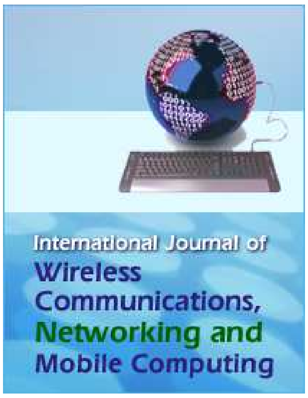
International Journal of Wireless Communications, Networking and Mobile Computing
2014; 1(4): 29-42
Published online November 10, 2014 (http://www.aascit.org/journal/wcnmc)

American Association for Science and Technology



Keywords
Network Integration,
Quality of Service,
Fuzzy Logic,
Evaluation,
Benchmarks,
JAVA

Received: October 10, 2014
Revised: October 28, 2014
Accepted: October 29, 2014

A conceptual framework on user perspective on factors of quality of service (QoS) for mobile SIM networks

Nnochiri Ifeoma Uzochukwu[1], Okafor Kennedy Chinedu[2]

[1]Dept. of Computer Science, Michael Okpara University of Agriculture, Umuahia, Nigeria
[2]Dept. of Electrical/Electronic Engineering, Federal University of Technology, Owerri, Nigeria

Email address
nwaife2002@yahoo.com (Nnochiri I. U.), arissyncline@yahoo.com (Okafor K. C.)

Citation
Nnochiri Ifeoma Uzochukwu, Okafor Kennedy Chinedu. A Conceptual Framework on User Perspective on Factors of Quality of Service (QoS) for Mobile SIM Networks. *International Journal of Wireless Communications, Networking and Mobile Computing.* Vol. 1, No. 4, 2014, pp. 29-42.

Abstract
This research developed a conceptual framework for a novel network integration with its decision rules considering the existing mobile network operators in Nigeria viz: *MTN, GLO, ETISALAT and AIRTEL*. In an earlier work, a Java VSIM portability Suite for Mobile Number Portability (MNP) was developed without detailing the formulation of the parametric network considerations based on user perspective on factors of Quality of Service (QoS). As such, network intelligent decision using fuzzy logic was leveraged to develop a focused evaluation based on a set of benchmarks which are considered to be crucial for its deployment viz: network integration and customer factor metrics. Using its 3D fuzzy logic plots, we showed that this will expand the frontiers of MNP research as well as the practicability of a trusted mobile platform. Consequently, this will improve the current MNP scheme in the world today when fully adopted.

1. Introduction

The need to miniaturize computing processes and eradicate bureaucracies in mobile communication architecture has now become the focus of various interest groups and researchers in the telecommunication industry as well as the academia. Starting with GSM networks, paper argues that this is possible as far as technologies of 21st century are concerned. Nigeria as the giant of Africa and a major consumer of telecommunication services can lead this revolution.

According to [1], there are five GSM network and 13 CDMA-based network operators in Nigeria. The GSM operators include Airtel, MTN, MTEL, Globacom, and Etisalat while CDMA network operators include Multilinks, Starcomms, O'net, Visafone amongst others.

User satisfaction is very important in today's business world, but this can be achieved through accurate process miniaturization. Consumers of telecommunications products and services in Nigeria are varied and their tastes, needs and expectations are also varied [2].

According to Deng et al [3], the ability of a service provider to create high degree of satisfaction is crucial for product differentiation and developing strong relationship with the user. However, user satisfaction makes the phone users loyal to one telecommunication service provider [4]. Satisfaction of the user can help the brands to build long and profitable relationships with their users [5]. Although it is costly to generate satisfied and loyal users of a product or service, however, Anderson et al [6] noted that it would prove profitable in the long run for the firm.

There must be a strategy to facilitate mobile SIM networks integration while accounting for user perspective on QoS of such integration. Analysis of strengths, weaknesses, opportunities and threats (SWOT) is a method to formulate the strategy [7]. Although the SWOT analysis successfully provides the key factors of the problem, it has some drawbacks in selecting appropriate strategy for the evaluation and final decision steps [7].

In this paper, linguistic variable represented with fuzzy logic system model are used to represent the networks, its weights and the customer parameters. This paper presents a fuzzy logic framework for evaluating the proposed alternatives. Fuzzy linguistic descriptors were used for describing the criteria. In this way, fuzzy logic enables the exploitation of tolerance that exists in imprecision, uncertainty and partial truth of the acquired research results. The paper presents a model for designing the miniaturized network SIM structure of the existing GSM networks on a portable mobile device. Key decision rules are proposed in application of the Mamdani Fuzzy Inference System (MFIS, taking into account the fact that the various networks should be designed and dimensioned so as to achieve the rudimentary goals and tasks for fulfillment of which they were established. The task set before the network operators require reliable and top-quality performance in all their services. Based on the rule base decision rules, a fuzzy logic 3D surface diagrams was used for the result analysis. Our approach demonstrates the replacabilty of the existing GSM architecture with an adequate trusted computing model for all mobile network operators in the mobile communication value chain.

The rest of this paper is organized as follows, viz: Section II presents the literature reviews and related research efforts. Section III discussed the methodology. Section IV presents the system model. Section V discussed the results of the system while concluding the research with its future directions in Section VI.

2. Related Works

2.1. Efforts on User Perceived QoS

Currently, MNP seems to be the driver to QoS improvements. This section will review related works on MNP vis-à-vis user satisfaction in the mobile communication era.

The authors in [8] evaluated the significance of price (call rate), service quality, service availability, promotion and brand image as it affect users' perception in selecting a mobile telecommunication services provider in the Nigerian telecommunication market, using Ibadan,a Nigerian municipality as a case study. Structural Equation Modelling (SEM) approach was adopted in understanding the users' choice process. Also, their empirical evidence was based on a model fit from the result of factor analysis, regression analysis, and chi-square goodness-of-fit statistics. Their result showed that paths to call rate, service quality and service availability were more significant in the users' choice process than promotion and brand image.

The work in [9] presented a study on consumer switching behavior in cellular service providers. The objectives of the study are to find the factors that influence the consumers in switching the service provider and to delve into finding out the likeliness of switching the service provider. The work used a descriptive research design while revealing that call rates plays the most important role in switching the service provider followed by network coverage, value added service and customer care while advertisement plays the least important role. It is found that there is a relation between switching the service provider and the factors (customer service, service problem, usage cost, etc.). The work recommended that mobile providers should concentrate on increasing network stability and setting tariff rates competitively.

The author in [10] examined possible affects of implementation of Mobile Number Portability (MNP) on market competition. The work developed theoretical model applicable for investigation of the effect of MNP under different market parameters such as growth rate and interconnection costs.

The work in [11] described analyzed mobile number portability (MNP) techniques, parameter on which MNP depends and MNP decision using fuzzy logic. The work outlined and discussed four main techniques used to route a number whose operator has changed, viz: All Call Query (ACQ), Query on Release (QoR), Call Dropback and Onward Call Routing.

The authors in [12] assessed the attitude of mobile telephone subscribers to the implementation of mobile number portability (MNP) in Nigeria. Using a survey design approach their data were collected data from 860 respondents across the six geo-political zones of Nigeria. The data was analysed using frequency distributions and cross-tabulations with the Chi-square statistic at the 0.01 level of significance. Findings revealed that while most subscribers supported the implementation of MNP in Nigeria, a significant proportion believed that tariffs would not drop as long as the power problem continued. The work revealed that of the demographic variables, and age had the strongest influence on subscriber attitudes. This was identified as a strategic focus for network operators and the regulatory authority.

From the existing literature, little research have been carried out in the area of fuzzy logic SWOT-like strategy

in integrating various networks on a unified mobile platform while using a decision to select an optimal network. Also, customer parameters must be considered in a proposed platform to satisfy user's expectations.

2.2. Fuzzy Logic Decisions

The term fuzzy set was coined by Zadeh (1965) [13] as a generalized form of set theory. Unlike traditional Boolean logic which defines whether or not an element belongs to a crisp set (1 or 0), a fuzzy set defines a degree of belonging through a membership function. In effect, fuzzy set theory deals with sources of uncertainty that are vague or non-statistical in nature such as operational definitions based on “rules of thumb”, estimations of natural processes, classification of environment types and the like.

According to [14], Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth and it a form of many-valued logic; and it deals with reasoning that is fixed or approximate rather than fixed and exact.

It accepts numbers as input, then translates the input numbers into linguistic terms such as Slow, Medium, and Fast (fuzzification). Fuzzification is the process of changing a real scalar value into a fuzzy value. Rules then map the input linguistic terms onto similar linguistic terms describing the output. Finally, the output linguistic terms are translated into an output number (defuzzification). Defuzzification is the process of producing a quantifiable result in fuzzy logic, given fuzzy sets and corresponding membership degrees [14].

