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Improved Lte Network Bandwidth and Data Rate Management and Appropriation Scheme for Fixed Users

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Abstract:*Wireless network resources exist as limited resources and as such several research efforts towards the improvement of managing these network resources are always an addition to enhance the work of telecommunication network deployment and management engineers, as wireless network management largely revolves around balanced allocation of radio resources. Existing Fuzzification based network management schemes employ 3 membership functions and are known to offer a challenge with fairness in resource management and allocation as they mostly tilt towards allocating resources to qualified users and refusing allocation to unqualified users without a decisive approach on handling fixed users who qualify for allocation by some slim margin or users in the low-average zone. This study presents a network bandwidth management and allocation scheme for fixed wireless network users using a Fuzzification based approach with the interest of achieving overall fairness in the network for fixed users in the poorly average qualified region. The study implementation is done using the riverbed modeler application tool to estimate a fixed user priority value based on the user's channel gain, data rate and LOS blocking probability. The 3-membership Fuzzification approach is enhanced by adding two membership functions to enhance the scheme and fairness in resource management. The study result showed that the replacement of 3-membership function allocation schemes with 5-membership schemes was not the optimal solution, rather a combination of both.*

Keywords: *Fuzzification, Qualified Users, Unqualified Users, Network bandwidth management.*

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I. Introduction

In the recent past, networks have experienced rapid growth and development. This is evidenced by the great many benefits gained by interfacing with a network; benefits of which examples could be increased productivity or decrease in operation cost. Good example to demonstrate this would be connecting a printer to a network; this will enable printing access to multiple users instead of providing multiple printers to individual users; basically, saving cost and increasing efficient use of the printing resource [1]. This same concept, albeit in a more expanded and complex form, is exactly what plays out when connecting resources such as files storage, a database, computation facilities, e-mailing systems, etc. to multiple users all over the world. Accordingly, networking has experienced an exponentially great recognition and implementation within various sectors such as: the educational institutions, governmental departments and commercial organisations [2]. The term Network Management is so broad; it covers a wide range of activities which are dependent on an equal wide range of factors. A simple definition of Network management can be taken as the supervision and administration of a network so as to perform tasks such as fault analysis, network resource allocation, performance analysis and maintenance of Quality of Service. In today's modern world, Network management is implemented by a combination of hardware and software in order to constantly extract and examine data and make appropriate configuration changes on the Network. The foundational aim of Network Management is basically to upgrade and even develop the network performance, Information safety; and reliability. In essence, network management seeks to maintain a high Quality of Service (QoS) for its various users.

II. Methodology

A. Analytical Approach

A fuzzified approach was used to decide whether a particular fixed user is worthy of receiving bandwidth allocation or not so as to enhance network bandwidth management and appropriation scheme for fixed wireless network users. The study approach is such that concerns itself with bandwidth since it is a particular resource which are considered to be of core concern to fixed wireless network users or subscribers. The study employs a user priority estimation technique to enhance the resulting network resource management scheme, such that all users are duly served as well as receive fairly appropriated network resources based on 3 dynamic features that the scheme presents.

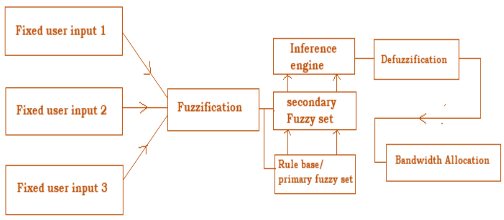

Fig 1: Block diagram for fuzzified enhanced bandwidth allocation scheme

B. Fixed User Network Scenario

This study seeks to offer improved radio resource management based on dynamic fixed user priority. The test analysis considers a single network access point within the wireless network and a number of N users as well. The study approach is illustrated in the flowchart of figure 2.

