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BENCHMARKING INTERNET PERFORMANCE USING FUZZY LOGIC APPROACH

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Abstract

Performance Dimensions (PDs) are variables used in measuring Internet performance. The PDs are usually evaluated using fuzzy logic with the logic serving as a co-intensive model of reality of human reasoning. Though many frameworks for benchmarking the Internet exist, studies addressing users' satisfaction or employing multiple PDs using fuzzy logic are few. This work was designed to develop an intelligent benchmarking tool that measures University Internet performance from the users' satisfaction perspective through multiple PDs. The PHP+MySQL was used in developing an Internet performance type of an intelligent benchmarking tool, named University Internet Network Benchmarking (UINB) as an internet-based information system. The UINB tool was used to facilitate data collection, storage and benchmarking of nodes. Fuzzy logic was used to measure performance. The University of Ibadan network (UINET) data on the PDs [Service Quality (SQ), users' logs, complaints, maintenance, equipment and monitoring] were used for analysing and benchmarking. The reliability of the UINB tool was tested using UINET. Benchmarked Internet performance of nodes clearly classified performance as satisfactory, dissatisfactory and very dissatisfactory. This tool was applied on the internet nodes of the Department of Economics, Faculty of the Social Sciences and the Department of Computer Science. It classified both Faculty of Social Science and the Department of Computer Science as unsatisfactory (-31.5, and -78.9 respectively). The intelligent benchmarking tool solved the problem of benchmarking internet performance. The multiple performance dimensions using fuzzy logic appropriately measured Internet performance through users' satisfaction. This could be used as Internet benchmarking tool for Universities.

Keywords: Internet users' satisfaction, Internet benchmarking, Fuzzy logic, Internet performance

1. INTRODUCTION

The Information Technology (IT) unit is one of the necessary elementary units of the contemporary world. Acquiring and grasping InfoTech skills is also a vital aspect of Nigeria's now educational system. The IT units of nearly all the university campuses provide internet services. Some units like administrative and academic units have taken their considerable part of their services online [1][2]. The Information & Communication Technology (ICT) Unit in University of Ibadan controls the network service. Unfortunately, the Internet services at University of Ibadan seem not to be sufficiently reliable, with elongated output moments and low dependability, particularly during high usage time. [3]reported that "the hit ratio of web access fell drastically and the University Internet users became disenchanted. Hardly could some of the offices have internet signals. Going outside to send and receive mails and output files became the norm." The afore-mentioned are some proofs the Internet services' performance level is low. However, the challenge is so far unresolved. The current research centred on developing a performance tool required for gathering more data within the University Internet service to "transform data from dust to gold" [4][5]. Obilor [6] presented realistic information for optimal internet connectivity and usage for educational research and communication for users' of University of Ibadan Internet Network. This centres on users' managing the network resources and enhancing the Internet performance, ensuring that these

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inadequate resources are fairly available to everybody.

As a response to these issues, systematic study of the expected performance of the Internet services needed to be carried out. Benchmarking is seen as one of the tools that can be used in improving performance by comparing methods from a knowledge study. According to VTT Annual Report [7], benchmarking is a comparative method where one learns, when applicable, to adapt one's own processes to the methods of the most successful companies in the market. In the views of Akarowhe [8] and Arrowsmith, *et. al.* [9], benchmarking is an unceasing, orderly investigation for, and application of, best practices which transform to higher performance. Importantly, benchmarking is the process of identifying the performance dimension with their performance indicators after which the processes, products, services or performances are analysed and compared within or between organizations with similar objectives.

The significance of benchmarking is the procedure of identifying the uppermost node of Internet performance and comparing that with a node of low performance and then identifying the indicators with problems. This paper develops a benchmarking model to incorporate fuzzy logic in order to benchmark and measure the performance of a University Internet with multiple performance dimensions. Additionally, the researcher's interest is in using fuzzy logic to derive indicators that would focus more on users' satisfaction from human reasoning. After this, decisions would be made for necessary improvements to reach those nodes with good performance.

Benchmarking has been used in studies but with a diverse focal point and system of benchmarking [10] [11][12]. Similarly, fuzzy logic has not been used in other fields of Internet performance nor was it combined with benchmarking process. Though many frameworks for monitoring Internet performance exists, rarely do they specifically address satisfaction of Internet users. These are the gaps this paper seeks to fill.

The common aim is to assemble a tool that will be utilized to evaluate and improve the performance of Internet Network in the University setting. The tool will bring out the human analysis and fulfilment while evaluating performance, using fuzzy logic and benchmarking ideas.

Human-readable law such as fuzzy laws, enable the measurement of fulfilment linking the performance measurement to a significant deliberate plan, valuable for reinforcing decision making. Fuzzy logic was adopted to replicate the domain knowledge of professionals as regards satisfaction evaluation; and build methods using quantitative metrics and satisfaction measures. The study intends to bring out the human analysis and satisfaction while evaluating performance, adopting fuzzy logic and benchmarking theories to model domain knowledge of specialists regarding performance. In particular, the purposes of the study are: to analyze the Performance Dimensions (PDs), user logs, complaints, maintenance, monitoring, equipment and service quality using fuzzy logic for a contemporary approach to performance evaluation and to develop an intelligent University Internet Network Benchmarking tool (UINB).

Mainly in this study, a model is recommended for benchmarking Internet performance that consists of soft and hard measures. The model would capture the measurement of all the multiple dimensions and the satisfaction measures. The next sections discuss related works, the methodology and the result.

2. Literature Review

It was difficult to get a study that met such approach in the Universities except the one for business enterprise. Some examples of application of benchmarking highlight its potential for use as an aid to learning in a variety of situations. While Fuzzy logic application is found in various fields, it cuts across control, signal processing, communications, integrated circuit manufacturing, and expert systems in business, Medicine, Psychology, and Computer Science. This section is divided into the three subsections as follows:

2.1 Internet Network Performance

This section discusses various studies that have been conducted in the area of internet network performance.

Nagaraja [13] focused on a methodical approach to improving and quantifying Internet services availability. A systematic approach to quantifying and improving the availability of Internet services was carried out. When choosing a platform, it was discovered that services often trade-off availability with other factors such as cost and scalability. It was noted that performance and availability were based on the offered load on the Internet service, when it did not exceed the maximum capacity deliverable by the Internet service under normal condition. Nagaraja [13] discovered the following problems which affect performance: hardware failures due to commodity nature and high load on the services; complex and heterogeneous environment which makes designing recovery mechanisms a difficult task; human mistakes which contribute to system outages. Other multiple empirical studies over the last two decades of large scale computer systems supported the findings that other incidental performance indicators also worsen the problem in Internet services. According to him, the results showed the primary reasons for failures, such as the inadequate understanding of the underlying system by the human operators which points to the complexity of the tasks performed. This was an obvious indicator that the challenge faced by network administrators in managing network could be as a result of their own limited mastery. The users felt that both executing tasks as well as checking the correctness of the performed tasks need system support. Hence, providing such support would improve the failure statistics and availability of network.

Borzemski [14] saw the challenges of how difficult it was to determine the slow response of the network, whether it is due to either network problems or end-system problems on both sides, or to both. The traceroute probing technique was used to measure round-trip time for Internet path performance evaluation. From the results, the researcher found out that the number of hops pass and the round-trip times of the packets vary. The basis of the variation was on the day of the week and the time of the measurement. The data was mined using IBM Intelligent Miner for Data system. The decision tree that could be a valuable monitor to the future features of appropriate properties of a given Internet path in a long-term scale was built using the knowledge obtained from the research.