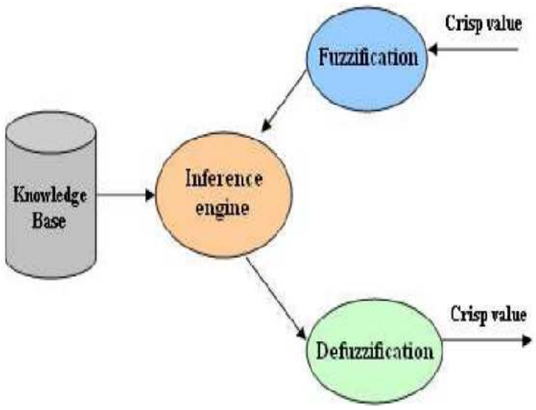


Figure 1. *Fuzzy inference system [14]*

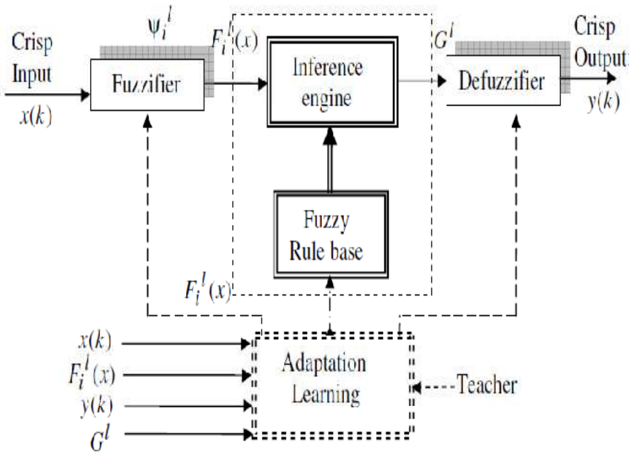


Figure 2. *A typical Fuzzy Logic System [17]*

The theory of fuzzy sets is used more and more widely in the description of uncertainty. Indeed, very often some poorly formalizable notions or expert knowledge are readily expressed in terms of fuzzy sets. In particular, fuzzy sets are extremely convenient in descriptions of linguistic uncertainties [15]. On the other hand, fuzzy notions themselves often admit extensible linguistic interpretations. This makes the exploitation of fuzzy sets especially natural and illustrative [16]. Applications of fuzzy sets within the field of decision making have consisted of fuzzifications of the classical theories of decision making. While decision making under conditions of risk have been modeled by probabilistic decision theories and game theories, fuzzy decision theories attempt to deal with the vagueness and non specificity inherent in human formulation of preferences, constraints, and goals. Applications, which may be generated from, or adapted to fuzzy set theory and fuzzy logic, are wide-ranging. Basically, the Fuzzy logic adoption in contextualizing the integration framework expected to yield a working prototype in future work.

The first two parts of the fuzzy inference process viz: fuzzily the inputs and applying the fuzzy operator are exactly the same. In general as shown in Figure 1 and figure 2, a fuzzy inference system consists of four modules [14],[17] viz:

1) Fuzzification module: transforms the system inputs, which are crisp numbers, into fuzzy sets.

This is done by applying a fuzzification function.

2) Rule/Knowledge base: stores IF-THEN rules provided by experts.
3) Inference engine: simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules.
4) Defuzzification module: transforms the fuzzy set obtained by the inference engine into a crisp value.

As shown in figure 1 the basic building block of fuzzy logic system is well depicted in [17]. Here the fuzzifier converts the real world crisp input sample $x_i(k)$ to a fuzzy output Fi^l described by the membership function ψ_i^l. This provides the degree to which the input scalar $x_i(k)$ belongs to the fuzzy set Fi^l. The inference engine provides the relationship between the fuzzy input in terms of membership functions and the fuzzy output of the controller using a set of IF …. THEN rules derived from the rule base. The rule l in the fuzzy rule base can be defined as

$R^{(l)}$: IF x_1 *is* Fi^l *and ......and* x_n *is* Fi^l *Then y is* G^l

The Defuzzifier converts the inference G^l to provide the crisp output $y(k)$. In fuzzy system, the rule base is generated in advance with expert knowledge of the system under consideration.

In this paper, Mamdani was selected for the network integration management for the proposed GSM design strategy and framework while still using it to implement the customer decision rules, owing to its optimal response.

3. Methodology

3.1. Mamdani Fuzzy Inference System for Network Integration

To design the framework for figure 3, the SWOT strategy leveraged involves the fuzzy block set. We used the fuzzy Logic Toolbox in MATLAB Simulink environment, R2011b [18]. After creating the fuzzy systems using the GUI tools, the FIS Editor displays general information about a fuzzy inference system. Using the Mamdani-type inference system, the input and output membership functions were fixed. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. Figure 3 shows the Mamdani-type inference framework used in this work.

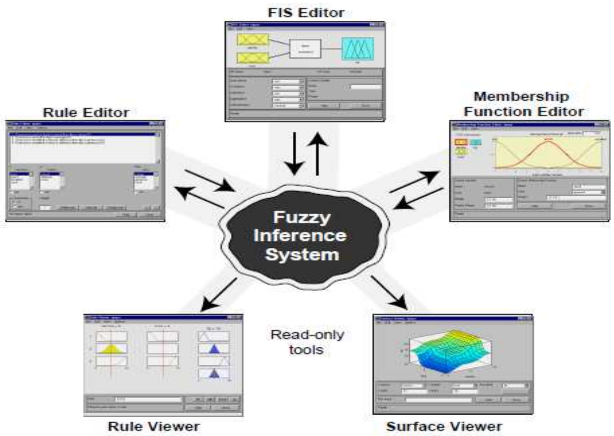


Figure 3. *Mamdani Inference System [19]*

In the fuzzy logic toolbox, there are five parts of the fuzzy inference process as shown in figure 4 viz:

1 Fuzzification of the input variables
2 Application of the fuzzy operator (AND or OR) in the antecedent
3 Implication from the antecedent to the consequent,
4 Aggregation of the consequents across the rules.
5 Defuzzification.

3.2. Specifications and Assumptions

This work introduced two major control strategies to realize the framework of the fuzzy trusted design, viz : Intelligent network integration for the control and process variables.

i Intelligent integration

The intelligent network integration used the rule base of the fuzzy algorithm to control the dynamic network switching system.

ii Process Variables

The fuzzy core was adapted to take faster decisions with respect to the process variables *F(n)* (in Equ 4.1)and *C(n)* (in Equ 4.2).

Figure 4 shows the process model of the trusted computing Engine which incorporates four process variables and control variables.

The multivalued fuzzy model processes its inputs by allowing linguistic variables classification such as low, high, medium, normal. Unlike binary logic, fuzzy system does not restrict a variable to be a member of a single set, but recognize that a given value may fit to varying degrees. The Fuzzy summation block which operates by testing variables with *IF-THEN* rules, was used to produce appropriate responses. Each rules then weighted by a degree of fulfilment of the rule invoked, this is a number between 0 and 1, and may be thought of as probability that a given number is considered to be included in a particular set. A wide variety of shapes was considered such possible, fulfilment functions, with triangles and trapezoids being the most popular. Membership functions $\mu(F_{n,} C_n) = \exp(-(|F_{n,} C_n|)^{Ip})$

Where F_n= GSM networks, Cn = Customer Parameters, and Ip = index parameter. These are the system chosen parameters whose values are tested and used to generate the surface diagrams in this work. The functions were chosen because of their flexibility, by changing them, whole families of different functions can be obtained. For μ $(F_{n,} C_n) = \exp(-(|F_{n,} C_n|)^{Ip})$, these are non normalized Gaussian density.

The degree of fulfilment for such a rule in this work was chosen to be the minimum of the degrees of fulfilment of the antecedent clauses. The total output of the control system is calculated as weighted sum of the responses to all *n* rules outputs. Outlined below is the step by step modelling approach in the trusted fuzzy logic summation block model.

Step 1. Fuzzification of Inputs (Process variables)

The first step is to take the inputs (the process variables,($F_{n,}$ C_n)) and determine the degree to which they belong to each of the appropriate fuzzy sets via membership functions. In the Fuzzy Logic Toolbox, the input is always a crisp numerical value limited to the universe of discourse of the input variable and the output is a fuzzy degree of membership in the qualifying linguistic set. Fuzzification of the input amounts to either a table lookup or a function evaluation in the rule base and inference engine.

Step 2. Application of the Fuzzy Operator

After the process variables have been fuzzified, the degree to which each part of the antecedent has been satisfied for each rule is ascertained. If the antecedent of a given rule has more than one part, the fuzzy operator is applied to obtain one number that represents the result of the antecedent for that rule. This number will then be applied to the output function. The input to the fuzzy operator is two or more membership values from fuzzified input variables. The output is a single truth value.

Step 3. Application of the Implication Method in the Rule Editor

Before applying the implication method, the rule's weight was taken care of in the FIS. Every rule has a *weight* (a number between 0 and 1), which is applied to the number given by the antecedent in the rule editor. From time to time the weight of one rule in the GNIS fuzzy core is varied relative to the others by changing its weight value to something other than 1. Once proper weighting has been assigned to each rule, the implication method is implemented. In this context, a consequent is a fuzzy set represented by a membership function which weights appropriately the linguistic characteristics that are attributed to it. The consequent is reshaped using a function associated with the antecedent in the rule editor. The input for the implication process is a single number given by the antecedent, and the output is a fuzzy set. Implication is implemented for each rule in the rule editor.

Step 4. Aggregation of All Outputs

The fuzzy decisions are based on the results of testing all the rules in an FIS. The rules are combined in order to make intelligent decisions. Aggregation is the process by which the fuzzy sets that represent the outputs of each rule are combined into a single fuzzy set. Aggregation only occurs once for each output variable, just prior to the defuzzification phase.

Step 5. Defuzzification

The input for the defuzzification process is a fuzzy set (the aggregate output fuzzy set) and the output is a single number which serves as a control signal for driving the output interface systems. As much as fuzziness helps the rule evaluation during the intermediate steps, the final desired output for each variable is generally a single number (drive signal). However, the aggregate of a fuzzy set encompasses a range of output controlled values, and so must be defuzzified in order to control the dashboard or other output interface units.

The centroid calculation, (the TE defuzzification method) which returns the center of area under the curve in the FIS model was carefully setup. There are five built-in methods supported by the MATLAB fuzzy blockset: centroid, bisector, middle of maximum (the average of the maximum value of the output set), largest of maximum, and smallest of maximum.

This work leverages on the open and easily modifiable fuzzy inference system (FIS) structure of the Fuzzy Logic Toolbox. In this context, within the basic constraints of the input process, this work customized the fuzzy inference process for the TE application to achieve a highly available and reliable system. Figure 4.3 depicts the Mamdani Inference System used to model the TE while figure 4.4 shows the FIS for the system for the customer network parameters.

