Uncertainty and Congestion Elimination in 4G Network Call Admission Control using Interval Type-2 Intuitionistic Fuzzy Logic

Uduak A. Umoh[1], Imoh Eyoh[2], Etebong Isong[3] and Andy Inyang[4]

[1] University of Uyo

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Abstract

The management and control of the global growth and complex nature of wireless Fourth Generation (4G) Networks elicits the need for Call Admission Control (CAC). However, CAC faces the challenge of network congestion, thereby deteriorating the network Quality of Service (QoS) due to inherent imprecision and uncertainties in the QoS data which leads to difficulties in measuring some objective and constraints of QoS using crisp values. Previous researches have shown the strength of Interval Type-2 Fuzzy Logic System (IT2FLS) in coping adequately with linguistic uncertainties. Intuitionistic fuzzy sets (IFSs) have indicated their ability to further reduce uncertainty by handling conflicting evaluation involving membership (M), nonmembership (NM) and hesitation. This paper applies the Interval Type-2 Intuitionistic Fuzzy Logic System (IT2IFLS) in solving CAC problem in order to achieve a better QoS in 4G Networks.

Index terms— call admission control, quality of service, fourth generation (4G) network, fuzzy logic, intuitionistic, logic.

1 Introduction

n recent years, wireless communication is changing and growing rapidly in the world. Due to its tremendous growth and complex nature, it has been challenging to manage and control the demands and complexities associated with this vast network such as I Fourth Generation (4G) Network. In telecommunications, 4G is the Fourth Generation of cellular wireless standards succeeding 3G and the 2G families of standards [1]. In 2008, the ITU-R organization specified the IMT-Advanced (International Mobile Telecommunications Advanced) requirements for 4G standards, setting peek speed requirements for the 4G service at 100 Mbit/s for high mobility communication (such as trains and cars) and 1Gbit/s for low mobility communication (such as pedestrians and stationary users).

Mobile network users in our society today strive to get the best service there is, and this has caused a migration of users to the 4G network as it provides better and improvement of services when compared to its predecessors. As the demand for better call and data services increases, there are changes and tremendous growth in 4G wireless network communications worldwide which cause the network to become complex and difficult to manage and control. Due to the influx of users on this network, network service providers can only satisfy a limited amount of traffic, thus causing network congestion. Congestion occurs when the network is overwhelmed with more service requests that it can accommodate, thus, causing delays, dropped and blocked calls. Congestion is a big contributing factor in the deterioration of QoS in a network.

In order to control and manage such complex4G Networks and still maintain good QoS, Call Admission Control (CAC) is necessary. CAC is a mechanism whose main purpose is to decide, at the time of call arrival whether a new call should be admitted. For example, a new call is accepted only if Quality of Service (QoS) constraints are fulfilled without affecting the QoS constraints of the existing calls in the network **??**2]. However, the CAC faces the challenge of network congestion which is a big contributing factor in the deterioration of QoS in a Network. This is because some objectives and constraints of QoS are often hard to be measured using crisp values due to the inherent imprecision and uncertainties in the QoS data.

Several methods have been used to improve QoS across 4G networks. These methods include Markov models, queuing models and expert systems, **??**3] [4] [5] [6] [7]. In recent years, the knowledge of fuzzy systems has been employed to solve QOS problems because of its ability to make decisions from vague and imprecise information **??**8] [9].

Fuzzy Logic (Type-1 Fuzzy logic) (T1FL) is a form of multivalued logic derived from fuzzy set theory to deal with reasoning that is approximate [10] [11]. The five stages involved in the development of a T1FL system are, fuzzy mathematical model, fuzzification of quantities, composition of fuzzy sets, composition of fuzzy relations and defuzzification of quantities. It has been established that T1FLSs have had great success in many real-world applications, but research has also shown that there are limitations in the ability of T1FLS to model and minimize the effect of uncertainties due to the fact that its membership grade is itself crisp **??**12] [13]. The solution to this problem is an extension of the T1FLS to type-2 fuzzy logic systems (T2FLS) by [14].

The T2FLS is derived from type-2 fuzzy set (T2Fswhich allows us to handle linguistic uncertainties. T2Fs, a fuzzy relation of higher type has been regarded as one way to increase the fuzziness of a relation by increased ability to handle inexact information in a logically correct manner [15]. The T2FSs allow for linguistic grades of membership, assisting in knowledge representation and also offer improvement on inference [16]. The structure of T2FLS is similar to it type-1 counterpart with additional unit called type-reduction. Type-reduction algoritims such as iterative Karnik-Mendel (KM) [17] algorithm, Wu-Mendel algorithm [18], etc can be explored to perform type-reduction.

Generally, because of the computational complexity of using a general T2FLS, an Interval type-2 fuzzy logic (IT2FL) which is quite practical and a special case of T2FS with a manageable computational complexity is designed by [13]. The extended version of type-1 defuzzification operation technique is usually applied on T2FSs case of the IT2FLS to obtain a T1FS at the output. The T1FS so obtained becomes a typereduced set which is a collection of the outputs of all of the embedded T1FLSs [17]. IT2FLs are complementary fuzzy sets which provide degree of membership (DoM) value of an element in a given set where the degree of non-membership (DoNM)value is equal to one take away the DoM value. However, IT2FLsmay not cope adequately with real-life situations because most often human beings are hesitant in specifying about set descriptions in terms of MF and NMF as such fuzzy sets theory may not be appropriate to deal with such problem, and hence IFS theory suffices [19].

Intuitionistic logic was introduced by [20] as logic for Brouwer's intuitionistic mathematics, [21] applied more generally to constructive mathematics (logic). It is mostly described as classical logic without the principle of excluded middle (?A?¬A) or the double negation rule (¬¬ A? A) [22]. Atanassov [22] extended the concept of Zadeh's fuzzy sets to intuitionistic fuzzy sets (IFSs) as a generalization of fuzzy sets which determines both a DoM and a DoNM in dealing with uncertainty and vagueness. Fuzzy sets provide DoM of an element in a given set where the DoNM is equal to one take away the DoM, whereas, the intuitionistic fuzzy sets being a higher order fuzzy set can handle both a DoM and a DoNM. The membership function (MF) and non-membership functions (NMF) representation of attributes to handle uncertainty are more or less independent of each other, thus providing a better way to express uncertainty. The presence of nonmembership or hesitation index in fuzzy sets gives more allowance to represent imprecision and uncertainty adequately in dealing with many real-world problems [23]. The concept of IFS is extended to interval valued intuitionistic fuzzy sets (IVIFS) as membership and nonmembership functions in the interval [0,1] called IT2IFLSs with degrees of membership as intervals can give better result in some applications than the T1FLSs and T2FLS [24] [25] [26] [27] [28]. (the highlighted refs. are not in order and please let the student confirm the rest that they match).

In this paper, we apply an IT2IFLS to model uncertain data for call admission control in 4G networks. It is a type of fuzzy logic controller that incorporates the experience of human experts in making appropriate decisions to handle uncertainty and congestion control in 4G Networks. This paper is motivated by the ability of IT2IFLS to handle imprecision and vagueness more accurately and make better decisions due to its ability to consider membership and non-membership of an element and expert's factor of hesitation.

To the best knowledge of the authors, there is currently no work in the literature where IT2IF set is applied in a fuzzy logic inference system in handling call admission control problem in 4G Networks in order to improve the QoS. Decision is made based on the information in the traffic contract and the condition of the network. T1FL and IT2FL are also implemented for the purpose of comparison. MAD, MAPE, MSE AND RMSE performance measures are applied in order to measure the performance and utilization of the proposed system. The paper employs system analysis and design and object design tools in the development of the system Matlab, Intellij, MySQL Intellij, MySQL and the java programming language are employed in implementing the system.

The rest of the paper is presented as follows: In section 2, an overview of IFS, T2IFS and IT2IFS are defined. In section 3, IT2IFLS is designed. We present our results in Section 4, and conclude in section 5.