Williamson [15] made use of the ability network traffic measurement method for troubleshooting the network by collecting data regarding the performance of network protocols and analysing. Troubleshooting enables the network administrator to understand the state of the network when operative and when not working and to identify the equipment malfunctioning and affecting performance. This would enable debugging the protocol, workload characterization and the performance evaluation protocols with different network configurations using simulations [16].

Furthermore, Srour and Weerdt [17] illustrated the possibility for a universal assessment model which was used for a freight logistic environment. The model solved the issue of calculating the production of contrasting decision support methods. To measure the employee, customer and the society's satisfaction Fuzzy logic was integrated. The researcher observed that the domain in operation was still limited. The benchmarking concept was employed, meanwhile significant implications for this valuation framework were considered. In addition, comparable to the project, but with a diverse method to this perspective, was quantifying users' perceived Internet performance in several places by Liston [18].

Liston's [18] aim was to examine how users-perceived Internet performance all over the world by making use of the information provided in applications at different locations. The efficiency of the different approaches used in collecting data from numerous localities in the Internet topology was evaluated. Lack of incentive for users was the major limitation of this method, preventing users from participation in measurement researches, and another limitation was the technical inability to install the software on each of the user's system. Finally, another limitation in terms of the researcher's paper was lack of database and benchmarking tool for continuous monitoring.

Joumblatt [19] built a methodology to automatically forecast user displeasure with internet application performance. The experimentation approach employed was design and apply "HostView" to gather network performance data annotated with user response at the end-hosts. It was found that users would run the tool only if their privacy was addressed and apply a pause button to temporarily stop data logging. It was also found that a large portion of users provided feedback about network performance but not more than three times per day. Based on survey results, the first prototype of HostView focused on collecting network performance data and evaluating the CPU overhead of candidate techniques. The second prototype of HostView was to minimize the user annoyance from the user feedback collected by tuning the algorithm.

Still, in a similar paper, Shaikh, Fiedler, Minhas and Arlos [20] observed inactive monitoring of user-perceived performance deprivation as a significant tool for service providers to develop client loyalty. Two on-going works on network-based methods were developed to objectively assess the user-perceived network performance. Shaikh et al [20] also observed that service provider's important tool to improve customer loyalty is based on passive approach to monitoring of user-perceived performance degradation. Based on the researchers' limitation, apart from the issue of collecting data from the users end in this research, benchmarking tool for a continuous monitoring of performance, was another issue.

Besides other researchers, Miller *et. al.* [21] discovered that with network performance, it was widely assumed that end-user gets irritated by certain network characteristics. The hypotheses were empirically examined by building a method and tool chain: SoylentLogger. The fear of users unwilling to partake in measurement studies that would entail researchers building and setting up end-host equipment on users' system had discouraged numerous from pursuing similar research. The researcher realized that from the re-evaluation of studies and several other authors, benchmarking has been employed in studies but with a dissimilar focal point and system of benchmarking [10] [11] [12]. Fuzzy logic has been used in other areas, but not in the field of Internet performance. It has been rarely combined with benchmarking procedure. Moreover, the researchers did not actually identify additional performance dimensions with performance markers that would be utilized in benchmarking Internet performance.

2.2 Network Performance Benchmarking

The term 'benchmarking' was borrowed from land surveying where it has to do with assessing objects against a known point of altitude reference. McNamee [22] relates an important historical event with regard to the evolution of the study of benchmarking. According to him, the history of benchmarking is connected with Xerox. Xerox compared their product with similar products in order to measure their performance. Xerox's result was alarming because it measured poorly against its major rivals. In the Xerox study, results obtained include higher quality of product, and more flexible and faster delivery. Xerox changed its strategy and paid more attention to the new areas needed for development that helped turn around its fortunes. Benchmarking, therefore, became a tactical planning tool for Xerox.

In Lund's view [23], the development of benchmarking was rooted in Japanese manufacturing practice as a usually used business tool for improvement of sale in the late 1980s; US was the first to adopt it into western management practice, originally in the manufacturing industry. Afterwards, several sectors such as education, health care industry, organizations, and government had applied to service. Australia, Hong Kong and the UK were other countries which have adopted benchmarking as a quality assurance tool.

The need for benchmarking database and performance indicators is clear and urgent as the necessary factors needed for appropriate benchmarking. This stresses the need for the current study. This study would be the starting point while other universities will join and build up benchmarking database and performance indicators based on Internet performance.

According to Kassa [24], the number of users and the growth of network capacities can't be scaled by simulation models. Computationally efficient analytical models were the most essential tools for investigating, designing, dimensioning and planning Internet Protocol (IP) networks. Existing analytical models of TCP performance were either too meek to capture the internal dynamics of TCP or were too problematic to be used to analyse correct network topologies with numerous hurdles links. The findings in these works showed that the Fixed Point Algorithm (FPA) was another beneficial way of resolving analytical models of Internet performance. Kassa presented speedy and precise analytical models of TCP performance with the FPA used in solving them.

Smith [25]utilized a benchmarking tool in order to enhance University of Windsor's network performance by monitoring the network and resolving issues. The limitation of this was that he did not focus on users' perception for measuring user satisfaction.

Dhamija, *et. al.* [26] explored the connotation of job satisfaction with the quality of work life factors of bank employees. Multi-stage sampling technique was used to collect primary data. Descriptive statistics, regression analysis was used to analyse (impact of the quality of work life factors on job satisfaction) and χ2 statistics (association of the quality of work life and job satisfaction with socio-demographic variables). The Herzberg Theory of Job Satisfaction was compared with results. The result of the research showed that job satisfaction had the presence of variance as clarified by the quality of work life built. The unconducive work setting has established negative association with job satisfaction.

The incorporation of conventional and maintainable benchmarking resulted in a structure consisting of 8 Performance Indicators with 30 evaluators. Also, Jasti and Ram [27]used a fuzzy logic approach to address vagueness associated with the scaling/ranking and developed a mode-specific benchmarking framework for Metro systems. Targets were set (absolute benchmarking), and benchmarked against performance. Lastly, Mumbai Metro Rail system performance rate was determined as 75% with satisfactory results in the service, quality and societal sectors. Even though, multimodal integration sector still needs improvement.

Jasti and Ram [28] solved the problem of the Indian benchmarking system of urban bus transport not having uniform calculated method in handling the fuzziness and the unknown that prevail in valuation mechanism. This was done by developing an appropriate and complete assessment scheme that evaluate the present situation of prevailing public transport system using Fuzzy Logic membership functions.

Cullen [12] evaluated some of the problems associated to benchmarking, and its effective application for quality management, in academic, public and special libraries. Despite the devotion paid to consultation with libraries to define and legalise the data being gathered, the Chartered Institute of Public Finance & Accountancy CIPFA/Best Value approach may act against the real benefits of process benchmarking, or the profits of peer examination, as reported in industry [29] where the focus was on refining business processes, not input/output measures.