The considered control variables/entities comprises of networks (N_1 to $N_{1+n,}$), and C_n. The membership situation is divided into Low, Medium, Normal, High and Very High States for all the process variables as shown in *Equ 4.1* and *Equ 4.2.* The definition of membership function was done using the fuzzy literal algorithm implemented in the fuzzy inference Engine (FIS).

4. System Modelling and Design

4.1. Fuzzy System Modelling for GSM Networks

Following table 3.4 to table 3.15, a fuzzy network integration framework will be presented using fuzzy logic concepts while deriving all the functional parameters. Consider figure 4, using the model of figure 1and figure 2, a decision rule model for the integrated GSM networks is created.

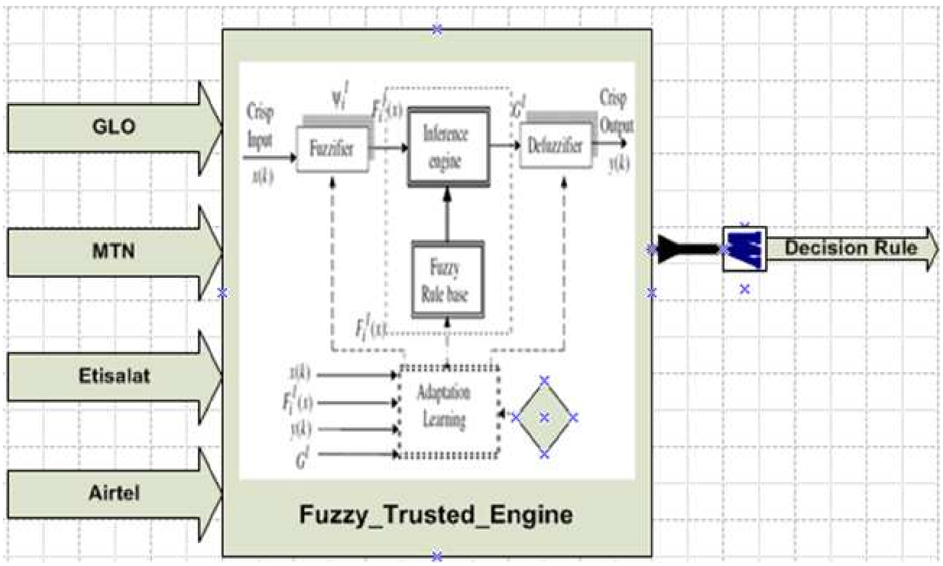


Figure 4. *System Model for Integrated base networks*

Now, for networks N_1 to $N_{1+n,}$ this work will now present the mathematical representation of the proposed system,. *Equa* 4.1 gives the component networks on a SIM Mobile device

$$F(n) = \sum_{n=0}^{N=1+n}(N_{k1+}N_{k2+}N_{k3+}N_{k4+}N_{k5+}N_{kn+1}) \quad (4.1)$$

Where Nk_1………………………… N_{kn+1} represents the various GSM networks.

The customer based parameters for all the networks is given by Equ.4.2

$$C(Fn) = \sum(C_{1+}C_{2+}C_{n+1}) \quad (4.2)$$

In context, the key networks include GLO, MTN, Etisalat and Airtel.

Figure 4.1 shows the proposed Mamdani Inference System (TE) for GSM networks comprising of the input network sources the inference engine and the decision rule output network

Figure 4.2 to figure 4.5 shows the Membership functions for all the Network input process variables. Figure 4.6 shows the membership functions for Output Decision Network. In context, these membership variables are used define the conditions of the network so as facilitate a porting scenario.