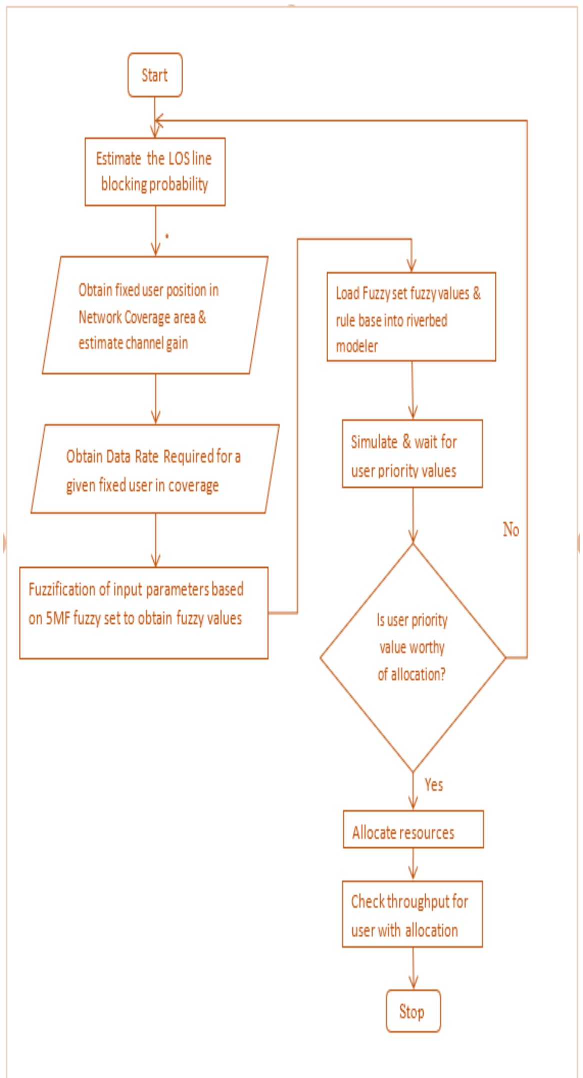

Fig 2: Flow chart illustrating the study approach

The premise for which the study has approached the resource management using a network scenario having just one access point is that all connected users within the wireless network are fixed, therefore all parameters like coverage range and mobility related concerns are not core requirements in the study analysis. The network scenario is presented in figure 3.

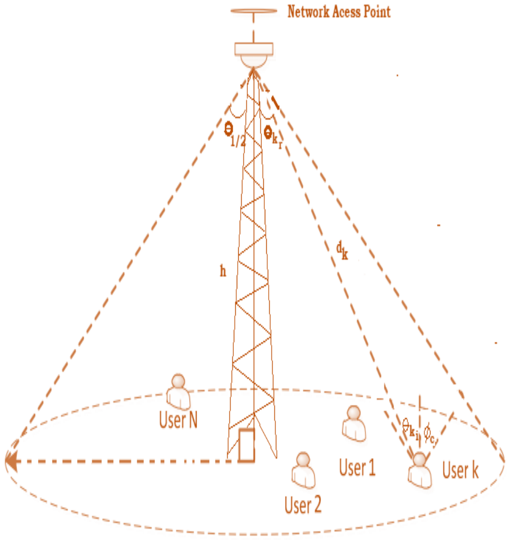

Fig 3: Single access point network scenario for implementation of bandwidth management over fixed users.

Where;

$\theta_{1/2}$ = angle of network coverage radius from access point

θ_{kr}= angle indicating position of kth user from network reference point (i.e., angle of position or distance from ref position where any fixed user is located)

θ_{ki}= angle of line-of-sight (LOS) distance from the network access point and the kth fixed user.

$\emptyset_c$= field of view of users

h = vertical distance of AP or height of AP tower

d_k = LOS distance between AP and the receiver of kth fixed user.

The approach is to employ more than one parameter in identifying or differentiating fixed users. A simple model to measure the level of user priority is created by setting a priority value and mapping to a set of multi-dimensional user features that can be used to identify users.

$$P = F(V) \quad (1)$$

Where;

P = user priority value

$F(V) = F(V_1, V_2, V_3, \dots V_n)$

F = mapping function

$V = (V_1, V_2, V_3, \dots, V_{nS})$ = multi-dimensional user feature data set or vector

From the user priority estimation model, the interest is to select the two effective features within the data set $V = (V_1, V_2, V_3, \dots V_n)$ and also define the mapping function.

C Analysis of Network Resource Management Based on User Priority.

The formulation of the resource allocation problem is to simply seek a division of the total bandwidth, B, and to maximize the system throughput under priority constraints. That means the proposed network resource allocation scheme will allocate bandwidth to different users based on the user priority estimate (which is based on the data rate or the data traffic information) obtained for each user.

The position of fixed users in the network area, the blocking parameter and the data traffic information are the parameters for the measurement of user priority. The analysis uses the position of fixed users to estimate channel quality, since the fixed user position has impact on the channel quality. The blocking parameter will provide information on the high density of users, while the data traffic information provides different data traffic rate requirement among varying fixed users. The analysis uses these three features to accurately obtain difference amongst users and thus used it to estimate the user priority model.