According to Wavetek [30], developing a benchmark, enables network performance monitoring methods and tools. This is made possible by first effectively characterizing and documenting the network when healthy in order to help identify the network problem. The system manager detects trouble spots speedily and downward trends easily by getting a "snapshot" of network movement, traffic, and behaviour when the LAN was working appropriately, this was done by using network management tools and reviewing network statistics regularly. An addition is to look for performance degradation and network or node-specific overload. Wavetek [30] suggested that Published performance specifications may not sufficiently apply to a unique site, demanding the improvement of exact criteria for the site's specific reasons. The limitation was that users' were not carried along.

The above applications show that more and more enterprises are making use of benchmarking. Benchmarking database and methodology for measuring performance is necessary. Also there is the need for the process of setting up the database itself. This model later serves as a template for those wishing to build benchmarking database.

2.3 Fuzzy

Zadeh who originated fuzzy logic had noted that the human language contains many descriptive terms whose relevance is context specific [31]. According to Wang [32] fuzzy systems are knowledge domain or standard based systems. Some words can be characterized by continuous membership functions where a fuzzy IF-THEN rule is described by an IF-THEN statement.

Furthermore, Dadone [33] described fuzzy set, using Zadeh's findings as an extension of standard notion of set, where elements have varying degrees of membership. Fuzzy logic is also able in handling naturally indefinite views in human thought. 'The propositions of the sets of a fuzzy logic are inspired by the need to capture and symbolise real world data with doubt, due to imprecise measurement. These uncertainties are also triggered by vagueness in the language of expression. However, fuzzy relations are built with the capability to capture the uncertainty and vagueness in relations between sets and elements of a particular set. Below are different applications of benchmarking, fuzzy logic and measuring of internet performance:

Development *et. al.* [34] developed a graduate profile benchmark, developed using fuzzy logic for analysis. The process uses data processing, analysis and evaluation to show the degree to which reputable academic practice at the host institution correlates to pre-conceived professional outputs. The achieved outcome led to the discussion of accepted practices including long-established and innovative teaching techniques.

According to MacDonell [35] "Aside from theoretical reasons for preferring fuzzy logic in some circumstances, several papers have shown favourable empirical comparisons supporting its usefulness by using software metric data sets to compare the predictive accuracy of various techniques". Using models of fuzzy logic offers an avenue to study from the resulting models that may be less evident with regression and (even more so) neural network models [36].

Huang *et. al.* [37] proposed a combination of both hardware-based and software-based metrics as a fuzzy logic method that consisted of three types of modules. The modules are the Fuzzifer module, the Inference module, and the Defuzzifer module. The proposed method was to improve the accuracy rate for evaluating a link quality. The proposed method had higher accuracy rates for evaluating a link quality when the proposed method was compared to other found related works using simulation.

Raghunath and Thirukumaran [38], another proposed fuzzy logic approach was specifically for the rapid transit system. The method was based on novel fuzzy logic-based fault tolerance and instant synchronized routing technique. The fuzzy logic concepts reduced most of the computational complexities and uncertainties of the system. During normal operations, the central thematic of the proposed design was concerned over the synchronized routing and permanent faults which abruptly depicts the non-functional nature of the sensor nodes. Moreover, the result of the suggested simulation proved to be unprepared indication on gaining maximum packet delivery ratio which tends to handle an emergency condition in the compartments of rapid transits.

Raghunath and Thirukumaran [38] considered trust as fuzzy that motivated them to apply fuzzy logic for computing the trust values of the cloud users and service providers in the cloud setting. the proposed trust model was based on the behaviour of user and service provider to calculate the trust values. The method used for fuzzy was mamdani while the membership function were; gauss for fuzzification, and triangular for defuzzification respectively. Performance and elasticity were Parameters taken for trust evaluation of their source. While workload and response time were the attributes for calculating performance. While scalability, availability, security, and usability were taken for calculating elasticity. To evaluate the trust value of users such as bad requests, bogus requests, unauthorized requests, and total requests, fuzzy C-means clustering was applied to the parameters. The researchers were able to control the trust values of service users, as well as the entree approval of users for accessing cloud resources. Hence, Cloud Service Providers (CSPs) provide cloud services to serve users by controlling access using trust values [29]. This study is on benchmarking the performance of Internet network within Universities, and the benchmarking partners considered are Network Administrators. The Network Administrators were chosen as benchmarking partners since they are directly involved in the challenges of performance. Due to the persistent fluctuation in the network and ever increasing performance demands, most network administrators are forced to embrace these as normal in the IT business since these two problems have become part of the challenges they face daily. There exists an aggressive rise in the impact of unanticipated network outages, low performance speed, and/or traffic bottlenecks which is brought about by an exponential growth of new business critical applications across corporate LANs [30].

3. METHODOLOGY

3.1 DEVELOPING AN INTELLIGENT UNIVERSITY INTERNET NETWORK BENCHMARKING TOOL (UINB)

A feasibility study was conducted in order to find out what the existing system is like on monitoring the performance of an Internet network. For Network administrators to analyse and benchmark data, an effective and efficient means of storing and retrieving vast amount of data was needed. Hence an RDBMS was used. With the help of PHP, data was accessed via a query tool through a backend MySQL with a predefined report capability. The end user (system administrator) can use the model to access and generate reports in order to support their decision - making process.

To determine the user satisfaction measure in a University setting, the model evaluated output for five dimensions using both established or hard metrics, and soft measures on the internet performance. Figure 1 is the application of the UINB model for a University internet simulation output, using the five dimensions. The performance dimension were fuzzified and de-fuzzified for final processing.

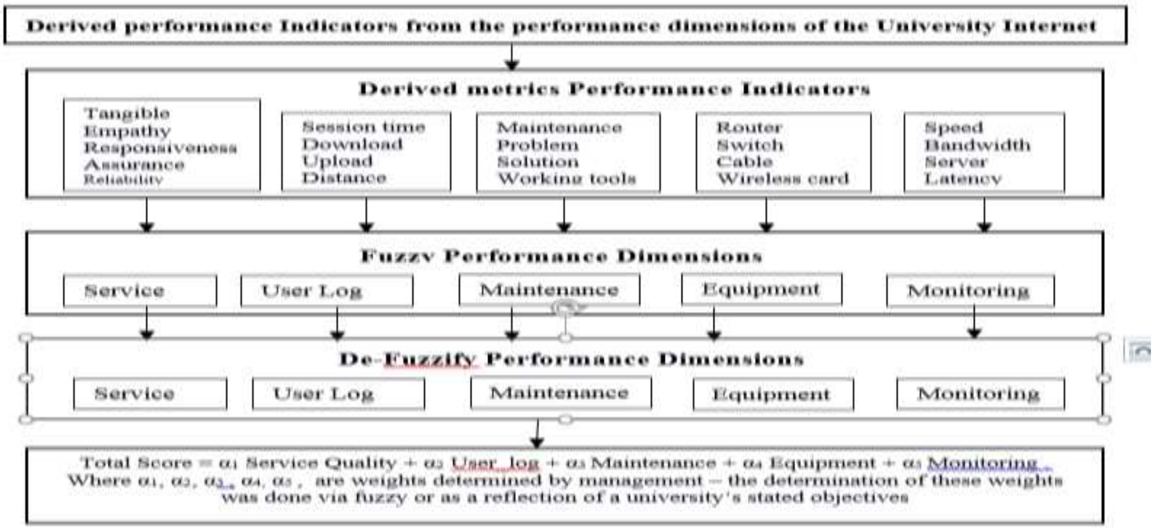

Figure 1: Application of the UINB model for a University internet simulation output (Source adapted: [17])

Figure 2 shows the different interface screen of the benchmarking performance tool. The screen displays the various links of the interface after the login process.