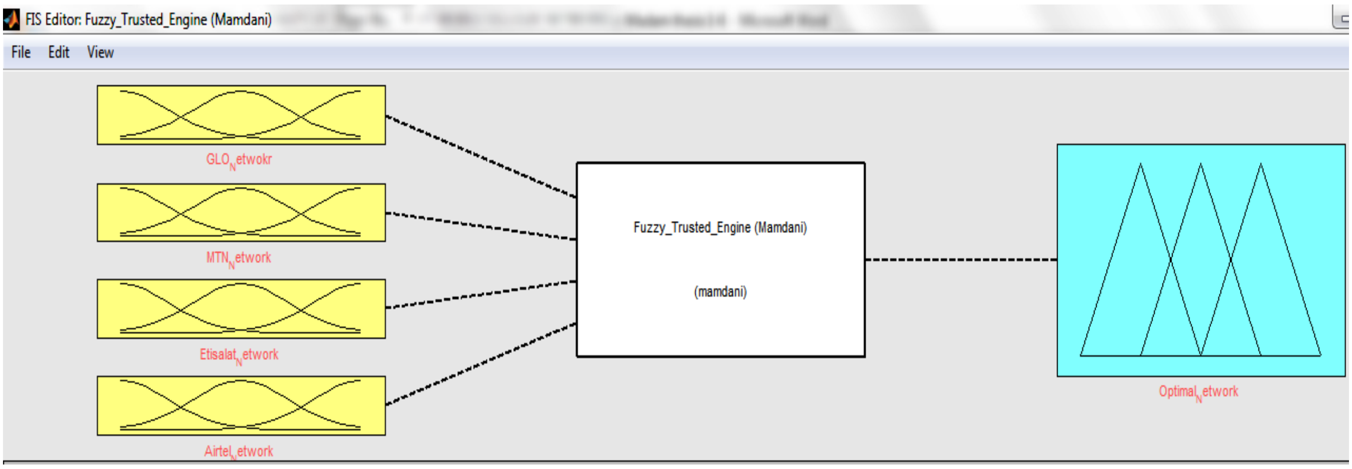


Figure 4.1. *Mamdani Inference System (TE) for GSM Networks*

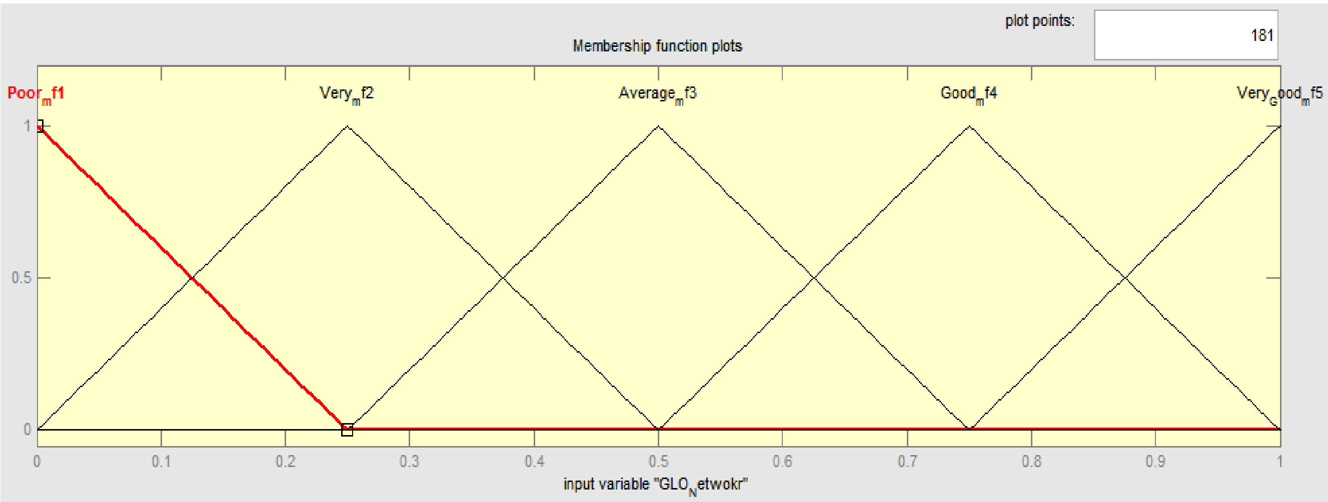


Figure 4.2. *Membership functions for GLO Network*

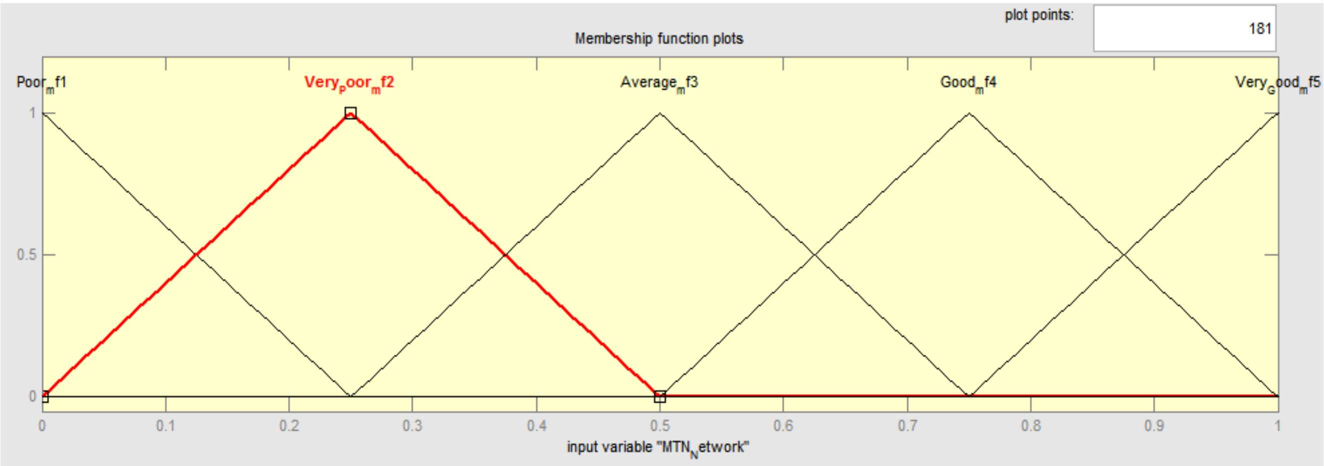


Figure 4.3. *Membership functions for MTN Network*

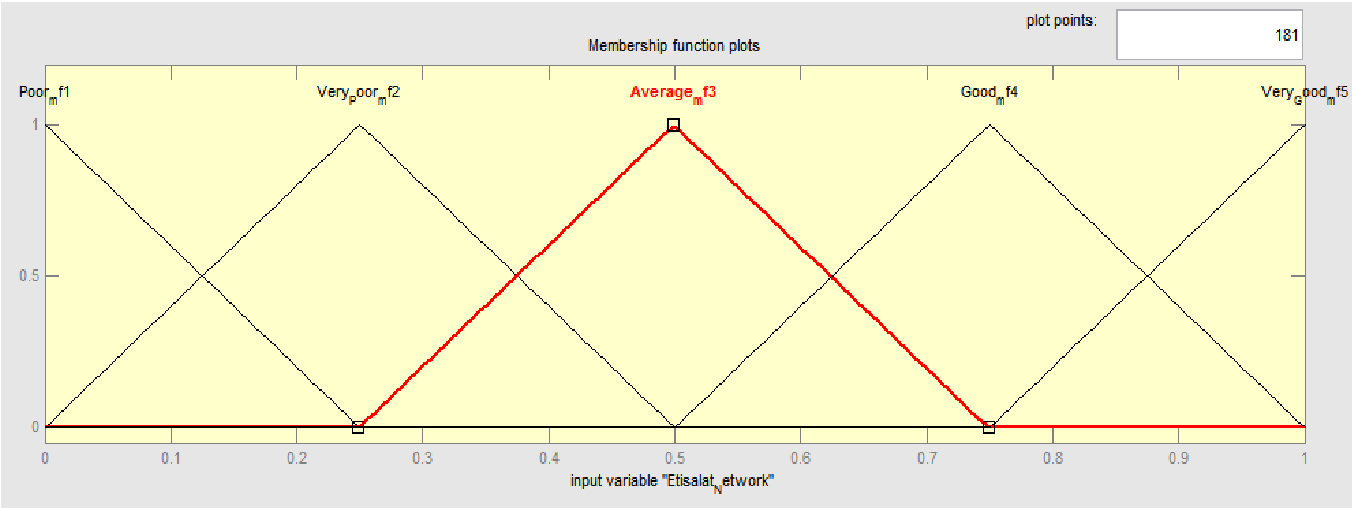


Figure 4.4. *Membership functions for Etisalat Network*

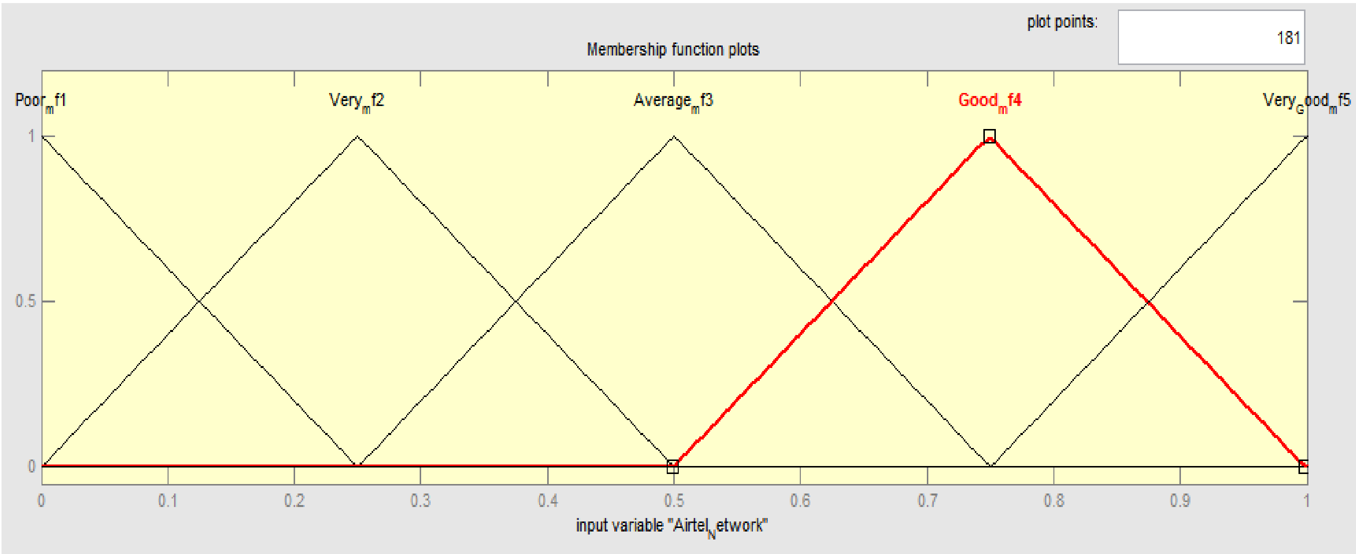


Figure 4.5. *Membership functions for Airtel Network*

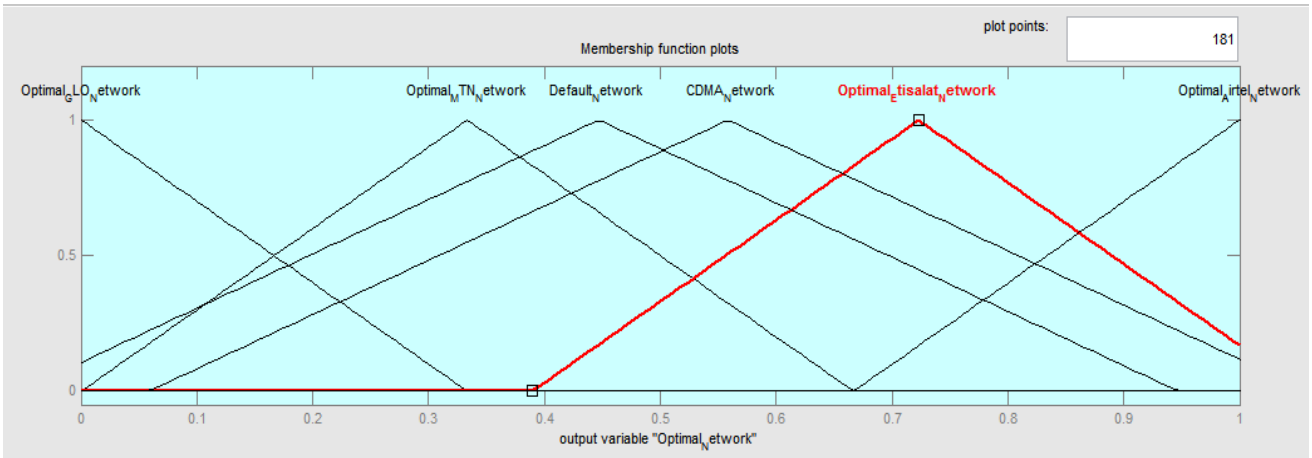


Figure 4.6. *Membership functions for Output Decision Network*

Figure 4.7 shows the Rule base Editor for the GSM network process variables. This is used to generate the 3D surface diagrams for figure 4 considering Equ.4.1 and 4.2.

Figure 4.8 shows the realized rule base optimal points for the process variables. Basically, 75 rule base was captured with its centroid mapping also.

Figure 4.9 shows the Surface diagram for the network process variables in this case MTN and GLO.

Figure 4.10 shows the FIS for the system for the customer network parameters. Figure 4.11 shows the Membership functions for Customer variable (Network_Coverage), Figure 4.12 shows the Membership functions for Customer variable (Tariff_Plan), Figure 4.13 shows the membership functions for Customer variable (Customer care management), Figure 4.14: Membership functions for Output decision rule, Figure 4.15: Rule base Editor for customer GSM network process variables. Figure 4.1 shows the Surface diagram for customer GSM network process variables (Tariff and Network Coverage), Figure 4.17 shows the surface diagram for customer GSM network process variables (Tariff and Customer care) and Figure 4.18: Surface diagram for customer GSM network process variables (Network Coverage and customer care management)

Consequently, this work strongly advocates for improvement in the GSM networks factors viz: Tariff and Network Coverage, Tariff and Customer care and Network Coverage and customer care management). These will completely improve QoS and improve end user satisfaction at large. These parameters have been validate by the selected operators in this work.