Channel gain of kth user is obtained as given:

$$\boldsymbol{H_k} = \begin{cases} \frac{(m+1)A}{2\pi d_k^2} cos^m(\theta_{kr}) T_s(\theta_{ki}) g(\theta_{ki}) \cos(\theta_{ki}), & 0 \le \theta_{ki} \le \emptyset_c \\ 0, & \theta_{ki} > \emptyset_c \end{cases} \quad (2)$$

Where m is a quantity given by

$$\mathbf{m = -ln2/(ln(cos\theta_{1/2}))}$$

A = variation area parameter for different fixed user receivers; this value is to be presented as unity assuming all fixed user receivers to be similar.

$\mathbf{T_s(\theta_{ki})}$ = gain error margin parameter for fixed users and is also preset to unityvalue (meaning 1) in the analysis so as to avoid different error margins for different users, keeping all fixed users under uniform conditions.

$\mathbf{g(\theta_{ki})}$ = channel gain estimation parameter

$$g(\theta_{ki}) = \begin{cases} \frac{(1.0003)^2}{sin^2 \emptyset_c}, & 0 \le \theta_{ki} \le \emptyset_c \\ 0, & \theta_{ki} > \emptyset_c \end{cases} \quad (3)$$

The signal to noise ratio for the k^{th} user is given by

$$S_{nR} = \frac{(rP_kH_k)^2}{n_0 B_k} \quad (4)$$

Where;

$\mathbf{P_k}$ = received signal strength of k^{th} user

$\mathbf{n_0}$ = power spectral density of noise

$\mathbf{B_k}$= bandwidth allocated to k^{th} user

r = receiver responsibility parameter

i Blocking Parameter

There is a tendency that the LOS communication link of the k-th user is blocked. The blocking parameter of a fixed k^{th} user, k_k can only be either 1(for case of LOS blocking) or 0(for a case of no-LOS blocking). The simple expression for estimating the probability of blocking is presented as

$$\begin{cases} 1 - \rho_k, & for\ k_k = 1 \\ \rho_k, & for\ k_k = 0 \end{cases}$$

Where;

k_k= blocking parameter for k^{th} user

ρ_k= Tendency of LOS blocking for k^{th} user or the blocking probability

ii Fixed User Data Rate

The estimation for the achievable data rate between the fixed user and the network access point is expressed by C_k as:

$$C_k = (1 - \rho_k) B_k \log_2(1 + S_{nR}) \quad (5)$$

It can simply be deduced that the data rate is a function of the tendency of LOS blocking for any arbitrarily chosen user, the bandwidth allocated to that user and the signal to noise ratio. Therefore, bandwidth management before estimation is aimed at management of data rate for varying fixed users, bearing in mind that in a time period, the position of fixed user, the blocking of the LOS link and the required data rate are independently distributed parameters and would vary for different fixed users.

D Fuzzification Approach in Network resource Management

The analysis for network resource management and allocation for fixed users requires a fuzzified approach to deliver optimal outcome since a fuzzified approach will create room for analyzing outcomes based on a range of dynamic input (fixed user input). The ranging feature of dynamic (changing fixed user parameters) input is an advantage of fuzzified approach over binary or digital inputs (I and O) that capture only two states of input parameters and thus is unable to interpret any input outside these two states. Therefore, fuzzy values is triangulated (usually between O and I)

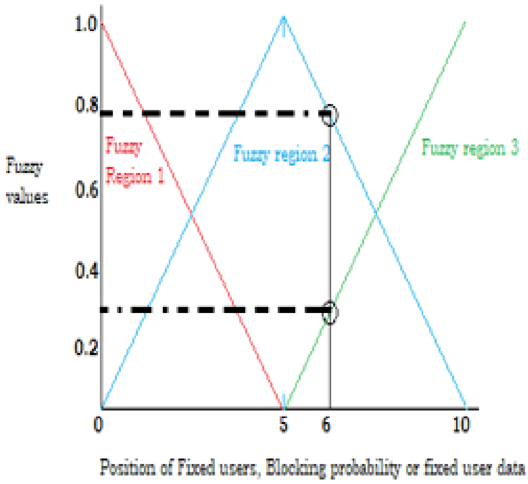

Fig4: Fuzzification and interpretation of fixed user input data with 3 membership function triangulation method

The implication of the Fuzzification test illustrated in figure 4 in regards to the bandwidth management is shown in figure 5:
From the Fuzzification analytical graphs of figure 5;If a preset of all possible fixed user dynamic parameters to be mapped to a range of 0 to 10, possible outcome can be obtained (or a fuzzified value, i.e., y-axis) from any preset input fed into the Fuzzification analysis.
In a test analysis for which the position parameter is preset to input 6 and blocking tendency preset to an input of 9, both triangles (referred to as the membership functions) provided two intersection points based on the reference input (i.e., 6 or 9) while the respective y axis values are the membership values.
Fuzzy region 1 = poor, Fuzzy region 2 = average
Fuzzy region 3 = medium