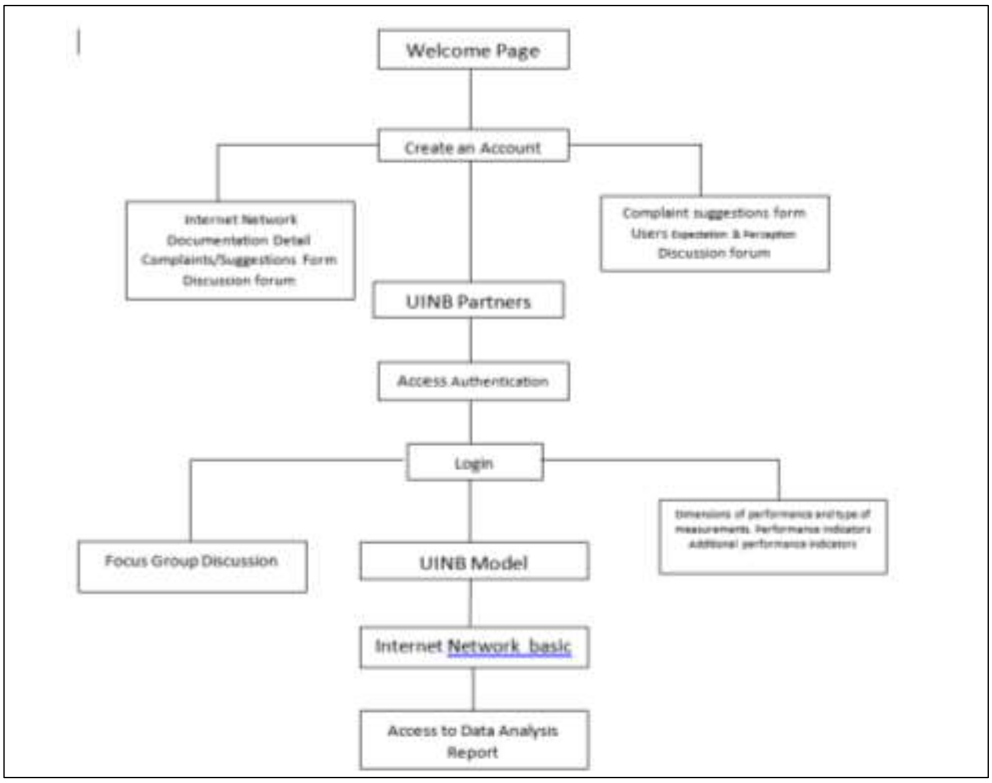

Figure 2: The different interface screen of the benchmarking performance tool

4. Results and Discussions

4.1 Developing an intelligent University Internet Network Benchmarking (UINB) tool

The benchmarking performance model was designed with the following functions:

- Home page
- Login page
- User's Expectation & Perception
- Network Administrators Expectation & Perception
- Discussion forum
- Detail documentation of Internet Network Equipment
- Data analysis
- Complaints/suggestions

The login page in Figure 3 is the page that permits users to have access to the program. Network administrators have access to create accounts using their username and password.

The first stage was to experiment the performance dimension (user log =U) using fuzzy logic in order to understand the system behaviour before applying the benchmarking model. The membership functions of each Key Performance Indicators for User log was constructed. The first performance indicator to consider for User log was (session time=UI) with five constructed functions. Namely; U1,vg(x), U1,g(x) U1,av(x), U1,b(x), U1,vb(x). The function was normalised by user downloaded total number of hours x, and the value of the functions U1,vg, U1,g, U1,av, U1,b, U1,vb returned. Whereby the verbal categories, vg = "very good", g = "good", a ="average", b = "bad" and vb ="very bad" represented the value that the degree x falls into.

This also applies to the other performance dimensions (U2 = number of uploads per user session, U3 = the distance between node and ICT unit and U4 = number of download per user session). The combination of researches, expert opinion and observation enabled the derivation of structured functions.

In this paper however, for the sake of simplicity, the method used for the fuzzy inference was Sugeno form for all the functions. The output membership functions of a Sugeno forms are either linear or constant in a fuzzy inference method [40]. Due to the needs of the problem, as it is frequently the case, the function of singleton output was sufficient. Hence the fuzzy rules of the performance dimension, user log within the University setting was set. The table 1 shows the summary of the fuzzy rules user log.

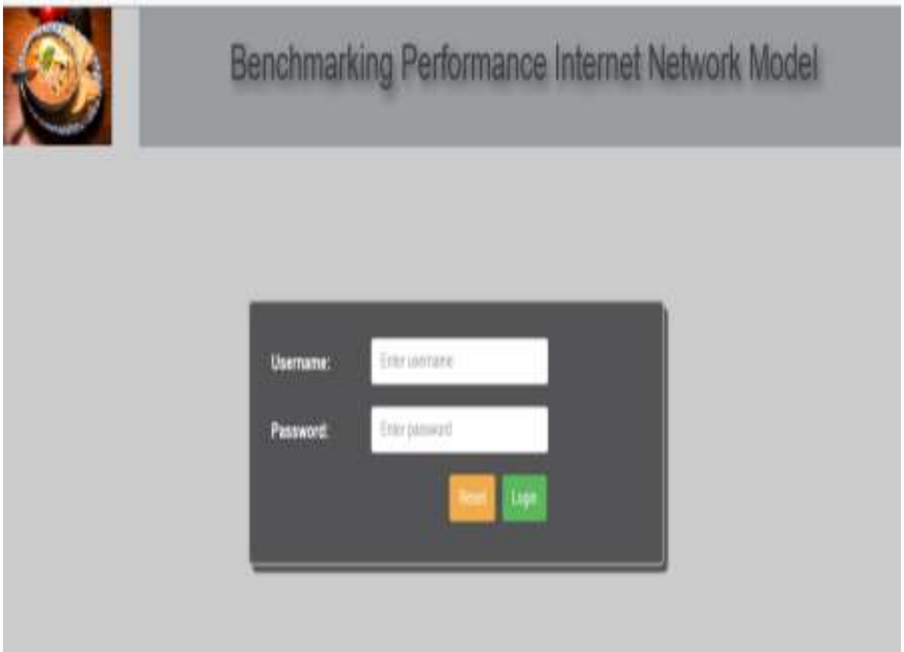

Figure 3: Login Page

Table 1 fuzzy set function of Performance dimension

Performance Dimension	Performance Indicators	Normalized	Fuzzy Set Functions	Fuzzy Rules
Users (Staff, Students Complain form Service quality rating Complain form Date: User name: Location: Node name: (drop down) Depart name: (drop down) Room No. Complain: Problem: Type of problem Rate of Problem occurrence Error message if any: Suggestion: E-mail if need be Phone No.	User's log Session Time; Upload; Distance; Download;	Internet available Number of minutes; Each users' total number of upload available The distance covered from each node to the ICT centre The mean total number of download available for each user	U1,vg(x) = 6294+(VG) U1,g(x) = 3506 - 6293(G) U1,av(x) = 1932 - 3505(AV)) U1,b(x) = 852 - 1931(B) U1,vb(x) = <= 851(VB) U2,vg(x) = 7202425+(VG) U2,g(x) = 2670097 - 7202424(G) U2,av(x) = 1025371 - 670096(AV) U2,b(x) = 223787 - 1025370(B) U2,vb(x) = <= 223786(VB) U3,vg(x) = [0.647 - 12.97VG) U3,g(x) = 0.371 - 0.646(G) U3,av(x) = [0.134 - 0.37(AV) U3,b(x) = 0.058 - 0.133(B) U3,vb(x) = 0.001- 0.057(VB) U4,vs(x) =7.02+(VS) U4,s(x) = 6.5 – 7.01(S) U4,dis(x) = 5.71 – 6.46(DIS) U4,vds(x) = 0 – 5.69(VDS)	If distance is VG and upload is VB and session Time is VB and download is B, or A or G or VG, then output is very dissatisfied. If distance is G and input is B and session Time is VB or B or A or G or VG, then output is dissatisfied. If distance is G and input is A or G and session Time is VB or B or A or G or VG, then output is Satisfied. If distance is G and input is VG and session Time is A or G or VG then output is Very Satisfied. ….(25 rules)