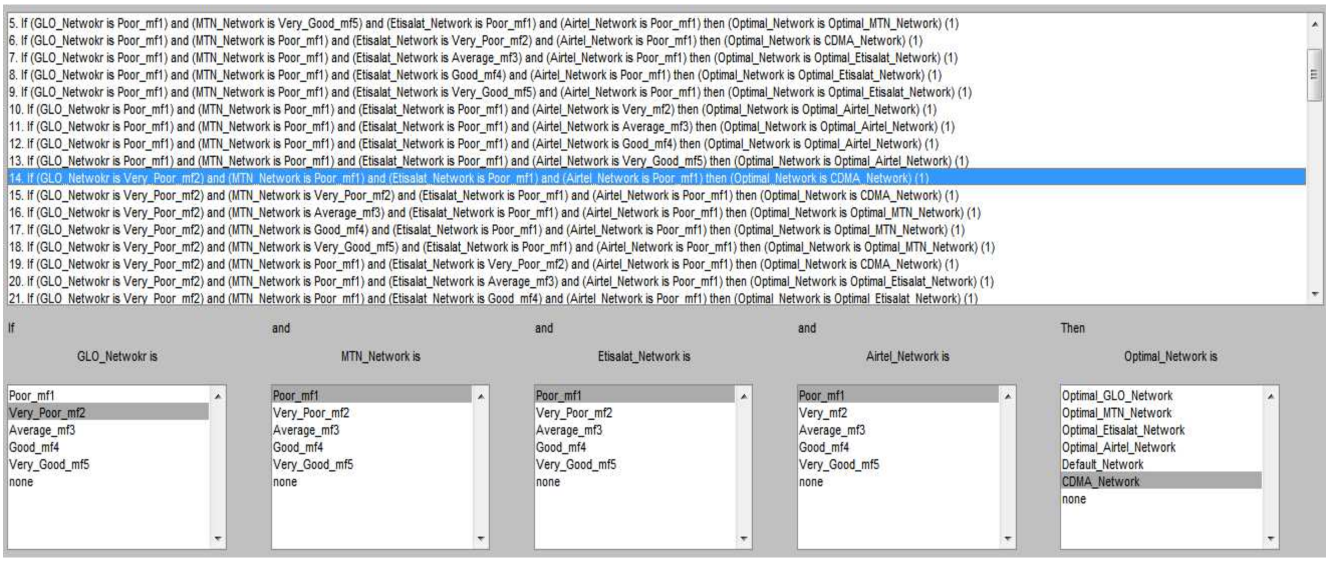


Figure 4.7. *Rule base Editor for the GSM network process variables*

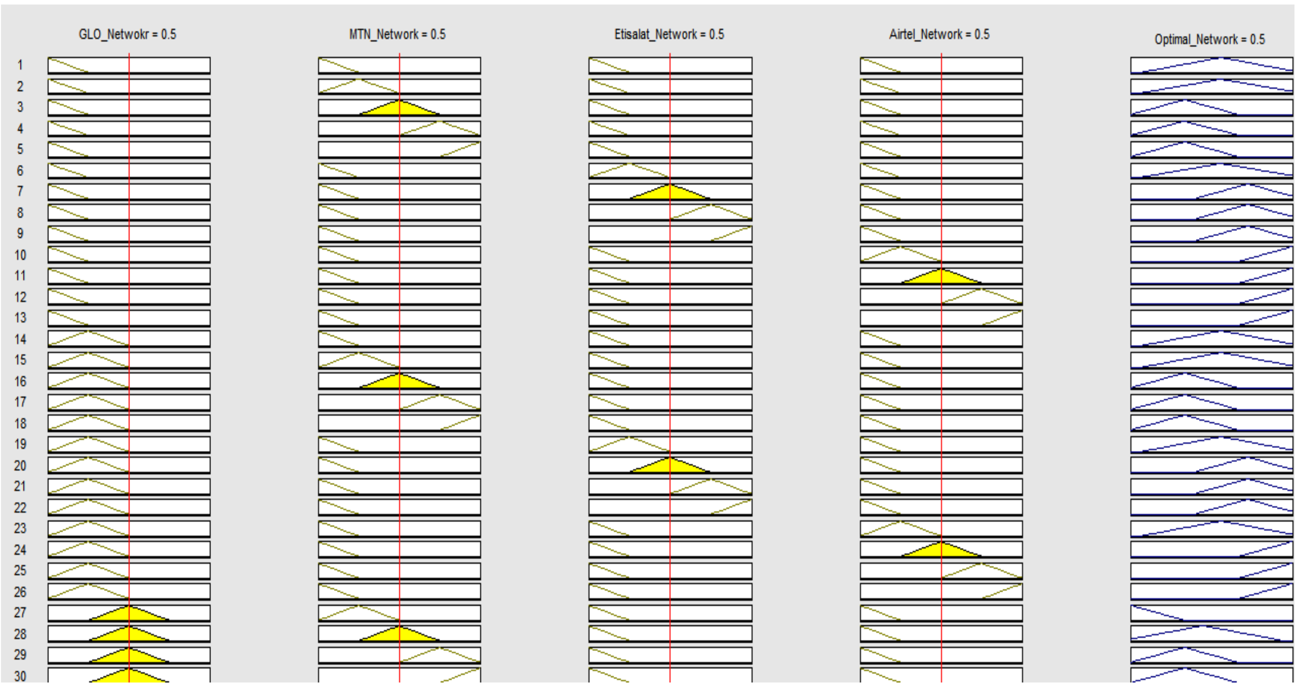


Figure 4.8. *Rule base Optimal points for the process variables (75 rule base centriods)*