2 II.

3 Related Work

The related work is concerned about the different researches which deal with CAC in improving QoS in mobile networks and also the different methods and characteristics that are explored in this paper.

4 Call Admission Control (CAC)

CAC is an important decision making tool which is employed to provide the needed QoS by controlling access to the network resources [29]. Maintaining QoS parameters such as signal quality, packet delay, loss rate, call blocking and dropping thresholds are required for efficient admission control in mobile multimedia networks [30]. The CAC can decide to either accept or block the new request depending on the available network resources and on network load conditions for a needed connection type. Fundamentally, a new request is accepted if the available resources are adequate to meet the QoS requirements for this new connection without violating the QoS of the request that has already been accepted, otherwise the call is rejected. Many researchers have applied several techniques including fuzzy logic to deal with CAC in order to improve QoS across 4G networks.

Mahesh et al., (2014) **??**2] applied soft computing technique in surveying call admission control in wireless networks. Congestion control mechanism is modeled with fuzzy logic [31]. Shen and Mark [32] proposed a call admission control in wideband CDMA cellular networks by using fuzzy logic. Sonmez et al., [33] studied a fuzzy-based congestion control for wireless multimedia sensor networks. [30], carried out a comparative study of CAC in mobile multimedia networks using soft computing paradigms. Metre et al., [34] surveyed soft computing techniques for Joint Radio Resource Management (JRRM). Mallapur et al., [35] developed a fuzzy based bandwidth allocation scheme for temporary borrowing of bandwidth from existing connections in order to accommodate newly arrival call connections. Chen and Chang [36] designed a fuzzy Q-Learning admission control for WCDMA/WLAN heterogeneous networks with multimedia traffic. Ramesh et al., [37] designed a fuzzy neural model for call admission control in multi class traffic based next generation wireless networks (NGWNs). Lawal et al. [6] carried out a survey on call admission control schemes in LTE Networks where the algorithms are grouped into CAC with Pre-emption, Resource Reservation (RR), Resource Degradation (RD), Delay Awareness (DA) or Channel Awareness (CA). The study further discussed the operational procedure, strengths and weaknesses of each scheme. G. Mali [38] designed a fuzzy based vertical handoff -decision controller for future networks. [39] [40] employed IT2FL to model connection admission control (CAC) in fourth generation (4G) networks to improve quality of service (QoS). The study applied Karnik-Mendel (KM) and Wu-Mendel (WM) algorithms for computing the centroid and to derive inner and outer-bound sets for the type-reduced set of IT2FS. The results indicate that IT2FLS-CAC using WU approach achieves minimal call blocking probability and provides better performance in CAC decision making with IT2FLS-CAC than IT2FLS-CAC using KM and IT1FLS methods.

Interval Type-2 Fuzzy Set (IT2FS) According to [41], IT2FS, is characterized by,Ã = ??(x, u), ? Ã (x, u)??? x ? X, ? u ?J x ? [0, 1 (1)

where x is the primary variable with a domain X and u?U is the secondary variable with domain Jx at each x?X. Jx is the primary membership of x and the secondary grades of all equal 1 [42]. The uncertainty about the union of all the primary memberships is called footprint of uncertainty (FOU) as shown in (2) and Figure 1 respectively.? Ã (x, u) = 1, ?????? (Ã) = ? J x ?x?X = {(x, u): u ? Jx ? [0, 1]} (2)

Fig. 1: Interval Type-2 Fuzzy set [41] Where the upper membership function (UMF) and lower membership functions (LMF) are represented as,UMF = ? Ã (x) ? ?????? (Ã) ??? ? ?? (3) LMF = ? Ã (x) ? ?????? (Ã) ??? ? ??**(4)**J x = {(x, u): u ? [? Ã (x), ? Ã (x)]}**(5)**

The MFs of IT2FS are twice T1MFs bounded by the FOU in (3) and (4) and J x is an interval set. The set theory operations of union, intersection and complement are applied to compute IT2FSs.

Type-1 Intuitionistic Fuzzy Set (T1IFS) Definition 1: According to [22]given a non-empty set , an intuitionist fuzzy set?? * in X is an object having the form:?? * = {???, ? ?? * (??), ?? ?? * (??)?: ?? ? ??}**(6)**

where the function ? ?? * (??) : ? [0,1] defines the degree of membership and ?? ?? * (??) : X ? [0,1] defines the degree of non-membership of element ?? ? ??. ?? ?? * (??) = 1 ? ? ?? * (??)**(7)**

The set A is a fuzzy set [19].

Definition 3: For every common fuzzy subset A on X, intuitionistic fuzzy indexin ?? * (degree of hesitancy or uncertainty) of the element x in A for every T2IFS is defined as in (8)?? ?? * (??) = 1 ? (?? ?? * (??) + ? ?? * (??))**(8)**

Type-2 Intuitionistic Fuzzy Set (T2IFS)

According to [26], a T2IFS is characterized by T2 membership function (MF) and non-membership functions (NMF) of defined as:? ?? ? * (??, ??) ? ?? ???? ?? ?? ? [0,1] (MF)**(9)**

and?? ?? ? * (??, ??): u ???? ?? ?? ? [0, 1] (NMF)**(10)**

Where ?? ?? ?? is the primary MF and ?? ?? ?? is the primary NMF of element in (x, u) defined in (11) and (12). ?? ?? ?? = {(??, ??): ?? ?? ??? ?? ? * (??), ??? ?? ? * (??)?} (11) = ?? ?? ?? = {(??, ??): ?? ?? ??? ?? ? * (??), ??? ?? ? * (??)?**(12)**IT2 NMFs = ??? ?? ? * (??) , ?? ?? ? * (??)**(14)**

For each?? ? ??, we have the IF-index or hesitancy degree as an outcome of an expert's uncertainty about the degree of M and NM as defined in **??**44]. There are two IF-indexes; the center IF-index and variance IF-index as seen in **??**16 -18) [45].?? ?? (??) = max(0, (1 ? (?? ?? ? * (??) + ?? ?? ? * (??))))**(16**

)?? ? ?????? (??) = max(0, (1 ? (??? ?? ? * (??) + ?? ?? ? * (??))))**(17)**?? ?????? (??) = max(0, (1 ? (?? ?? ? * (??) + ??? ?? ? * (??))))**(18)**

Such that 0 ? ?? ?? (??) ? and 0 ? ?? ?????? (??) ? 1

An IT2IFS, is fully bounded by two T1 MFs and two T1 NMFs as upper MF, ??? ?? ? * and lower MF, ?? ?? ? * (??) (14) and upper NMF, ??? ?? ? * (??) , and lower NMF, ?? ?? ? * (??) (15) which define the footprints of uncertainty (FOUs) of a T2FS. The upper MF is a subset with maximum membership grade of FOU while the lower MF is a subset with minimum membership grade of FOU and both the MF and NMFs of the IT2FS are combined into M and NM FOUs respectively to handle the uncertainty about IT2FS as shown in Figure 1 and **??**19 -20) as the primary M and NM respectively [26].?????? ?? ??? ? * ? = ? [?? ?? ? * (??), ?????? ??? ?? ? * (??)**(19)**?????? ?? ??? ? * ? = ? [?? ?? ? * (??), ?????? ??? ?? ? * (??)**(20)**

Interval Type-2 Intuitionistic Fuzzy Logic System (IT2IFLS)

The IT2IFLS is the hybridization of IT2FL and Intuitionistic Logic (IL) tools to deal adequately with uncertainty and vagueness associated with real world problem. The structure of IT2IFLS is similar to IT2FL with the following components: intuitionistic fuzzification unit, intuitionistic rule base, intuitionistic fuzzy inference engine and intuitionistic composition/defuzzification processes respectively. Figure 3 gives the structure of IT2IFL which is a modification of the work done in [40]. Intuitionistic Fuzzy Logic membership) in each IT2IFS division. The study considers IT2I Gaussian MF and NMFs with a fixed center (mean) and uncertain width (deviation) because it is suitable for a highly dynamic system and has the advantage of being smooth at all points as define in (21)(22)(23)(24) respectively .??? ???? (?? ??) = ?????? (? (?? ?? ? ?? ????) 2 2?? 2,???? 2) * (1 ? ?? ??,???? (?? ??))**(21)**?? ???? (?? ??) = ?????? (? (?? ?? ? ?? ????) 2 2?? 1,???? 2) * (1 ? ?? ??,???? (?? ??))**(22)**?? ???? (?? ??) = (1 ? ?? ?????? ,???? (?? ??)) ? ?? ???? (?? ??)**(23)**?? ???? ((?? ??) = (1 ? ?? ?????? ,???? (?? ??)) ? ??? ???? (?? ??)**(24)**

Where, ?? ??,???? (??)is the IF-index of center and?? ?????? ,???? is the IF-index of variance. The premise parameters, ?? 2,???? , ?? 1,???? and ?? ??,???? (??), ?? ?????? ,???? define the M and NM grades of each element of and are combined to give FOUs.