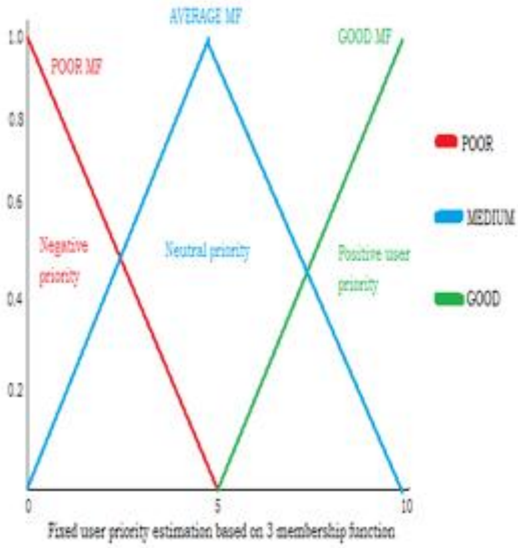

Fig5: Triangulation with three membership functions

Thus, the areas under 3 membership functions in figure 5 are fuzzy regions and when the intersection points to the y axis ismapped out, fuzzified values are obtained. On obtaining the fuzzified values,Fuzzification process is termed complete since there are outputs based on inputting dynamic fixed user parameters.

E **Fuzzy Inference Engine for Network Management and Resource Allocation.**

In the fuzzy influence analysis, the fuzzy sets rule base as well as the fuzzified values (y axis values) from theFuzzification analysis are delivered. Thus, a set of rules to train the fuzzy inference engine must be defined. These sets of rules serve as the rule base. The fuzzy sets are ranges for each parameter (i.e., set of all possible outcomes for each fixed user parameter, blocking parameter, data rate and position)

i Rule Base

The rule base are behavioral parameters used to train how the entire allocation and network management scheme will behave. This study presents an enhanced rule base for the network management and allocation scheme.

ii Enhanced Rule Base for Fuzzy Inference Engine in Improved Network Management Scheme

To efficiently represent the enhanced rule base for the analysis, two separate possible outcomes were induced. Thus, other than presenting poor, medium, and good as the fuzzy sets (i.e., as the range shows 1 to 10) in figure 5, two new average membership functions are embedded, one between the low membership function and the average or medium membership function, the other between the average membership function and the good membership function. This will quickly improve the fuzzy sets and thus improve the accuracy of the allocation scheme. The graphs shown in figure 6 illustrate the enhanced Fuzzification graph with added membership function:

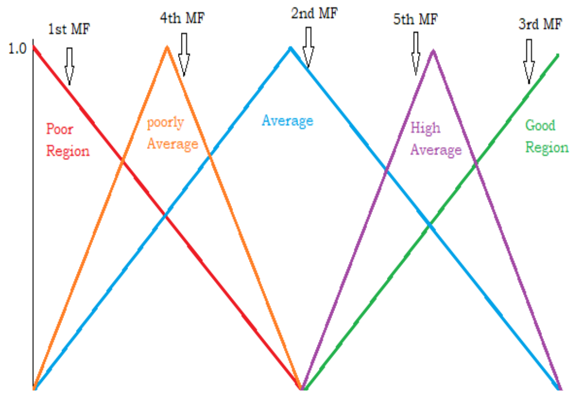

Figure 6: Triangulation with five membership function for enhanced bandwidth management and allocation

To enhance the Fuzzification analysis by enhancing the triangulation. This is done by deploying added membership functions to low, medium and high in other to enhance the fuzzy set and thereby the entire network management and allocation scheme.

The new fuzzy set becomes {poor, average poor, average, average high, high}.To progress into developing the rule base for the enhanced fuzzy set, 3 parameters (inputs) are required for the fuzzy influence engine and they are; the fuzzy set, rule base and the fuzzified values.Since the proposed approach enhances the membership functions in the Fuzzification analysis, the enhancement reflects in the fuzzy set. Thus, there is a primary fuzzy set and a secondary fuzzy set. The primary fuzzy set is the first stage of the Fuzzification while the secondary fuzzy set is the enhancement for more accurate interpretation of the input data; position, blocking probability parameter and data traffic rate. When the input data is fed into the membership function, the primary fuzzy set interprets it as low, average and high. The primary and secondary fuzzy sets are given as:

Primary fuzzy set:

$$H_k(P_{os}) \in \{poor, average, good\}$$
$$C_k \in \{low, medium, high\}$$
$$\rho_k \in \{low, average, high\}$$
$$user\ priority \in \{negative, neutral, positive\}$$

Secondary fuzzy set

$$Average \supset \{average\ low, average, average\ high\}$$
$$medium \supset \{medium\ low, medium, medium\ high\}$$

The primary fuzzy set interprets input data into poor, average and good. However, the secondary fuzzy set is to further interpret average data, it enquires to know what orientation of average the input data is in, i.e., average low, average high or average.