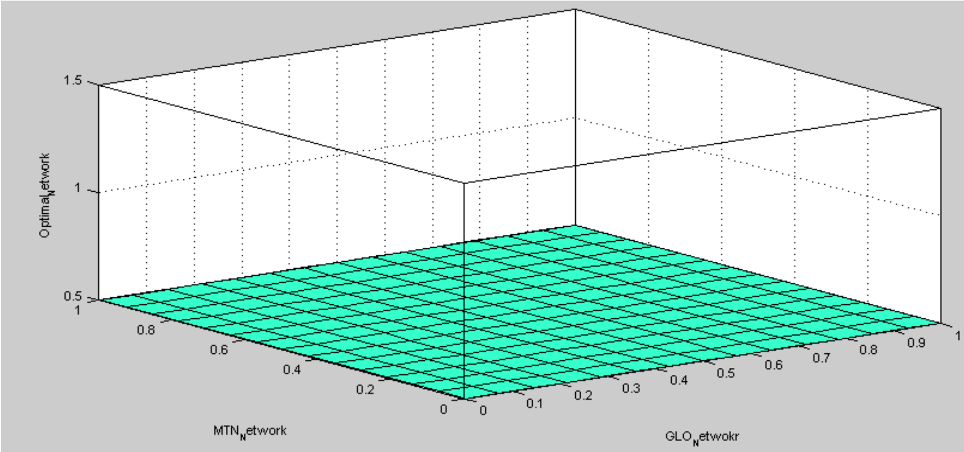


Figure 4.9. *Surface diagram for the network process variables (MTN and GLO)*

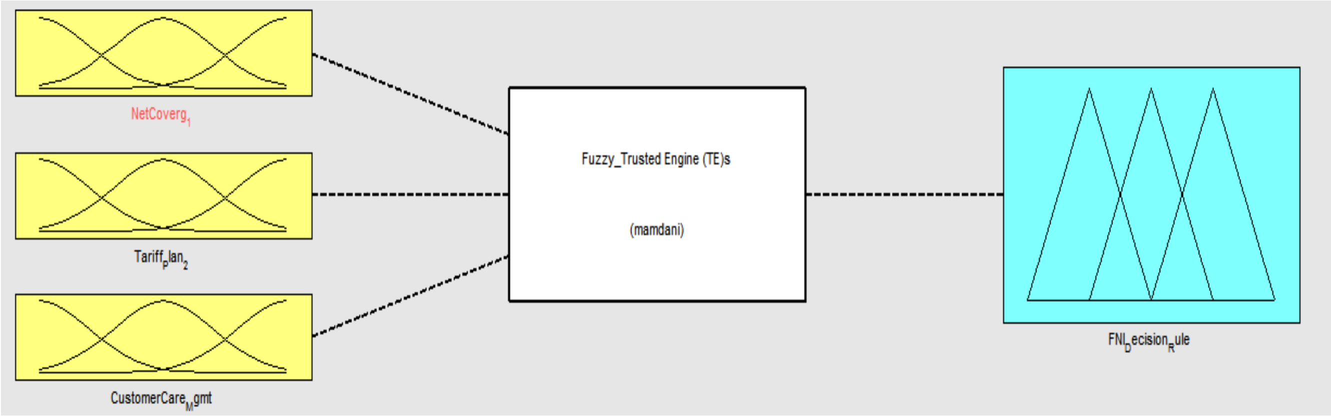


Figure 4.10. *FIS for the system for the customer network parameters.*

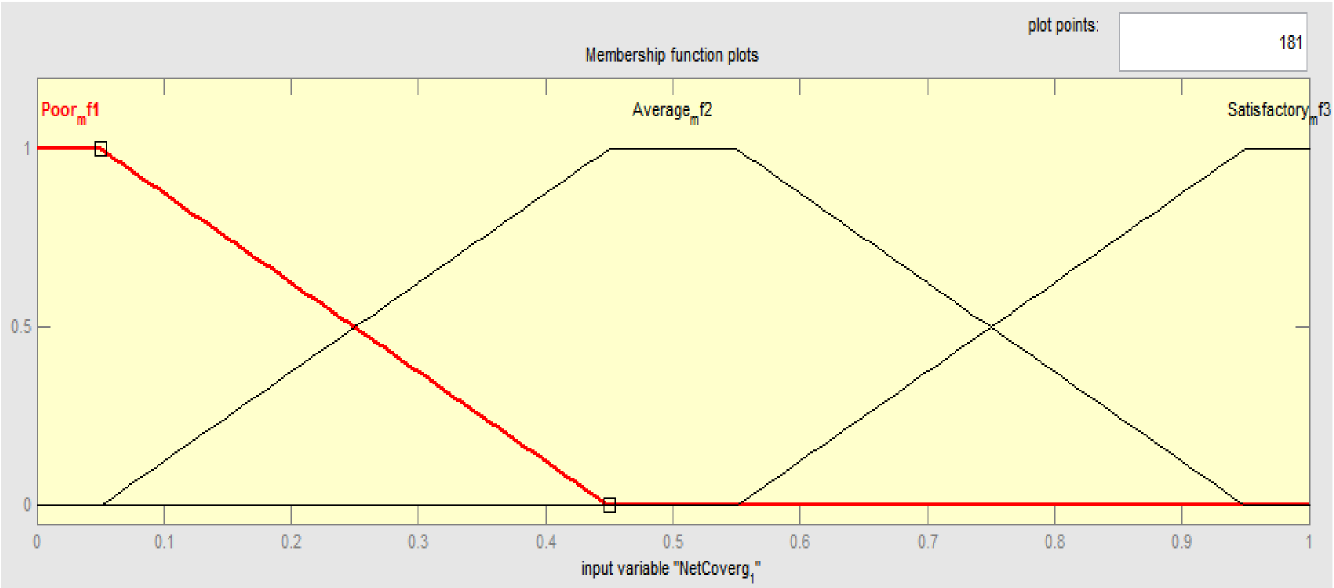


Figure 4.11. *Membership functions for Customer variable (Network_Coverage)*

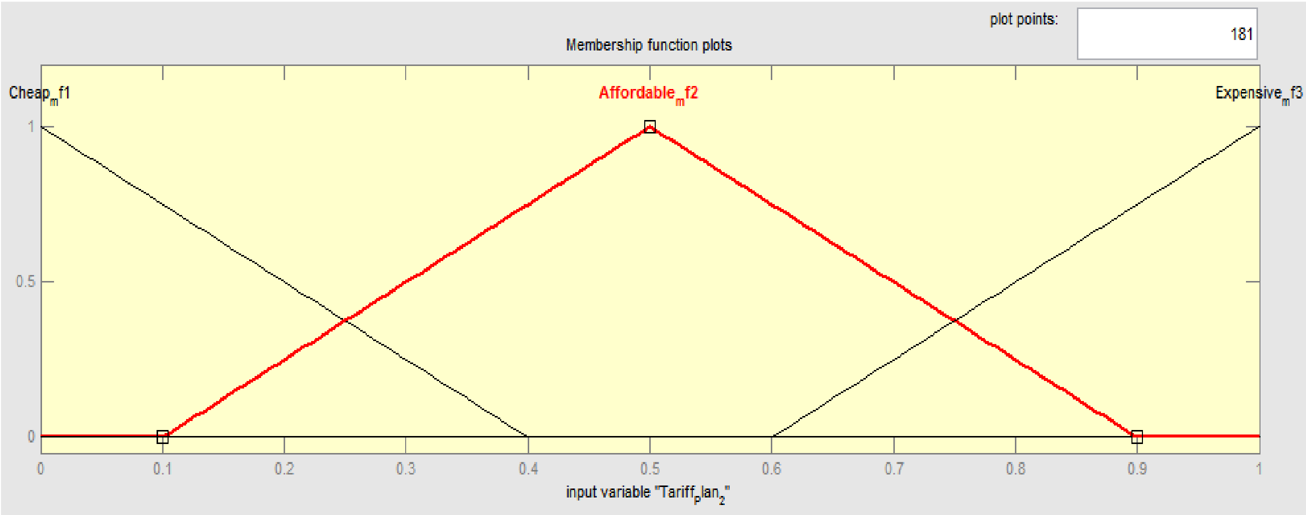


Figure 4.12. *Membership functions for Customer variable (Tariff_Plan)*

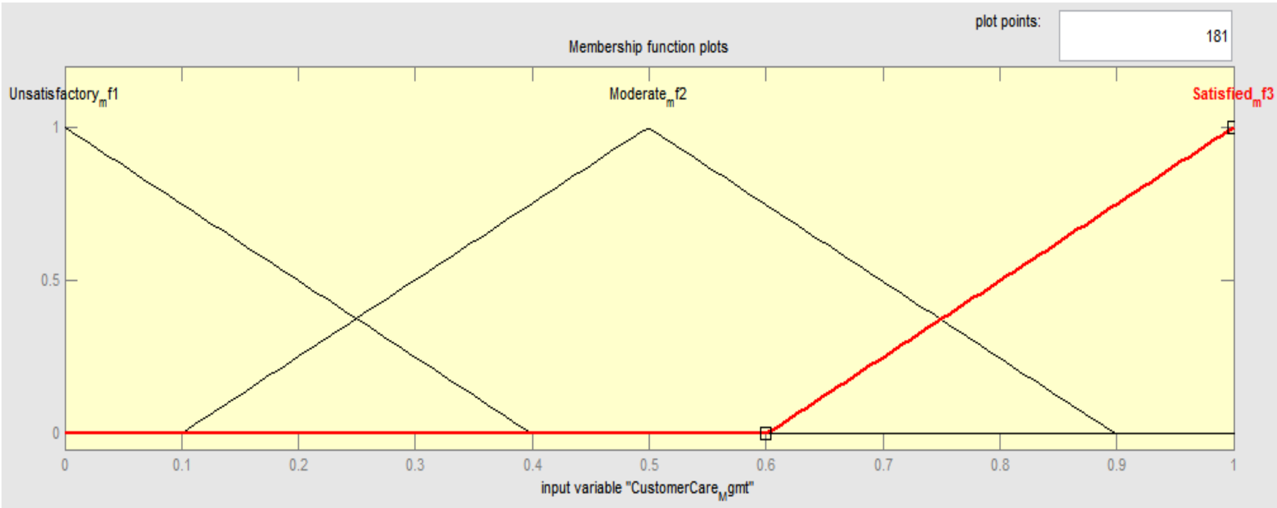


Figure 4.13. *Membership functions for Customer variable (Customer care management)*