5 Intuitionistic Fuzzy Rule (IFR)

IT2IFLS Mamdani's fuzzy rule syntax is similar to that of IT2FL rule and is expressed in (**??**5) and (**??**6

6 Intuitionistic Fuzzy Inference

There are two general fuzzy inference mechanisms based on their characterization and the evaluation of the output. They include; Mamdani and Takagi -Sugeno-Kang (TSK) fuzzy inference engines. The Mamdani fuzzy inference is adopted in this paper because it proves to be more intuitive. In IT2IFLS, Mamdani fuzzy inference approach evaluates the rules in a rule base against IT2IF input set from fuzzification to produce IT2IF output set by the composition of MFs output, and NMFs output . Then the firing strength of the pth rule of the fired M/ and NM values for both the upper and lower bounds are computed (28) and (29)(30)(31)(32) respectively.?? ?? ? (?? ?) = [ð ??"ð ??" ?? ?? (?? ?), ð ??"ð ??" ?? ?? ???? (?? ?), ð ??"ð ??" ?? ?? (?? ?), ð ??"ð ??" ?? ?? (?? ?)] = [ð ??"ð ??" ?? ?? , ð ??"ð ??" ?? ?? ???? , ð ??"ð ??" ?? ?? , ð ??"ð ??" ?? ??] (**28**)ð ??"ð ??" ?? ?? = ?? ?? ? 1?? (?? 1) * ?? ?? ? 2?? (?? 2) * ? * ?? ?? ? ???? (?? ??)**(29)**ð ??"ð ??" ?? ?? ???? = ?? ?? ? 1?? (?? 1) * ?? ?? ? 2?? (?? 2) * ? * ?? ?? ? ???? (?? ??)**(30)**ð ??"ð ??" ?? ?? = ?? ?? ? 1?? (?? 1) * ?? ?? ? 2?? (?? 2) * ? * ?? ?? ? ???? (?? ??)**(31)**ð ??"ð ??" ?? ?? = ?? ?? ? 1?? (?? 1) * ?? ?? ? 2?? (?? 2) * ? * ?? ?? ? ???? (?? ??)**(32)**

Where ?? ?? ? (?? ?) is the antecedent of kth. ?? ?? ? ???? and ?? ?? ? ???? are the degrees of membership and non-membership for i=1,?, p.

7 Intuitionistic Defuzzification

The crisp output, y is computed using the composition of M and NM outputs. Although there are several techniques available in the literature for the defuzzification of the final crisp output, the study employs TSK method in **??**45][46] to compute the IT2IFLS final crisp output as presented in (**??**3) and (34) and the M and NM fired strength are evaluated using (34)-(36) respectively.(1 ? ??) ? ð ??"ð ??" ??? ?? ?? ?? ?? ?? ??=1 + (1 ? ??) ? ð ??"ð ??" ??? ?? ?? ?? ?? ?? ??=1 (33) ?? = (1 ? ??) ? ?ð ??"ð ??" ?? ?? + ð ??"ð ??" ?? ?? ???? ??? ?? ?? ?? ??=1 ? ð ??"ð ??" ?? ?? ?? ??=1 +? ð ??"ð ??" ?? ?? ???? ?? ??=1 + ?? ? ?ð ??"ð ??" ?? ?? + ð ??"ð ??" ?? ?? ???? ??? ?? ?? ?? ??=1 ? ð ??"ð ??" ?? ?? ?? ??=1 +? ð ??"ð ??" ?? ?? ???? ?? ?? =1**(34)**

Where,ð ??"ð ??" ??? ?? = ð ??"ð ??" ?? ?? + ð ??"ð ??" ?? ?? ???? ? ð ??"ð ??" ?? ?? ?? ??=1 +? ð ??"ð ??" ?? ?? ???? ?? ?? =1**(35)**

andð ??"ð ??" ??? ?? = ?ð ??"ð ??" ?? ?? + ð ??"ð ??" ?? ?? ???? ? ? ð ??"ð ??" ?? ?? ?? ?? =1 +? ð ??"ð ??" ?? ?? ???? ?? ??=1**(36)**

The parameter ??is a user defined parameter which specifies the contribution of the M and NM values in the final output such that0 ? ?? <= 1. If ?? = 0 , the outputs of the IT2IFLS are determined using MF else if ?? = 1, only the NM will contribute to the system's output.

8 III.

9 Research Methodology

Uncertainty and Congestion Elimination in 4G Networks CAC using IT2IFL.

The main goal of this paper is to apply the interval type-2 intuitionistic fuzzy Logic (IT2IFL) in solving call admission control problem in order to achieve a better QoS in 4G Networks. The model of the proposed system is shown in Figure **??** and the components of the system include; knowledge engine (which provides both the structured and unstructured information required by the system), intuitionistic fuzzifier, knowledge base, intuitionistic defuzzifier. The knowledge base processes both the fuzzy rules and the membership functions. The algorithm for the steps in modeling CAC intuitionistic fuzzy controller is summarized in the Figure 5.

10 Intuitionistic Fuzzifier -CAC for Uncertainty and Congestion Elimination in 4G Networks

The paper designs an intuitionistic fuzzy -CAC system for elimination of uncertainty and congestion control in 4G Networks for improving QoS. The universe of discourse is defined for our linguistic variables in Table **??**. From Figure **??** 4, firstly, intuitionistic fuzzification is performed on the values of five QoS control input variables, namely: the LA, PL, LD, SS and UB respectively. center and variance are determined for the five parameters based on (16) -(18) respectively. By putting the values of the five input variables (LA, PL, LD, SS and UB) in the MF and NMFs of LA, PL, SS and UB respectively, we obtain the fuzzified values. Tables 2 -6 show the matrixes values of MF, NMF and hesitancy for the five input parameters of CAC process respectively. The MF and NMF of the output variable (CAF) of our IT2IFL system is evaluated. Intuitionistic fuzzy rules are defined in the work based on (25). Fuzzy rules for the MF and NMFs are defined respectively based on and (26)(27). Rules are defined based on human expert opinion. There are 243 rules defined for the IT2IFLS and parts of the rules are presented Table 7 for simplicity. In the IT2FLS, the rule base part re enclosed with five antecedents (LA, PL, SS, LD, UM). In IT2IFLS, the IFIM is applied and the appropriate IF-THEN type intuitionistic fuzzy rules in the knowledge base is activated using Mamdani inference method in (28).The M and NM interval of each of the crisp input is computed and then the firing strength of the pth rule of the fired M/NM values for both the upper and lower bounds are calculated. The fired rules are combined and the input IT2FSs and output IT2FSs are mapped by computing unions and intersections of type-2 sets, as well as compositions of type-2 relations for the MFs and NMFs using (29)-(32) respectively.The main idea is to determine the effect of the five input parameters (Latency, Packet Loss, Load, Signal Strength and User Mobility)in the antecedent partsuch that a concise representation of the system's behavior which is Call Admittant Factor (CAF)in this case is produced in the consequent part.