The performance dimension, user log had four subsets of the output space. The emerged four subsets were expressed as linguistic terms "very satisfied", "satisfied", "dissatisfied" and "very dissatisfied". The grade of users' of satisfaction of the internet performance was translated to a single output from the measure of contentment [41].

Users' experience about internet performance was derived by mapping the designated Performance indicators with a level of contentment of performance of the internet. The rule viewer displayed the fuzzy logic outputs, rules viewer and surface viewer. Based on the whole fuzzy inference process, the rule viewer in Figure 4 displayed a roadmap and allowed interpretation. The overall result can be influenced by the shape of certain membership functions when every part of every rule was plotted.

In Figure 4, the first three columns represent the "antecedent" while "consequent" is the last column of the rules. The row of plots for each rule showed the membership functions for each column. The consequent consists of a single column of plots. While bold vertical line on this plot displayed the defuzzified download. The result of the inference system was represented by the aggregate weighted of the plot of the fourth column which depended more on the upload values. At the top of the columns, the values for each performance indicators were displayed.

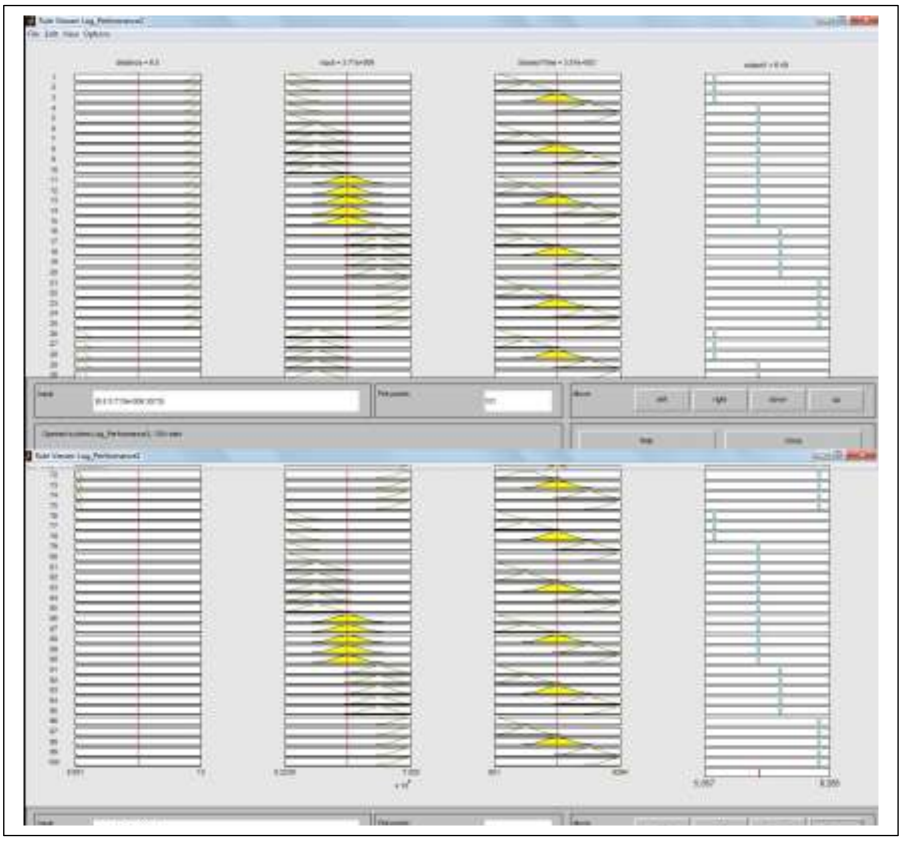

Figure 4: Top rule viewer

4.2 Using fuzzy logic to measure Overall Internet performance

The benchmarking model was to measure the overall internet performance using fuzzy logic. The model considered the data available for each performance indicator derived from the multiple dimension from the study. Each performance indicators had a constructed membership function of the fuzzy terms. Some of the performance indicators were mapped only to a few linguistic terms, since not all the users would classify the Internet based on all five linguistic terms.

From the users' perspective no connection means, any internet connection that is not good or that is bad. While fast connection means good. The functions for each performance indicators were constructed from each performance dimension. When the degree x falls into the verbal categories, the value represents the linguistic variables while crisp set was converted into fuzzy set applying Sugeno membership function [42].

4.3 Fuzzy Rule and Inference Mechanism

For each of the performance indicators, the result gave the if-then rules of the range of linguistic variables. The input and output membership functions were determined by the rule using inference process. With the help of many performance indicators, 62 rules were set in order to justify the vital variables of the Users' Internet satisfaction of performance. The set rules were based on the results achieved from the performance dimensions, from observation of the internet and discussion with the Network Administrators. Table 2 shows the 62 set rules [42].

Table 2: Performance diemenison Rules

NO	Service Quality P1	User log P2	Maintenance P3	Equipment P4	Speed P5	Performance	Satisfaction Rate
1	Very Good	Very Good	Bad	Very Bad	Very Good	Very bad	Very Dissatisfied
2	Very Good	Very Good	Average	Average	Very Good	Good	Satisfied
3	Very Good	Good	Good	Average	Very Good	Good	Satisfied
4	Very Good	Good	Very Good	Good	Good	Very Good	Very Satisfied
5	Very Good	Very Good	Very Good	Very Good	Very Good	Very Good	Very Satisfied
6	Very Good	Good	Very Good	Very Good	Very Good	Very Good	Very Satisfied
7	Average	Good	Bad	Average	Very Good	Good	Satisfied
8	Average	Very Good	Average	Good	Very Good	Average	Dissatisfied
9	Average	Good	Good	Good	Very Good	Good	Satisfied
10	Average	Very Good	Very Good	Average	Bad	Very Good	Very Satisfied
11	Average	Good	Very Good	Very Good	Average	Very Good	Very Satisfied
12	Average	Average	Very Good	Average	Good	Average	Dissatisfied
13	Average	Average	Very Good	Average	Very Good	Very Good	Very Satisfied
14	Bad	Bad	Bad	Very Bad	Average	Very Bad	Very Dissatisfied
15	Bad	Bad	Bad	Bad	Bad	Bad	Very Dissatisfied
16	Bad	Average	Good	Average	Very Good	Good	Satisfied
17	Average	Very Good	Very Good	Very Good	Average	Very Good	Very Satisfied
18	Average	Good	Very Good	Very Good	Good	Very Good	Very Satisfied
19	Average	Good	Very Good	Very Good	Very Good	Very Good	Very Satisfied
20	Very Bad	Good	Very Bad	Bad	Very Good	Very Bad	Very Dissatisfied
21	Very Bad	Bad	Bad	Average	Very Good	Bad	Very Dissatisfied
22	Average	Good	Average	Good	Very Good	Good	Satisfied
23	Average	Average	Average	Average	Average	Average	Dissatisfied
24	Very Bad	Good	Very Good	Average	Average	Bad	Very Dissatisfied
25	Very Bad	Bad	Very Good	Bad	Average	Very Bad	Very Dissatisfied
26	Very Bad	Bad	Very Good	Very Bad	Good	Very Bad	Very Dissatisfied
27	Very Good	Good	Bad	Average	Very Good	Good	Satisfied
28	Very Good	Good	Average	Good	Very Good	Good	Satisfied
29	Very Good	Average	Good	Good	Very Good	Good	Satisfied