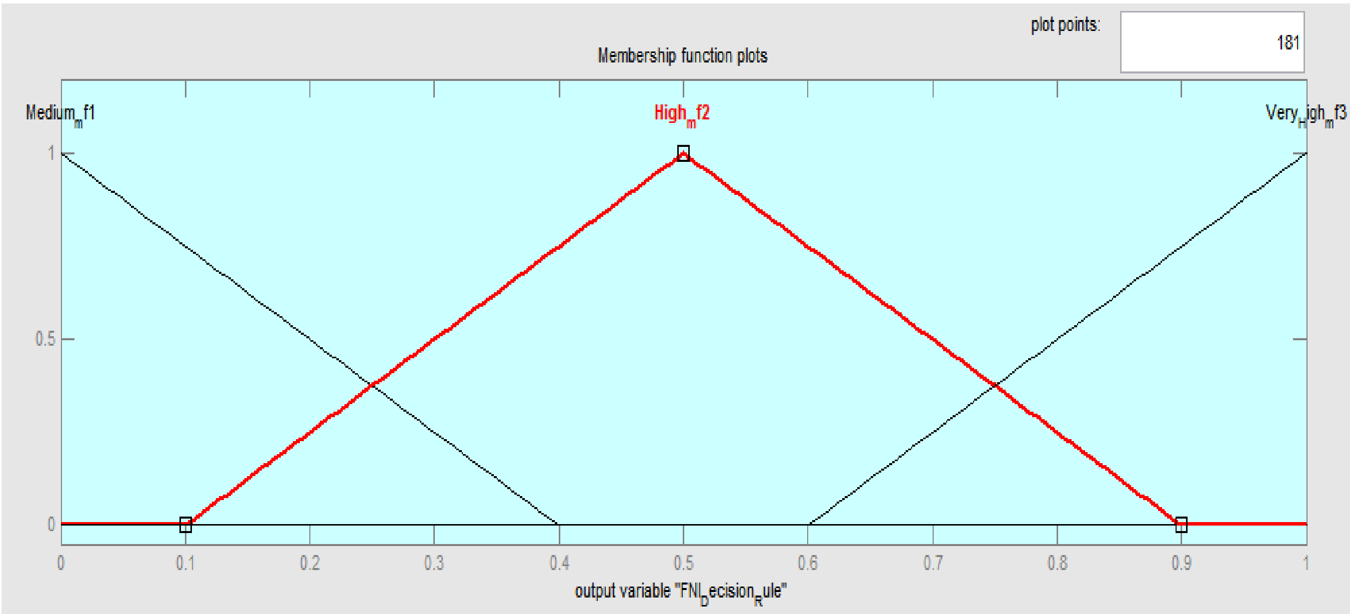


Figure 4.14. *Membership functions for Output decision rule*

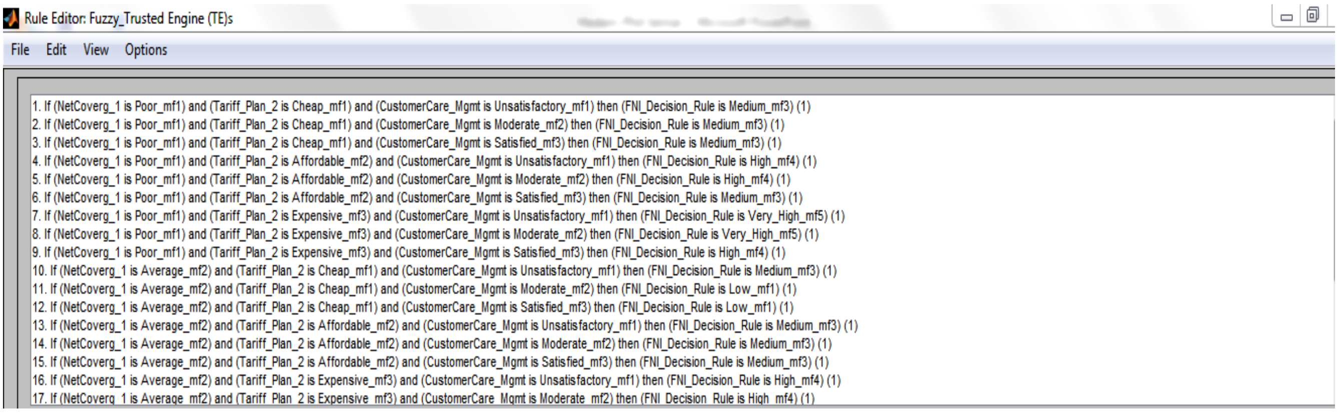


Figure 4.15. *Rule base Editor for customer GSM network process variables*

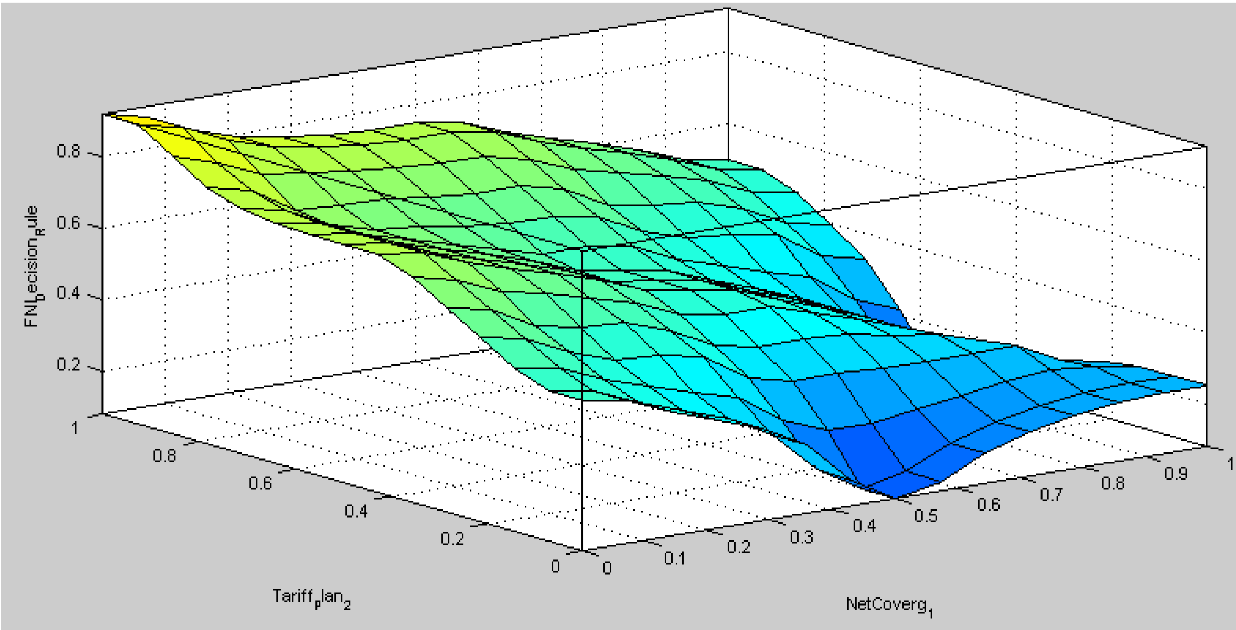


Figure 4.16. *Surface diagram for customer GSM network process variables (Tariff and Network Coverage)*

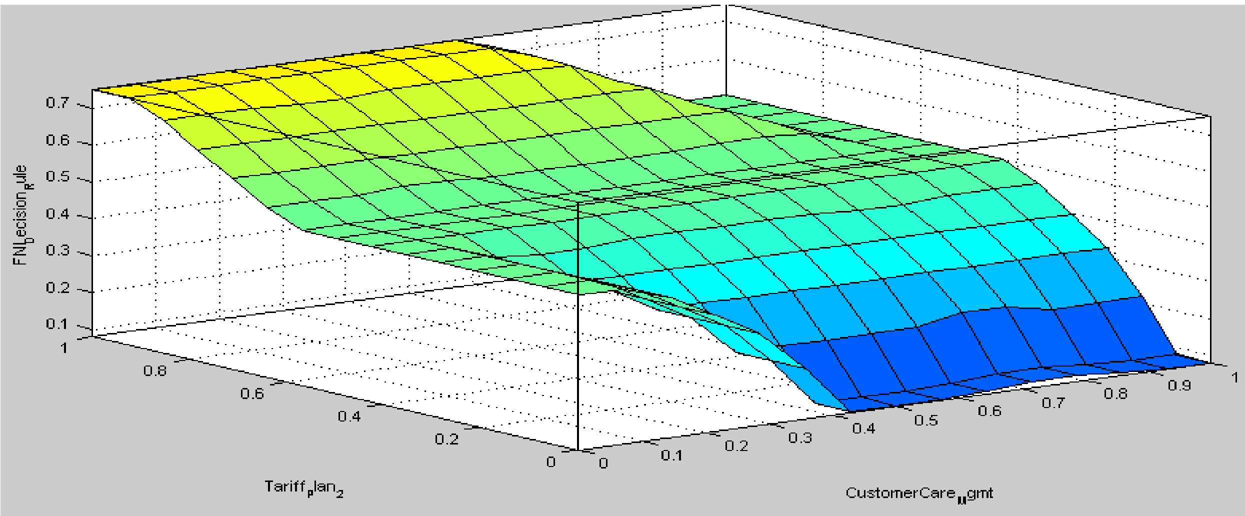


Figure 4.17. *Surface diagram for customer GSM network process variables (Tariff and Customer care)*

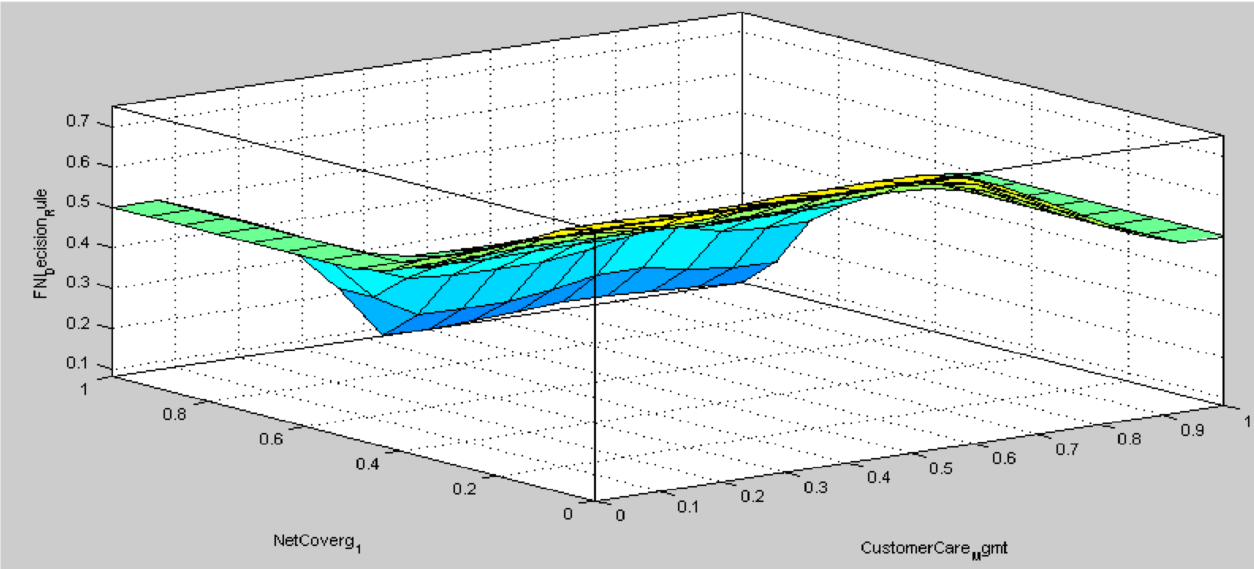


Figure 4.18. *Surface diagram for customer GSM network process variables (Network Coverage and customer care management)*

From the foregoing, this work have used figure 4.13 to figure 4.18 to characterize *Equ 4.1* and *Equ 4.2*.

Conceptually, these must sit on the trusted mobile computing engine. Leveraging the Mobile node SIM card, the principle stakeholders in a trusted mobile platform are:

- Users, who store their data in the platform. There may be multiple User stakeholders in a platform.
- Service Providers, who provide services consumed in a platform. There may be multiple Service Provider stakeholders in a platform.
- Communications Carriers, who are specialist Service Providers providing cellular radio access for the platform.
- The Device Manufacturer, who provides the internal communications within a platform and typically provides all the hardware resources within a platform. Figure 4.19 shows the interaction model between the user service engine on the SIMcard, the communication carrier, service provider and network services/applications.

As depicted in figures 4.13 to figure 4.18, the activity diagram of figure 4.20 must sit in the fuzzy trusted platform for efficiency and reliability for the mobile user experience. Each time the user logs on to the mobile device, the device owner trusted engine must be instantiated as well as the device manufacturer and network provider all on the trusted mobile platform. The network with the best service quality becomes the preferred active network by default.

