistic data to match.

VIII. RECOMMENDATIONS

Our near future research work will try to apply the result from this paper to real-life scenario, in order to improve and extend the fuzzy KPI algorithm, by taking into consideration more information about the users and the network

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