30	Very Good	Good	Very Good	Average	Average	Very Good	Very Satisfied
31	Very Good	Very Good	Very Good	Average	Average	Very Good	Very Satisfied
32	Average	Average	Bad	Bad	Very Good	Bad	Very Dissatisfied
33	Average	Good	Average	Bad	Very Good	Bad	Very Dissatisfied
34	Average	Good	Good	Good	Very Good	Good	Satisfied
35	Average	Average	Very Good	Very Good	Average	Good	Satisfied
36	Average	Good	Very Good	Good	Good	Very Good	Very Satisfied
37	Average	Very Good	Very Good	Very Good	Very Good	Very Good	Very Satisfied
38	Bad	Bad	Very Good	Good	Very Good	Very Bad	Very Dissatisfied
39	Good	Good	Good	Good	Very Good	Good	Satisfied
40	Good	Good	Very Good	Very Good	Good	Good	Satisfied
41	Good	Very Good	Very Good	Good	Very Good	Very Good	Very Satisfied
42	Average	Bad	Bad	Average	Good	Bad	Very Dissatisfied
43	Average	Very Bad	Average	Bad	Average	Bad	Very Dissatisfied
44	Average	Average	Good	Good	Very Good	Good	Satisfied
45	Average	Good	Very Good	Very Good	Good	Good	Satisfied
46	Average	Good	Very Good	Good	Average	Average	Dissatisfied
47	Average	Good	Very Good	Average	Good	Very Good	Very Satisfied
48	Bad	Very Bad	Very Good	Very Good	Average	Bad	Very Dissatisfied
49	Very Bad	Very Bad	Very Bad	Very Bad	Very Bad	Very Bad	Very Dissatisfied
50	Very Bad	Bad	Bad	Very Good	Very Good	Very Bad	Very Dissatisfied
51	Very Bad	Bad	Average	Average	Very Good	Very Bad	Very Dissatisfied
52	Good	Good	Good	Good	Good	Good	Satisfied
53	Very Good	Good	Very Good	Very Good	Average	Very Good	Very Satisfied
54	Good	Very Good	Very Good	Very Good	Good	Very Good	Very Satisfied
55	Good	Good	Very Good	Very Good	Very Good	Very Good	Very Satisfied
56	Very Bad	Bad	Bad	Very Good	Very Good	Bad	Very Dissatisfied
57	Good	Good	Average	Very Good	Very Good	Good	Satisfied
58	Good	Good	Good	Average	Very Good	Good	Satisfied
59	Average	Very Good	Very Good	Good	Bad	Bad	Very Dissatisfied
60	Very Good	Good	Very Good	Very Good	Average	Good	Satisfied
61	Very Good	Very Good	Very Good	Very Good	Good	Very Good	Very Satisfied
62	Average	Good	Very Good	Very Good	Very Good	Very Good	Very Satisfied

4.4 Defuzzification (Performances) of Fuzzy Output

The overall performance of the internet of the output variable had four linguistic variables. Equation (5) gives the degree of membership functions.

While $\mu p = Maxk\{min\{ \mu A (P1), \mu B (P2), \ldots\ldots\}\}$ k = 1,2,3,4,………r

if then rule following:

Ri : if x1 is Pi1 and if x2 is Pi2 … and if xn is Pin then y is Si ………. … .(1)

Where Ri is the ith rule ($1\leq i\leq m$), xj($1\leq j \leq n$) are input variables, y is the output and Uij and Si are fuzzy variables.

Where x = (x1, ………xn) and P = (P1,…Pn). Linguistic labels are associated with values fuzzy numbers

Given the inputs x01, x02, …., and xon, calculate the degree of match, α, in the premises for the ith rule $1\leq i \leq m$ as input variables Pij andPi

αi = Pi1(x01) x Pi2(x02) x …………x Pin(x0n)……… ……………. … ..(2)

Then defuzzified Si in the consequents by taking the center of gravity:

$Si = \int Si (y)ydy/ \int Si(y)dy$……………………………………………(3)

The inferred value was calculated, ý by taking the weighted average of si with respect to αi

$Ý = \Sigma\alpha i si / \Sigma\alpha i$ ……………………………………………..(4)

To find in the process of reasoning, the rule Ri translate to the form Ri:

if xis Pi then y is si ……………………….. (5)

A position-gradient model is of the form:

Ri : if xis Pi then y is Si and dy/dx is Ci ……..(6)

Where dy/dx = (dy/dx……., dy/dx), Ci = (Ci1… Cin) The reasoning algorithm of the position-gradient rules is therefore,

Ri : if xis Pi then y is si and dy/dx is ci ………..(7)

Where Si and Ci defuzzify as si and ci respectively

Total Score = α1 Service Quality + α2 User log + α3 Maintenance + α4 Equipment + α5 Monitoring.

Where α1, α2, α3, α4, α5 are weights allocated by the University Management. – the determinant of these weights

For each of the active rule of the output membership function value was determined by the expression above. The operation AND, was applied between/among inputs of the active rule. The standardized means of evaluating the satisfaction performance rate for each linguistic variable for the performance dimension are shown in Table 3

Table 3: Standardized Users' Internet satisfaction Performance

Dimension Performance	P	**Satisfaction Rate**
Very Bad	< 0.4	Very Dissatisfied
Bad	0.4<P>0.49	Very Dissatisfied
Average	0.5<P>.59	Dissatisfied
Good	0.6<P>.69	Very Satisfied
Very Good	>0.7	Very Satisfied

The standardised users' satisfaction performance (P) of the output variable of the membership Function is shown in Figure 5. The satisfaction value represents, Very Dissatisfied" (VD), "Dissatisfied" (D), "Satisfied" (S), or "Very Satisfied" (VS), respectively. Trapmf, a trapezoidal Membership Function, was used for the overall Internet performance.