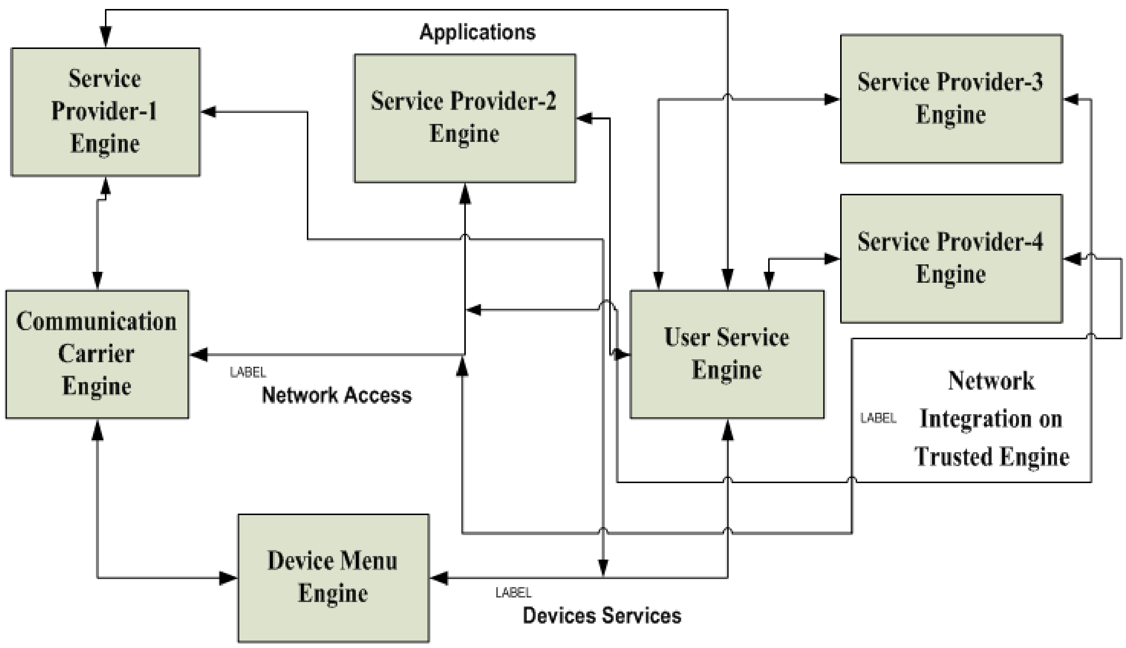


Figure 4.19. *Interaction Model for network integration*

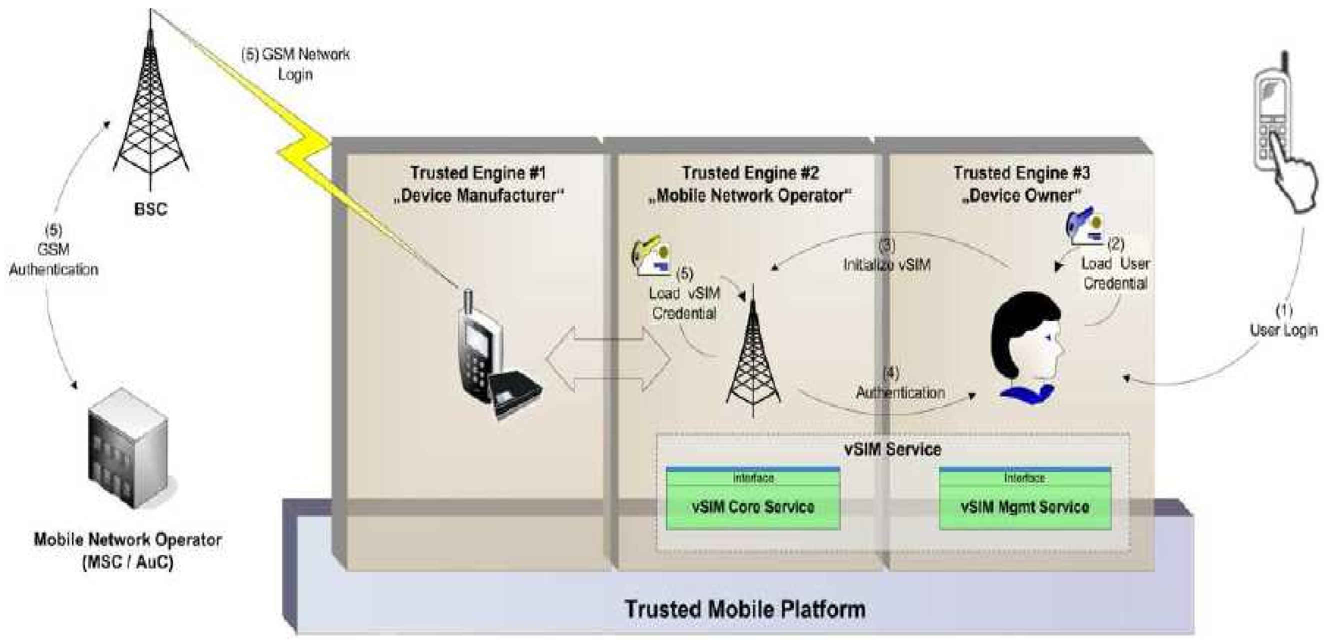


Figure 4.20. *Activity diagram for network integration [20]*

5. Conclusion and Future Works

This paper provides an insight into a proposed conceptual framework for mobile SIM networks which seeks to enhance the current MNP scheme in Nigeria. The results have shed light on the 3D fuzzy logic plots for the mobile networks integration and subscriber factors for QoS. A chronological procedure for the implementation for both the network integration and the customer perspective on QOS were accounted in the implementation.

The work was designed as an initial exploration to demonstrate the feasibility of a flexible trusted platform .

To this extent, the study is limited as it did not explore and empirically determine extent of improvement. Another limitation is that the study did not capture the Key Performance Indices (KPIs) of the network regulators for switch as a result of NP availability. These shortcomings could be examined in further studies.

According to [12], since the NCC insists that SIM registration is a necessary step before commencing MNP, the Commission should use the same sensitization channels for SIM registration to educate the public on the benefit of NP and provide information on its plans for NP implementation. Furthermore, the NCC and other stake holders organize a forum aimed at enabling and encouraging the subscribers to register their SIM cards for the number they would like to be associated with because the integration provides an avenue for migrating to a network of choice irrespective of the phone number anyway..

The regulatory authority, NCC, would find the results of this proposal useful in developing policies and strategies for improving the current MNP technologies that actualize the reduction in tariffs, network coverage and customer care to subscribers. Furthermore, the network operators would be able to utilize this proposal in formulating their strategies to gain favorable switching habits from customers.

References

[1] Roger, F. (2010). *Nigeria rises* (Internet). http://www.arabianbusiness.com/580722nigeriarises 9th February 2010.

[2] NCC Press Release, (2007). Quarterly Summary of Telephone Subscribers In Nigeria, (internet) http://www.ncc.gov.ng/. 19th September 2010.

[3] Deng, Zu., Lu, Y., Wie, K. K. and Zhang, J. (2009).Understanding customer satisfaction and loyalty: An empirical study of mobile instant messages in China. *International Journal of Information Management* 30, Pp.289-468.

[4] Hanif, M., Sehrish, H., Adnan, R., (2010). "Factors Affecting Customer Satisfaction", *International Research Journal of Finance and Economics"*, http://www.eurojournals.com/finance.htm Accessed on 20 October 2010.

[5] Eshghi, A., Haughton, D. and Topi, H. (2007). Determinants of customer loyalty in the wireless telecommunication industry. *Telecommunication policy* 31(2), 93-106.

[6] Anderson, E. W., Fornell, C. and Mazvancheryl, S.K. (2004). Customer Satisfaction and Shareholder Value, *Journal of Marketing* 68, 172-185.

[7] Dragan Pamučar, Goran Ćirović, Dragoljub Sekulović and Aleksandar Ilić, (2011), "A new fuzzy mathematical model for multi criteria decision making: An application of fuzzy mathematical model in a SWOT analysis", Scientific Research and Essays Vol. 6(25), pp. 5374-5386, Available online at http://www.academicjournals.org/SRE.

[8] W. Olatokun,S. Nwonne, "Determinants of Users' Choice of Mobile Service Providers", in the Nigerian Telecommunications Market, African Journal of Computing & ICT, Vol 5. No. 4, June 2012, Pp.19-32.

[9] M.Sathish, K.Santhosh Kumar, K.J.Naveen, V.Jeevanantham (2011), "A Study on Consumer Switching Behaviour in Cellular Service Provider: A Study with reference to Chennai", Far East Journal of Psychology and Business, Hong Kong Vol. 2 No 2,

[10] Yuriy Podvysotskiy (2006), "An Investigation Of The Effect Of Mobile Number Portability On Market Competition", M.A, National University Kyiv-Mohyla Academy.

[11] Ajay Malik, Sunita Malik, and Vijay Pal Singh, "Mobile Number Portability Decision using Fuzzy Logic", International Journal of Electronics Engineering, 3 (1), 2011, pp. 89– 92

[12] Tiamiyu, Osuolale Abdramon, Mejabi, Omenogo Veronica, (2013), "Evaluation of Subscriber Attitude to Mobile Number Portability Implementation in Nigeria", Journal of Emerging Trends in Computing and Information Sciences, Vol. 4, No. 4 Online: http://www.cisjournal.org.

[13] Decision Making In A Fuzzy Environment, R. E. Bellman, L.A. Zadeh, Management Science, Vol. 17, No. 4, Application Series (Dec., 1970), Pp. B141-B164

[14] Rizal Munadi, " *Fuzzy Logic-Based Mobility Management Scheme For Cellular Radio System"*, Phd, Dissseartation, 2011.

[15] Navigation Techniques For Small-Screen Devices: An Evaluation On Maps And Web Pages 2008, Burigat, S., Chittaro L., Gabrielli S., International Journal Studies 66(2), Pp. 78-97.

[16] Intuitionistic Fuzzy Spatial Relationships In Mobile Gis Environment 2007, Malek, M.R., Karimipour, F., Nadi, S., Lecture Notes In Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics) 4578 Lnai, Pp. 313-320

[17] Nihar Ranjan Panda, "Development Of Fuzzy Receiver For GSM Application" National Institute Of Technology, Rourkela, India – 769008, May- 2005

[18] MATLAB,Getting Started Guide, 2011 by The MathWorks, Inc, Online-https://www.ma.utexas.edu/users/haack/getstart.pdf

[19] Fuzzy logic toolbox for use with MATLAB user's guide version 2 fuzzy_tb.pdf- Abobe Reader.http://www.phys.ufl.edu/docs/matlab/pdf_doc/fuzzy/fuzzy_tb.pdf

[20] Trusted Computing Group. TCG Specification Architecture Overview. Technical Report Revision 1.3, TCG, 2007.