For example, given the crisp input vector, v = [20, 2, 50, -94, 2] their degree of M and NM are calculated from respective Gaussian MFs and the fuzzified values for the five input parameters and is presented in Table 8. Evaluating rules 20, 22, 30, 32, 45 against the IFS yields the firing level as shown in Table 9. R20 [ð ??"ð ??" 1 ?? , ð ??"ð ??" 1 ?? , ð ??"ð ??" 1 ?? , ð ??"ð ??" 1 ??] = = [0.001443,0.00006331, 0, 0] [?? 1 ?? , ?? 1 ??] = GOOD [0.3, 0.8] R22 ?ð ??"ð ??" 2 ?? , ð ??"ð ??" 2 ?? , ð ??"ð ??" 2 ?? , ð ??"ð ??" 2 ?? ? = = [2.7420e-06, 1.0567e-06,0.4956, 0.2404] [?? 2 ?? , ?? 2 ??] = GOOD [1.0, 0.0] R30 [ð ??"ð ??" 3 ?? , ð ??"ð ??" 3 ?? , ð ??"ð ??" 3 ?? , ð ??"ð ??" 3 ??] = = [0.0, 0.0, 0.0, 0.0] [?? 3 ?? , ?? 3 ??] = GOOD [0.3, 0.8] R32 [ð ??"ð ??" 4 ?? , ð ??"ð ??" 4 ?? , ð ??"ð ??" 4 ?? , ð ??"ð ??" 4 ??] = = [0.0, 0.0, 0.5966, 0.3405] [?? 4 ?? , ?? 4 ??] = GOOD [1, 0.1] R45 [ð ??"ð ??" 5 ?? , ð ??"ð ??"**5**

11 Intuitionistic Defuzzification

The study adapts TSK method to compute the IT2IFLS final crisp output using (**??**3) -(36) respectively. For our illustration, the crisp output, y is computed using the composition of member and non membership output values with the value ?? and P at 0. 5 and 5.(1 ? ??) ? ?ð ??"ð ??" ?? ?? + ð ??"ð ??" ?? ?? ???? ? ?? ?? ?? = ?? ??=1 2.2977?? ? 4 ? ð ??"ð ??" ?? ?? ?? ?? =1 + ? ð ??"ð ??" ?? ?? ???? = 0.0015 ?? ??=1 ?? ? ?ð ??"ð ??" ?? ?? + ð ??"ð ??" ?? ?? ??? ? ?? ?? ?? ?? ?? =1 = 0.4585 ? ð ??"ð ??" ?? ?? ?? ?? =1 + ? ð ??"ð ??" ?? ?? ??? ?? ??=1 = 2.8327 ?? = 0.3151

Hence, given the crisp input vector v = [20, 2, 50, -94, 2] for LA, PL, LD, SS and UM, the Call Admittance Factor (CAF) produced is 0.3151 or 31.51% fair quality of service influence on the 4G network. This indicates that based on the level of influence of the five input variables on the output parameter, the IT2IFLS gives a CAF with 31.51% possibility.

The output of the system is described mathematically using (37).A threshold is set to categorize the level of system order to constrain the limits of acceptance values. A threshold is a value of a metric that should cause an alert to be generated or management action to be taken **??**Ramkumar and Mandalika, 2010). In this work, a threshold of 50% and above indicates that network resources are available hence; a call can be accepted into the network. Therefore, in regard the output of "CAF = 31%", the call will be blocked i.e. not accepted into the network.???????????? = ? ? ? ? ? ????????: ??ð ??"ð ??" ???????????? ? 25% ????????: ??ð ??"ð ??" 25% < ???????????? ? 50% ????????: ??ð ??"ð ??" 50% < ???????????? ? 75% ??????????????????: ??ð ??"ð ??" ???????????? > 75%**(37)**

For the purpose of comparison and testing of the utilization of our work, we employ the following performance measures: Mean Absolute Difference (MAD), Mean Absolute Percentage Error (MAPE), Mean Squared Error (MSE) and Root Mean Squared Error (RMSE) to measure our experimental results. The performance metrics are defined in (38) to (41) respectively.?????? = 1 ?? ? |?? ?? ? ??| ?? ??=1 (38) ???????? = 1 ?? ? |?? ?? ? ??| ?? ??=1 /?? ?? (39) ?????? = 1 ?? ? (?? ?? ? ??) 2 ?? ??=1**(40)**???????? = ? 1 ?? ? (?? ?? ? ??) 2 ?? ??=1**(41)**

Where ?? ?? is desired output, y is the computed output and N is the number of data items respectively.

IV.

12 Results and Discussion

The paper applies the IT2IFL model for uncertainty elimination and congestion control in 4G Networks call admission control. The system uses 4G network admission control quality of service indicators (variables) which are, Latency, Packet Loss, Load, Signal Strength and user Mobility to model their effects on Call Admittance Factor (CAF). The model employs intuitionistic fuzzifier based on a Gaussian membership function approach for membership function evaluation with intuitionistic width (variance) and center (mean) membership and non-membership for the input vectors respectively. Mamdani Fuzzy Inference is used to infer knowledge from the rule base where the output of each IF-THEN rule is an Intuitionistic fuzzy set. The inference engine returns a crisp set using the composition of the membership and the non-membership functions through defuzzification process. The system is developed using Java software development toolkit (SDK), Intellij Intergrated Development Environment (IDE), MySQL (Structured Query Language), etc.

The system is simulated with different sets of selected input values from the input parameters and the output (CAFs) are produced as results. Sample results of the application are shown in Figures **??** to 9 respectively. Parts of the results obtained from applying different IT2IFLS to the admission control process to eliminate uncertainty and control congestion in order to guarantee efficient QoS are presented in Table 10. Tables **??**1 give the results of the comparison of IT2IFLS with IT2FLS and T1FLS in CAC. Table 12 shows the results of performance evaluation of the application of the three approaches, IT2IFLS, IT2FLS and T1FLS in call admission control in 4G Network respectively. Figures 10 shows the graphs of Tables 10 forIT2IFLSand Figures 11 and 12 represent the graphs of the resuls of applying IT2FLS and T1FLSrespectively. Figure 13 shows the graph of the results of comparison of the three approaches. The horizontal x-axis of the graphs presents the sample input dataset for the five input parameters (LA, PL, LD, SS and UM). While the computed output values being the Call Admittant Factor (CAF) are displayed on the vertical y-axis of the graphs respectively. From Figures 6, it is observed that when the input values of moderate latency of 65%, moderate packet loss of 4%, high load of 80%, weak signal strength of -95dBm and moderate user mobility of 4m/s are selected and applied in the IT2IFLS-CAC system, the result yields approximately 96% excellent call admittant factor possibility. This indicates that the network has excellent resources to admit/accept the call into the network. From Figure **??**, the result of IT2IFLS-CAC with input values of LA=70, Pl=5, LD=50, SS=-95 and UB=3 gives a good call admittance factor of 68% based on the level of influence of the input on the output. This indicates that the network has good resources to admit/accept the call into the network. Figure **??**, shows that with the input values of LA=70%, Pl=3, LD=30%, SS=-95dBm and UB=3m/s, the results show that a 73% good call admittance based on the level of influence of the inputs on the output. This indicates that resources are available and the call is admitted into the network with a good QoS. With input values of LA=45%, Pl=3, LD=19, SS=-81dBm and UB=2.7m/s, the result in Figure **??** shows a poor call admittance factor of 30% based on the level of influence of the input on the output. This indicates that the network does not have enough resources to admit the call i.e. the call is not accepted into the network.