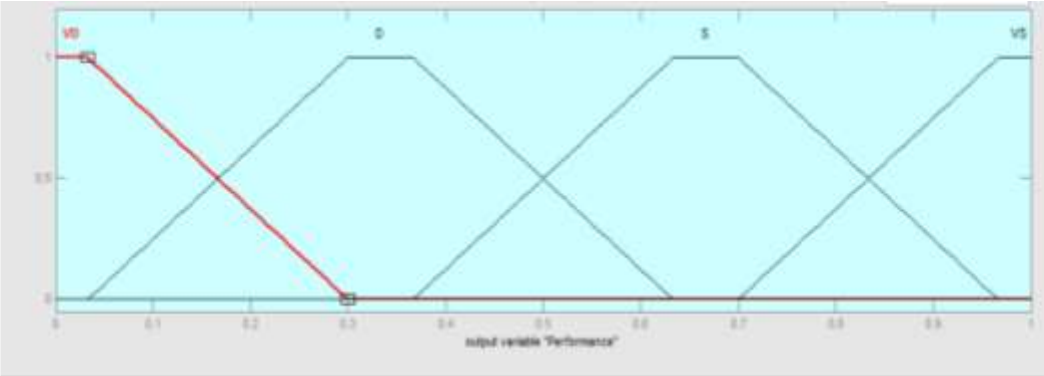

Figure 5: Users' Internet overall performance Membership function

The overall Internet's performance rule viewer is shown in Fig. 6 [42].

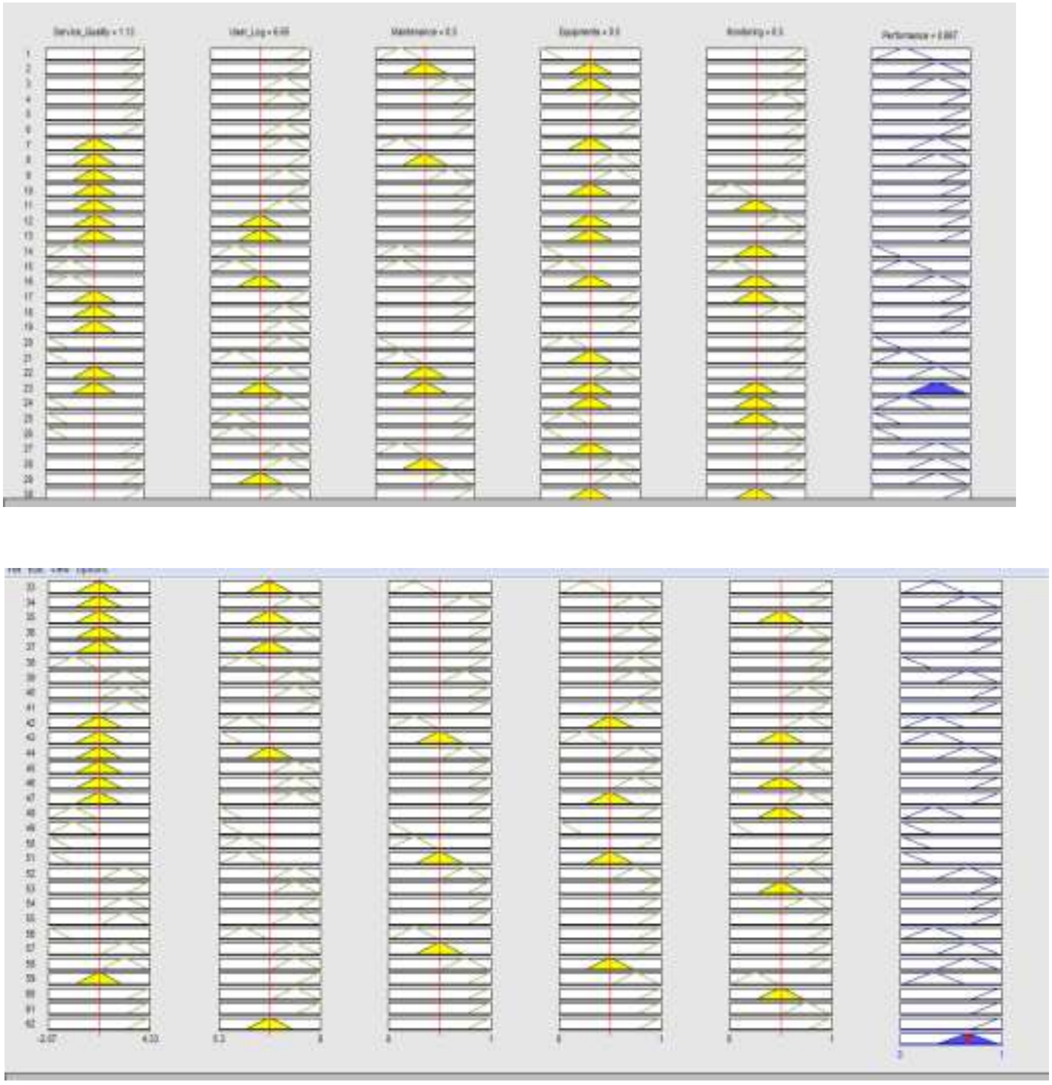

Figure 6: Rule viewer of the overall Internet's performance

The overall result can be influenced by the shape of certain membership functions when every part of every rule was plotted. In Figure 6, the first five columns represent the "antecedent" while "consequent" is the last column of the rules. The row of plots for each rule showed the membership functions for each column. The consequent consists of a single column of plots. While bold vertical line on this plot displayed the defuzzified performance. The result of the inference system was represented by the aggregate weighted of the plot of the sixth column which depended more on the performance values. At the top of the columns, the values for each performance dimensions were displayed.

To examine the Internet performance, two axes (X and Y) were allocated to performance dimension and Z axis was assigned to performance variable using surface viewer of a Fuzzy Inference System (FIS). In order to visualize the performance values were low and high, at different angles, the surface viewer was manipulated. The colours changed according to the download values of the two variables.

Figure 7 shows the few examples of the surface viewers of: Maintenance and Monitoring; Maintenance and Equipment; User's log and Service Quality; user's log and equipment; Maintenance and Service Quality. The colour represented the different level of users' performance of satisfaction value; blue represents very dissatisfactory, the light blue represents dissatisfactory, the light green represents satisfactory, while yellow colour represents very satisfactory. The result from the overall Internet performance based on the various surface viewer was very dissatisfactory.