From Tables 10 and 12it is observed that the result of IT2IFLS outperforms IT2FLS and T1FL on the same set of input parameters values. Example 1, with 20% Low Latency and 2% low packet loss, and 50% Low load, -94 low signal strength and 2% moderate user Mobility, 31.51(32%) fair CAF is achieved using IT2IFLS approach against 25.74(26%) fair and 0.2134(21%) poor CAF with IT2FL and T1FLS methods. Example 2, with 80% high Latency and 3.5% moderate packet loss, and 45% Low load, -94dBm low signal strength and 2.5m/s moderate user Mobility, 0.6372(64%) good CAF is achieved using IT2IFLS approach against good CAF IT2FL with 0.5501(55%) possibility and 0.4706(47%) fair CAF with T1FLS method. From Figure 10, it is generally observed that approximately 100% excellent optimal value in terms of QoS demands and overall network performance is achieved using the three approaches with 55% medium latency, 4.5% high packet loss, 35% low load, -75strong signal strength and 3.0m/s moderate user mobility factor. While approximately 70% good optimal quality of service demands and overall performance of the 4G network is accomplished using IT2IFLS, IT2FLS and T1FLS with 25% low latency, 3.6% high packet loss, 29% very low load, -92 strong signal strength and 5.5m/s high user mobility factors respectively. Generally, it noticed that an average of 35% poor quality of service demands and poor overall performance of the 4G network is accomplished using IT2IFLS, IT2FLS and T1FLS with 25% low latency, 3.6% high packet loss, 29% very low load, -92 strong signal strength and 5.5m/s high user mobility factors respectively.

Considering the entire dataset, it is generally observed that the network exhibits 20% excellent, 47% good, 33% fair and 0% poor performance with respect to IT2IFLS against IT2FLS with 20% excellent, 40% good, 40% fair and 0% poor performance and T1FLS with 20% excellent, 26.7% good, 47% fair and 6.7% poor performance in uncertainty and congestion elimination in 4G Networks for improve QoS. From the above result, it can be deduced that on the same sets of data, the three approaches exhibit same level of optimal excellent performance. While our system outperforms it counterparts in achieving 47% good performance against 40% and 26.7% respectively in handling uncertainty and congestion control in 4G network. However, there is an indication that T1FLS has produced 47% fairest performance compared to IT2IFLS and IT2FLS generally. This is an indication that in some cases, where the system is less noisy, classical F1LS achieve the fairest performance to the IT2IFLS and IT2FLS counterparts.

The result of the measurement and evaluation of IT2IFLS-CACdeveloped system using VARIANCE, MAD, MAPE, MSE and RMSE for the purpose of comparison and testing of the experimental results for utilization against IT2FLS and T1FLS are presented in Table 13. From Table 13, it is observed that, our model, IT2IFLS gives the least VARIANCE of 0.01577 against IT2FLS with 0.02007 and T1FLS with 0.02359 respectively. From the table, it is also noted that, the MAD performance measure shows the lowest error rate of 0.03439 with IT2IFLS as it outperforms IT2FLS and T1FL with error rates of 0.04099 and 0.04534 respectively. Performance evaluation with MAPE gives the least percentage error of approximately 36% with IT2IFLS as it outperforms IT2FLS and T1FL with the approximate percentage error of error of 43% and 48% respectively From the same table, it is also indicated that IT2IFLS outperforms both classical IT2FLS and IFLS in terms of the MSE test with error rates of 0.00105 against 0.00134 and 0.00157respectively. Also, it is interesting to observe from the table that RMSE performance measure applied in the work gives the least error rate of 0.01025 with IT2IFLS as it outperforms IT2FLS with error rate of 0.01157and T1FL with error rate of 0.01254 respectively.

From the results of the five performance indicators applied in the study, it is generally observed that MSE gives the least error rate followed by RMSE. The least MSE and RMSE in IT2IFLS compared with IT2FLSand T1FL is as a result of the presence of additional degrees of freedom in the NMF and hesitation indexes. It is observed that the lower the error, the better the performance of the technique. Also, the increase in the level of fuzziness in IT2IFLS gives a more accurate and promising approximation and a significant performance improvement compared to IT2FLS and T1FL approaches in handling CAC control problem. This way our Fuzzy system behaves more humanly as it can cater for the situations where an expert cannot give sufficient knowledge about a criterion or parameter. The system is expected to improve the utilization of network resources as well as keeping satisfactory QoS levels.

V.

13 Conclusion

The paper uses the IT2IFLS call admission control (CAC) approach for uncertainty elimination and congestion control for guaranteed QoS in 4G mobile Networks in order to improve the system performance. Also, the study implements IT2FLS and T1FLS CAC for the purpose of comparison. The system is able to determine the effect of input variables, latency, packet loss, load, signal strength and user mobility in the antecedent part and a concise representation of the system's behavior which is call connection is produced in the consequent part. We have shown that IT2FLS-CAC outperforms IT2FLS and T1FLS on the same set of input parameters values. From the study, it is shown that [1]

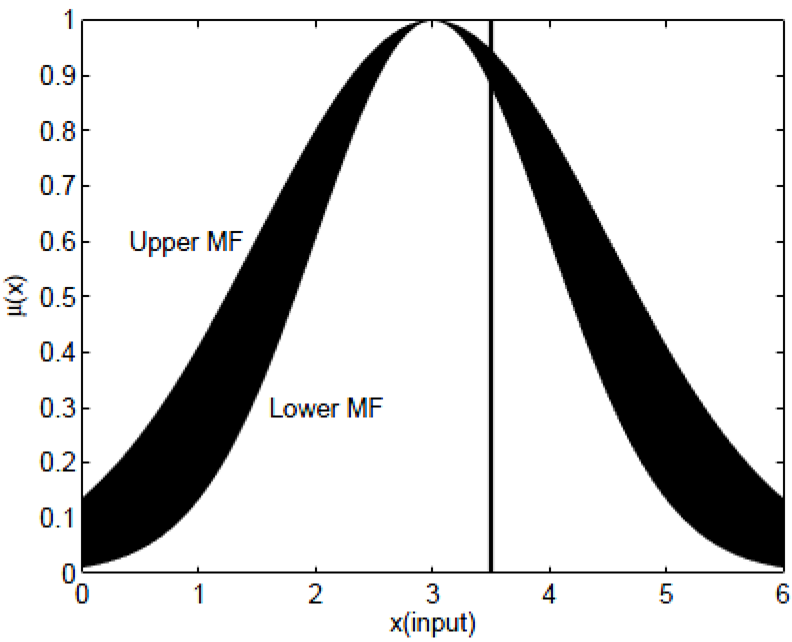
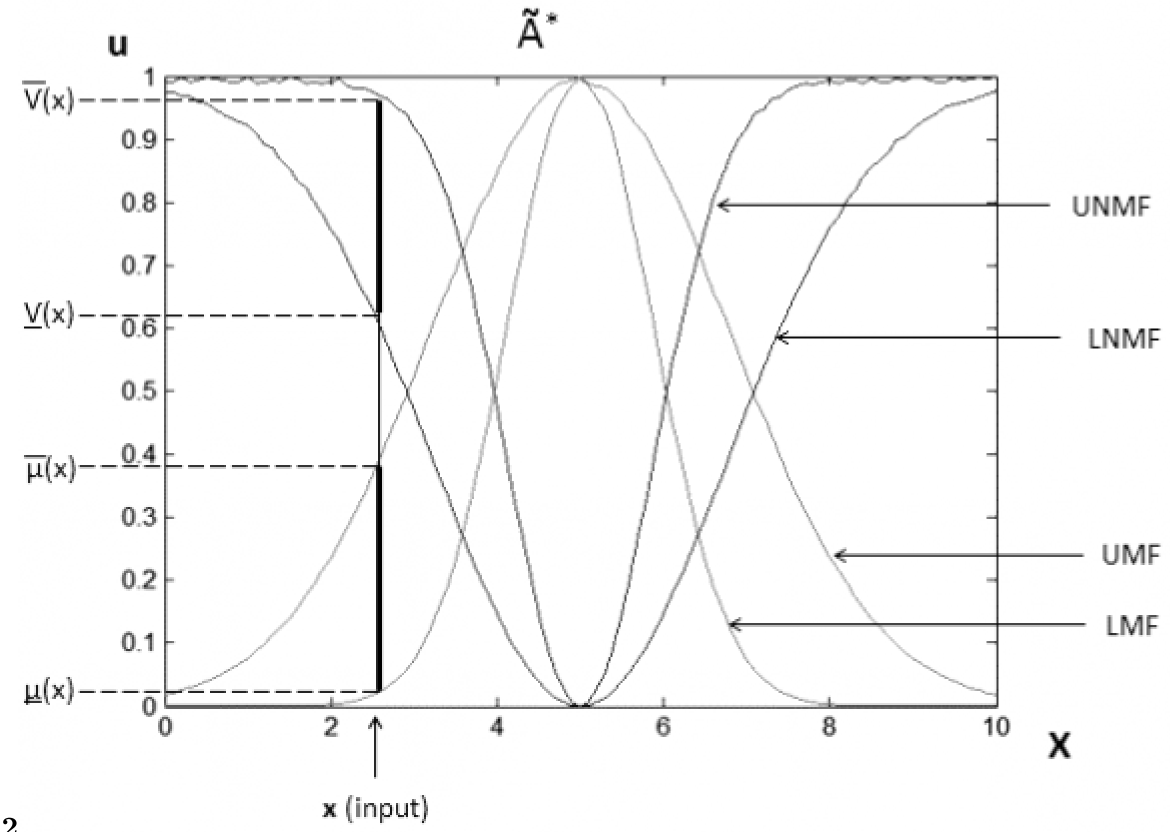


Figure 1:



2

Figure 2: Fig. 2 :

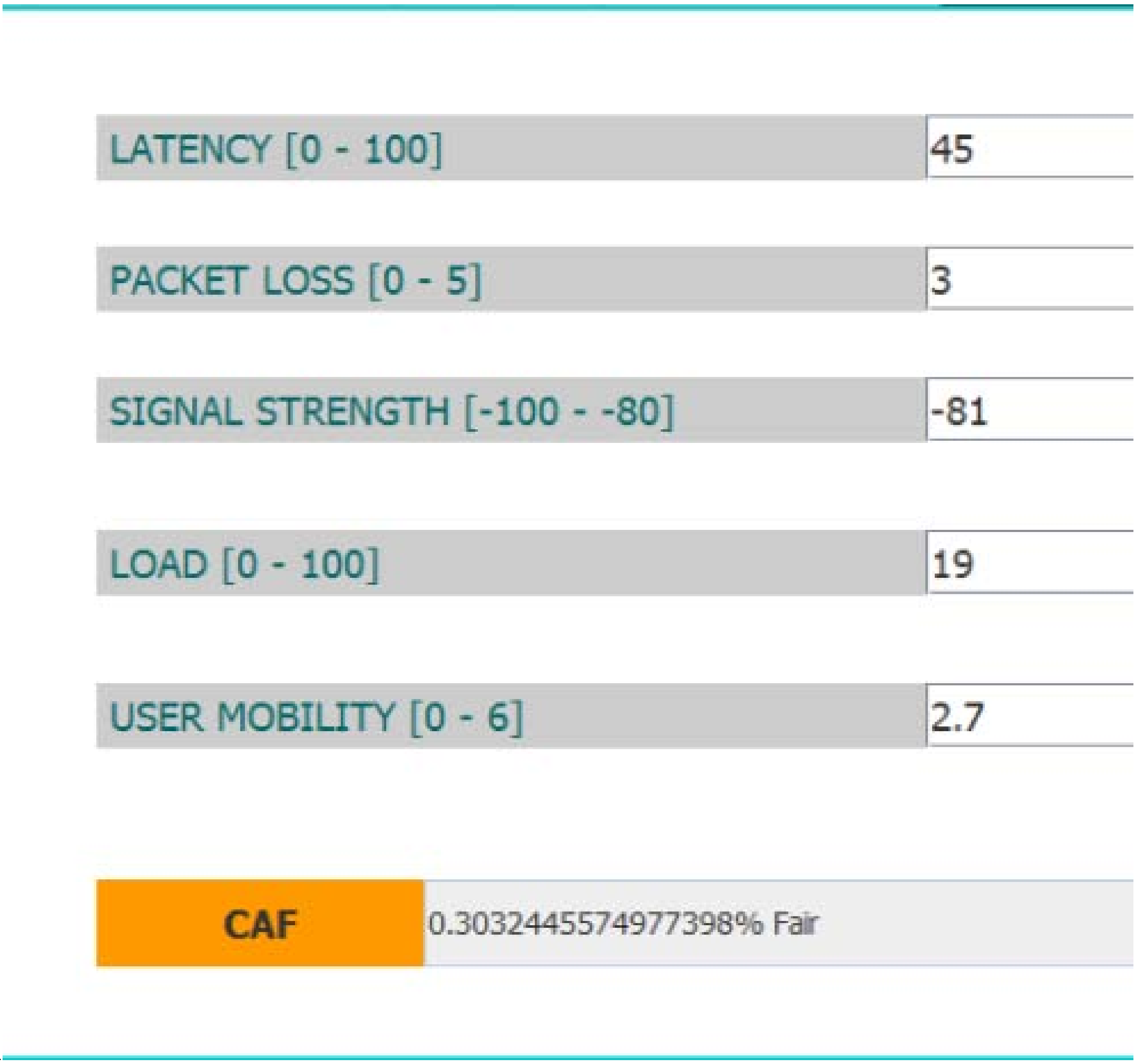
3

Figure 3: Fig. 3 :

Figure 4:

45

Figure 5: Fig. 4 :Fig. 5 :



LATENCY [0 - 100]	45
PACKET LOSS [0 - 5]	3
SIGNAL STRENGTH [-100 - -80]	-81
LOAD [0 - 100]	19
USER MOBILITY [0 - 6]	2.7
CAF	0.3032445574977398% Fair

1

Figure 6: Table 1 :