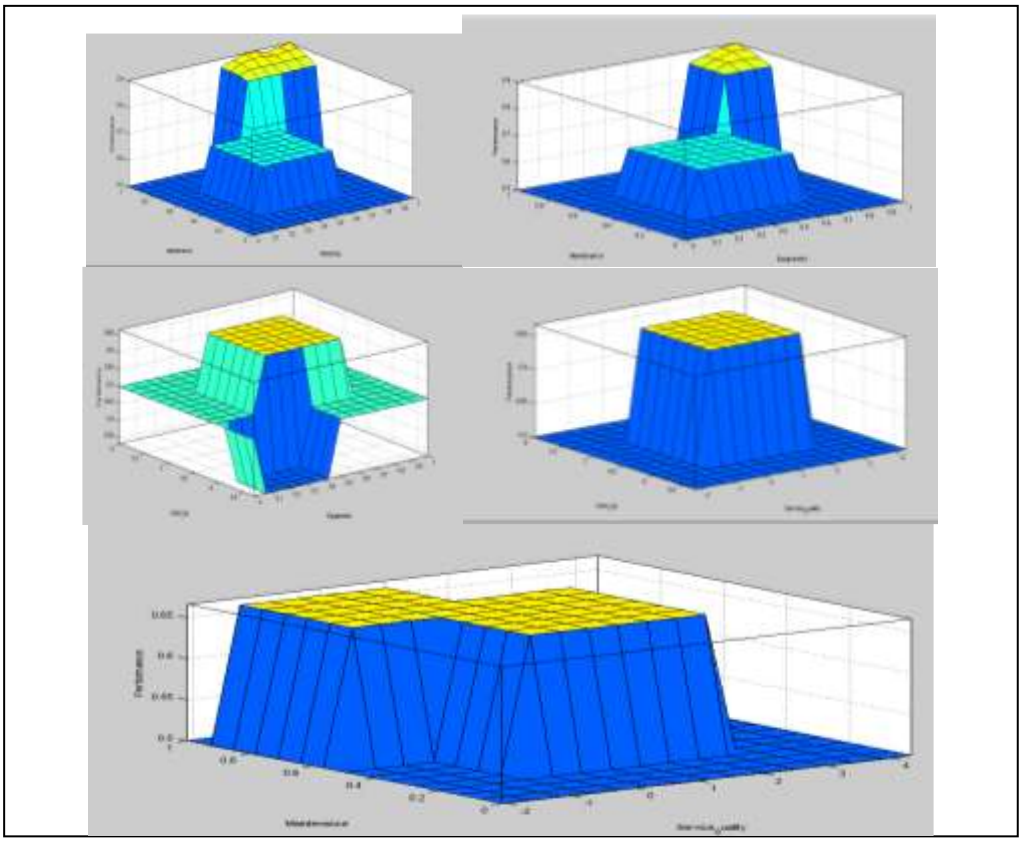

Figure 7: The fuzzy surface viewer of Internet performance evaluation

4.5 Discussion of Results from the UINB Tool

The UNIB model facilitated storage of collected data and benchmarking of the nodes. The reports generated showed the multiple dimension of performance concerning the node. Benchmarked Internet performance of nodes clearly classified performance as satisfactory, dissatisfactory and very dissatisfactory. The UNIB model using fuzzy logic approach to measure the overall performance of the University internet was dissatisfied. This showed that the University internet users' were dissatisfied. Figure 8 shows the output of some reports.

Unlike the findings in Joumblatt [19], the problem of users being suspicious of hosting the software on their system was solved by making sure that the tool was installed on the server. Even though, the security question was raised, the assurance that only the network administrators would have access to their data allayed their fears.

The overall performance of Economics node is shown in Figure 8, based on the five performance dimensions within a given period. The overall performance for the Economics Internet is 0.5. This shows dissatisfactory.

It is important to recap the major findings of this study. A benchmarking model was developed and used as Benchmarking Communications Infrastructure for an Internet Network. This was done after investigating the performance dimension. The UNIB model executed, facilitated data collection, storage, and benchmarking of data. Fuzzy logic handled the imprecision observed for the performance dimension which produced a highly manageable mechanism for measuring internet performance and the causes inducing internet performance. From this relationship the rules to build up performance satisfaction were constructed. The average mean of the download performance was grouped into very dissatisfied as 5, dissatisfied as 6, satisfied as 7 and very satisfied as 8. Different reports were generated on the nodes from the UINB model. Fuzzy logic constructed 62 rules for overall performance dimension. The overall Internet users' satisfactory performance was dissatisfied.

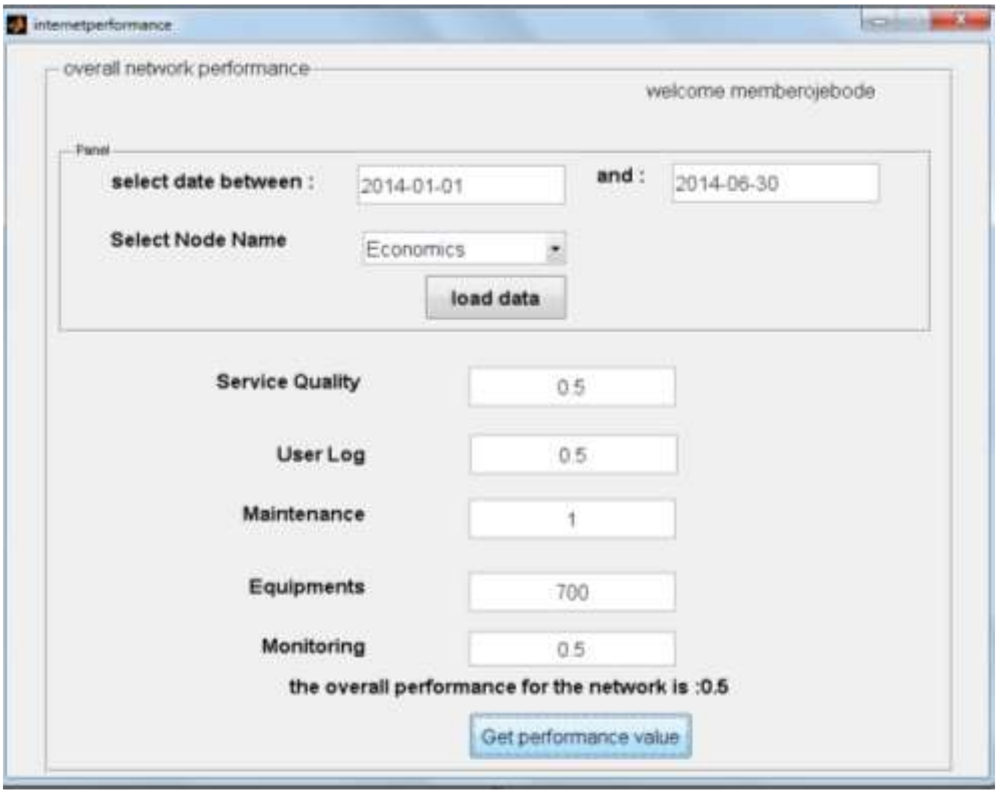

Figure 8: Result of a node (Economics Department)

5. Conclusion

Users' satisfaction was derived from measuring and benchmarking the factors influencing internet performance using a highly tractable method of the UNIB model. Fuzzy logic benchmarked the qualitative performance dimension mapped into numeric results through various performance indicators. The performance measure formed the basis for current and future decision making.

The result shows that the documentation of the network information from database is relevant for the Network Administrator to acquire knowledge from previous Internet performance and improve on the performance. The benchmarking model avoids biased decision making by viewing full Internet performance from multiple performance dimension. The Network Administrator would be able to view the network in multiple dimensions (including users) and be able to identify exactly where the problem is while benchmarking, by comparing nodes that are doing well and the nodes that are not. From the fuzzy rules, considering the performance indicators form the performance dimension, performances were classified into hierarchical preference levels. The classification is to help the Network Administrator to take decision on how to improve the internet performance.

In particular, the plan was to model the benchmarking of the University Internet network, in such a way that the benchmarking revealed significant university-performance indicators of each performance dimensions so as to result into improvement. Above all, the decision made from the benchmarking model can be confidently shared and grasped by network management. The benchmarking communication model has multiple performance dimensions than the existing monitoring tool. The result from the benchmarking model captures users' satisfaction when measuring and benchmarking Internet performance from multiple performance dimensions.

The main restrictions are funds and time constrains. Also, the cooperation of UINB network administrators in providing information was another challenge. Future research should extend the work to other universities, thus making it an enterprise model for universities in Nigeria. This will identify more performance indicators and attract more information that will be useful for benchmarking in all the collaborating universities. The collaborative model will involve teamwork of all network partners in a networked environment and methods that will enable assessment of virtual university effectively.

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