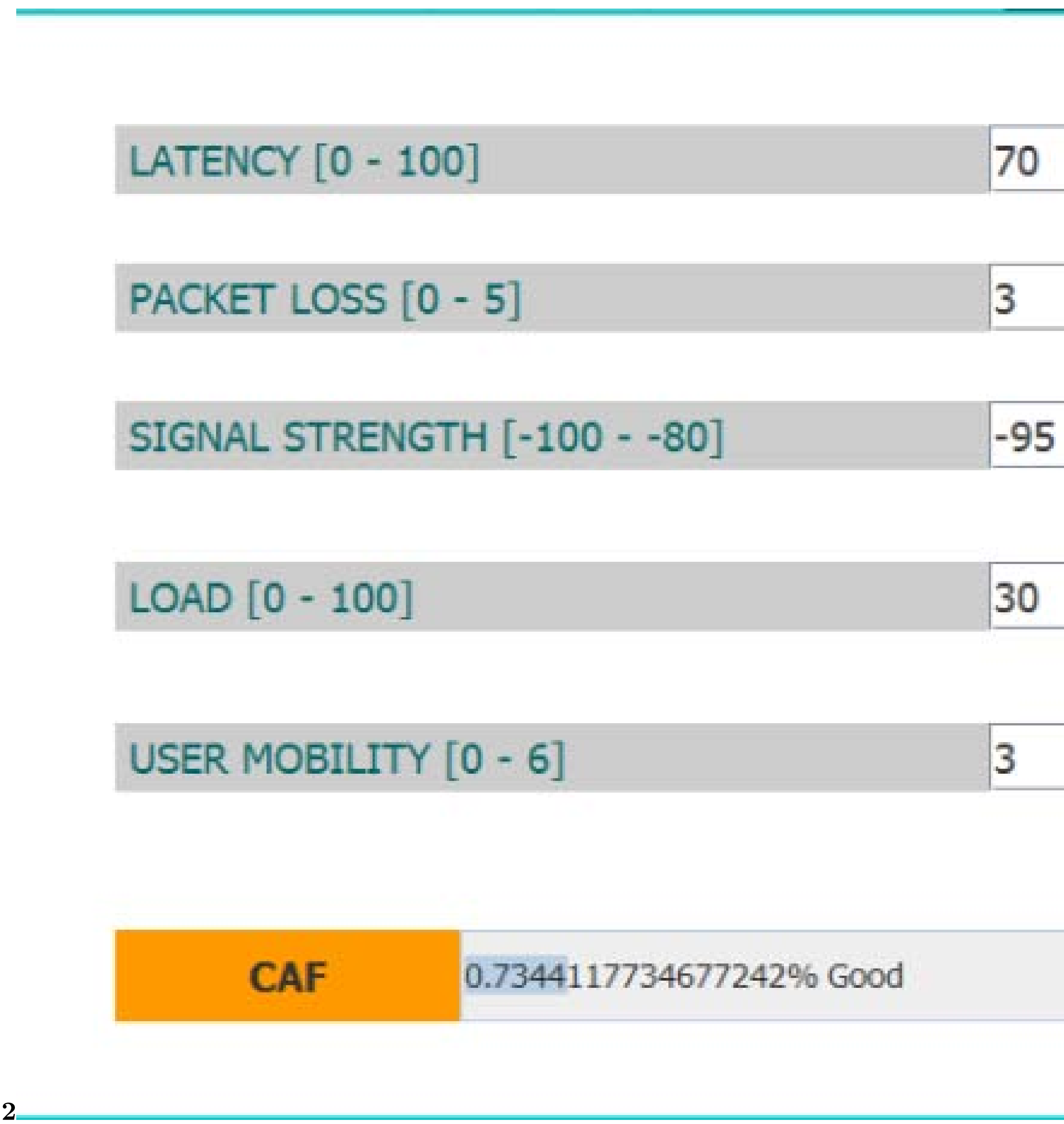


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Figure 7: 2 = 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ?? 2 ??

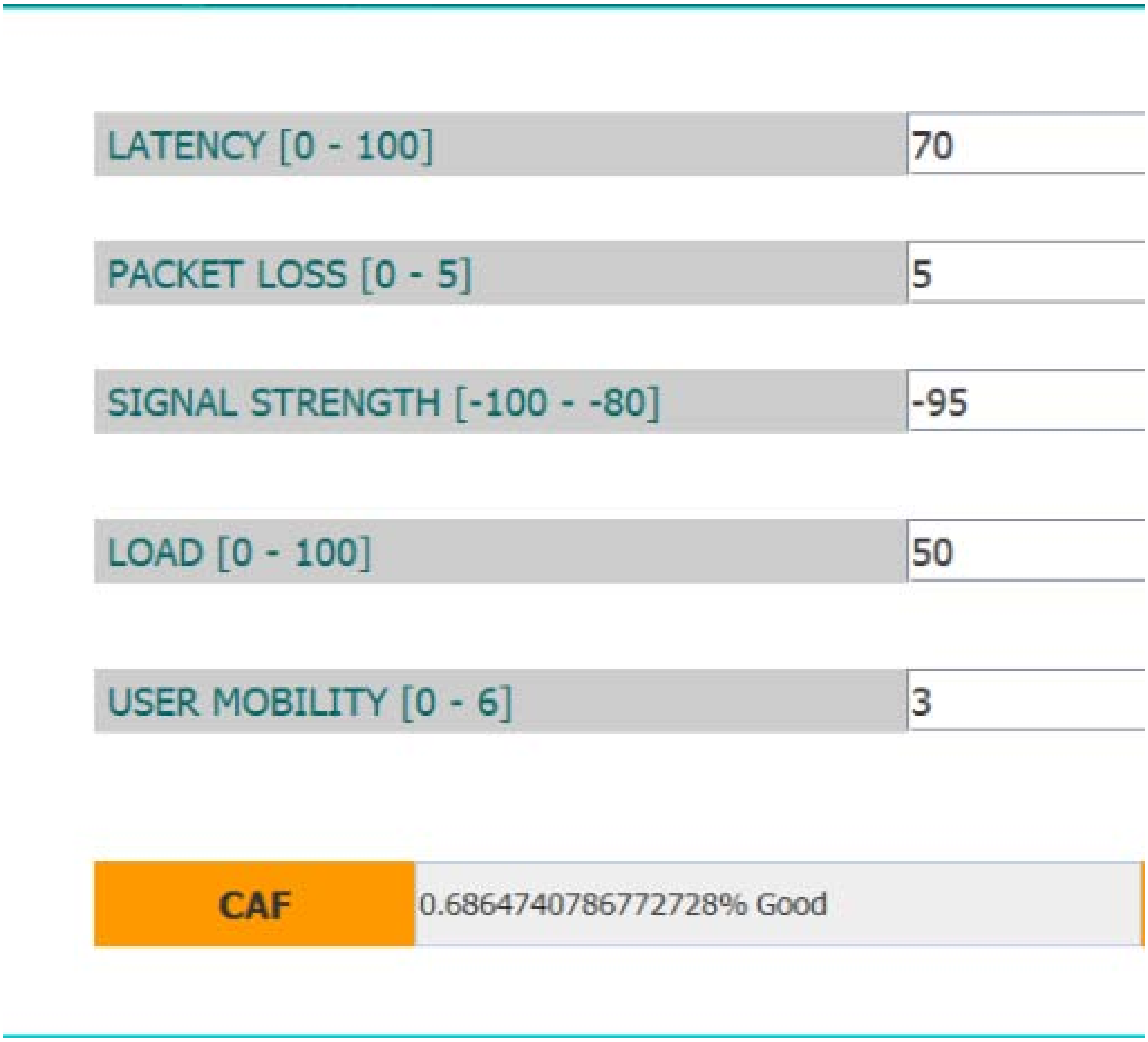
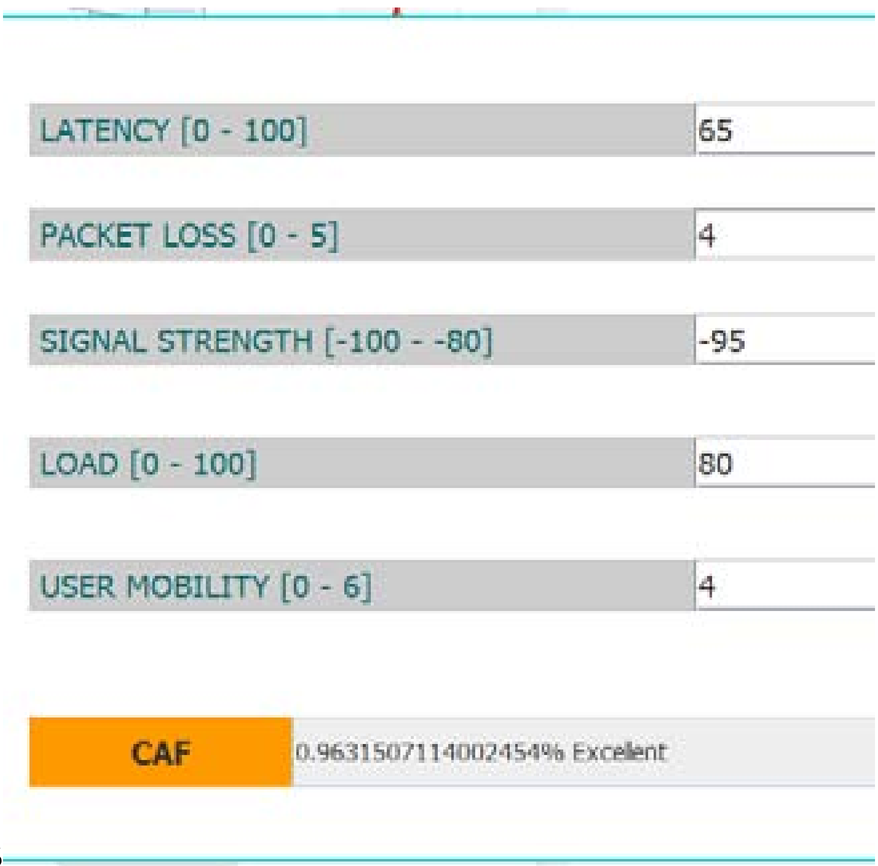

LATENCY [0 - 100]
70
PACKET LOSS [0 - 5]
5
SIGNAL STRENGTH [-100 - -80]
-95
LOAD [0 - 100]
50
USER MOBILITY [0 - 6]
3
CAF
0.6864740786772728% Good

Figure 8:



5

Figure 9: ?? , ð ??"ð ??" 5 D

*[Note: ?? and,., and ?? ?? is ?? ? * ???? ?? then ?? ?? is ?? ? * ???? ?? (26 ?? ?? ?? IF ?? ?? is ?? ? * ???? ?? and,., and ?? ?? is ?? ? * ???? ?? then ?? ?? is ?? ? * ???? ?? (27)]*

Figure 10:

2

Fuzzy			Crisp Input			
Set	10	20	40	60	80	100
L	[0.08, 0.7, 0.22]					

Figure 11: Table 2 :

3

Fuzzy Set	0	1	2	3	4	5
			CRISP INPUT			
Set	0	1	2	3	4	5
L	[1.0, [0.2494, [0.0039, 0.0, 0.5422, 0.9561, 0.9991, 0.0] 0.2085] 0.0401] 0.0009]			[0.0,	[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]
M	[0.0, [0.001,0 [0.3604, [0.3604, [0.001, [0.0, 1.0, .9961,		0.4606, 0. 1790]	0.4606, 0.9961, 1.0,		

Figure 12: Table 3 :

4

Fuzzy Set	10	30	50	70	90
VL	[0.1352, [0.1352, [0, 0.999, 0.6396, 0.2251] 0.2251]	0.6396,	0.0001]	[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]
L	[0, 0.9991, 0.0009] 0.2085]	[0.2494, [0.2494, 0.5422,	0.5422, 0.9991, 0.2085] 0.0009]	[0,	[0.0, 1.0, 0.0]
H	[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]	[0, 0.999, [0.1353, 0.0001] 0.6396, 0.9999,	0.2251] 0.0001]	[0.0,
VH	[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]	[0, 0.999, [0.1353, [0.1353, 0.0001] 0.6396, 0.6396,	0.2251] 0.2251]	

Figure 13: Table 4 :

5

Fuzzy		Crisp Inputs			
Set	-96	-94	-90	-85	-82
W	[0.7066, [0.7066, [0.002, 0.1589, 0.1589, 0.9689, 0.1345] 0.1345] 0.0131]			[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]
M	[0.0, 0.9980, 0.9372, 0.0020] 0.00589]	[0.0039,	[1.0, 0.0, 0.0]	[0.002, 0.9868, 0.0131]	[0.0, 1.0, 0.0]
S	[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]	[0.002, 0.9868, 0.0131]	[1.0, 0.0, 0.0]	[0.0044, 0.7893, 0.1668]

Figure 14: Table 5 :

6

Fuzzy Set	1	2	3	4	5
			Crisp Input		
L	[0.2494, [0.0039, [0.00, 0.5422, 0.9561, 0.9991, 0.2085] 0.0040] 0.0009]			[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]
M	[0.0003, [0.1353, 0.9831, 0.6396, 0.0165] 0.2251]		[1.0, 0.0, 0.0]	[0.1353, 0.396, 0.225]	[0.0003, 0.9831, 0.0165]
H	[0.0, 1.0, 0.0]	[0.0, 1.0, 0.0]	[0.000, [0.0039, [0.2494, 0.991, 0.9561, 0.5422, 0.0009] 0.0040] 0.2085]		

Intuitionistic Fuzzy Rules (IFR) -CAC for Uncertainty and Congestion Elimination in 4G Networks.

Figure 15: Table 6 :

7

S/N	Latency	Packet Loss	Load	Signal Strength	User Mobility	CAF
1	L	L	VL	W	H	EXCELLENT [1.0,0.0]
2	H	H	VH	S	L	FAIR [1.0, 0.0]
3	H	H	VH	S	L	FAIR [1.0, 0.0]
4	L	M	VL	W	H	EXCELLENT [1.0, 0.0]
5	L	H	VL	W	H	GOOD [0.3, 0.8]
6	L	L	VL	W	H	EXCELLENT [1.0, 0.0]
7	L	M	VL	W	H	GOOD [0.3, 0.8]
8	L	H	VL	W	H	GOOD [1.0, 0.0]
9	M	L	VL	W	H	GOOD [0.3, 0.8]
10	M	M	VL	W	H	GOOD [1.0, 0.0]
11	M	H	VL	W	H	GOOD [1.0, 0.0]
12	H	L	VL	W	H	GOOD [1.0, 0.0]
13	H	M	VL	W	H	GOOD [1.0, 0.0]
14	H	H	VL	W	H	FAIR [0.32, 0.71]
15	H	L	VL	W	H	GOOD [1.0, 0.0]
16	H	M	VL	W	H	FAIR [0.32, 0.71]
17	H	H	VL	W	H	FAIR [1.0, 0.1]
18	L	M	L	M	M	EXCELLENT [1.0, 0.0] GOOD [0.3, 0.8]
29	L	M	H	S	L	EXCELLENT [1.0, 0.0]
30	L	M	H	S	L	GOOD [0.3, 0.8]
31	L	H	H	S	L	GOOD [1, 0.1]
32	M	M	H	S	L	GOOD [1, 0.1]
33	M	H	H	S	L	GOOD [1.0, 0.0]
34	H	M	H	S	L	GOOD [1.0, 0.0]
35	H	H	H	S	L	FAIR [0.32, 0.71]

Figure 16: Table 7 :

8

Latency
[??

[Note: ?? , ?? ?? , ?? ?? , ?? ??] PacketLoss [?? ?? , ?? ?? , ?? ?? , ?? ??] Load [?? ?? , ?? ?? , ?? ?? , ?? ??]]

Figure 17: Table 8 :

9

Rule No.	Firing Interval	Consequent

Figure 18: Table 9 :

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10

	Congestion Elimination in 4G Networks					
S/N	LA	PL	LD	SS	UM IT2IFLS (CAF)	
1	70	3.0	65	-86	1.0	0.8518
2	20	2	50	-94	2	0.3151

Figure 19: Table 10 :

Intuitionistic Fuzzy Logic IT2IFLS-CAC gives a better and more accurate performance than IT2FLS and T1FL. This is as a result of the presence of additional degrees of freedom in the NMF and hesitation indexes. Also, as shown in the Table ??3, IT2IFLS approach exhibits superior performance with MSE and RMSE on test data than IT2FLS and T1FLS respectively. The IT2IFLS approach exhibits most superior performance with MSE in all cases. Particularly, the study has been able to show that an IT2IFLS for call admission control is able to preserve all the qualities of an IT2IFLS for call admission control of congestion and has the ability to still cope with adequately with uncertainty in the packet delay measurements in 4G networks. The IT2IFLS has indicated its ability to further reduce uncertainty by handling conflicting evaluation involving membership (M) non-membership (NM) and hesitation and the capacity to cope with more imprecision thereby modeling imperfect and imprecise knowledge better than IT2FLS and T1FLS. In the future, we aim to employ triangular membership functions and TSK fuzzy inference in the design of IT2IFLS for CAC in 4G networks. Also, we intend to learn and optimize the parameters of the membership and non membership functions of IT2IFLS-TSK for a better performance by using learning tools such as gradient descent (GD), decoupled extended Kalman filter (DEKF), particle swarm optimization (PSO), flower pollination algorithm, etc and compare results with our system.

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