Allocating bandwidth or other network resources to fixed users with low priority (e.g., high blocking probability or low channel gain) is a mismanagement of scarce radio resources. So, network parameters are managed in an improved manner using the enhanced Fuzzification analytical approach. To validate that the allocation to a certain user is not a waste of resources, the proposed approach will thus be to estimate the expected throughput for that user at his position, data rate and blocking probability. The expected throughput $E[C]$ is given by:

$$\boldsymbol{E[C] = \sum_{k=1}^{N} E\,[C_k]} \qquad (6)$$

Substituting equation 5 into equation 6 and expanding SnR,

$$\boldsymbol{C_k = (1-\rho_k)B_k \log_2(1+S_{nR})}$$

$$\boldsymbol{= \sum_{k=1}^{N} E\left[(1-p_k)\frac{B}{N}\log_2\left(1+\frac{\left(rH_k\frac{P_t}{N}\right)^2}{n_0\frac{B}{N}}\right)\right]}$$

$$\boldsymbol{= \frac{B}{N}\sum_{k=1}^{N} E\,[1-p_k]E\left[\log_2\left(1+\frac{(rH_kP_t)^2}{n_0BN}\right)\right]}$$

Where;

$\mathbf{P_t}$= power of the AP

B/N = Bandwidth allocated to each user

$\mathbf{P_t}$**/N** = power allocated to each user

$\boldsymbol{E[1-p_k] = 1-\bar{p}.}$

$$\boldsymbol{\rho = \frac{(rP_t(m+1)h^{m+1}AT_s(\emptyset)n^2)^2}{n_0B(2\pi sin^2\emptyset_c)^2}}$$

Hence,

$$\boldsymbol{E\left[\log_2\left(1+\frac{(rH_kP_t)^2}{n_0BN}\right)\right]}$$

$$\boldsymbol{= E\left[\log_2\left(1+\frac{\rho}{N(x_k^2+y_k^2+h^2)^{m+3}}\right)\right]}$$

Where x_k and y_k are position variables, It is assumed that x_k and y_k are mutually independent.

$$\boldsymbol{\frac{1}{S_0 ln2}\iint_{S_0} ln\left(1+\frac{\rho}{N(x_k^2+y_k^2+h^2)^{m+3}}\right)dx_k dy_k} (7)$$

Where S_0 is the network coverage area. When N is less than 10, $\frac{\rho}{N(x_k^2+y_k^2+h^2)^{m+3}}$ is much larger than 1. Therefore, equation 6 is expressed as $\boldsymbol{E\left[\log_2\left(1+\frac{(rH_kP_t)^2}{n_0BN}\right)\right]}$

$$\boldsymbol{= \frac{1}{S_0 ln2}\iint_S ln\left(1+\frac{\rho}{N(x_k^2+y_k^2+h^2)^{m+3}}\right)dx_k dy_k}$$

$$\boldsymbol{= \frac{1}{S_0 ln2}\iint_S ln\left(1+\frac{\rho}{(x_k^2+y_k^2+h^2)^{m+3}}\right)dx_k dy_k - \frac{1}{S_0 ln2}\iint_S lnN\, dx_k dy_k}$$

F Fuzzification based Bandwidth Management Simulation for fixed users in Riverbed modeler

Riverbed simulation environment is designed to run the wireless network in multiple stages. The stages are the sub-network stage and the component stage. To validate the approach employed, two network scenarios are designed and simulated using the riverbed modeler application tool. An empty scenario is created in the integrated development environment and initial configurations saved. The configuration process presets an estimate dimension of a sample area which is the network coverage area to give an idea of the coverage area for the Access points in the network. From the simulation input parameter in table 1, the coverage radius for the wireless network access point is given as 50m.

Table 1: Simulation data set table

PARAMETER	VALUE
Network coverage radius	50m
Transmit power of AP	9dB
height between AP and user, h	18m
$\theta_{1/2}$	60˚
$\emptyset_c$	60˚
Uniform receiver responsivity	0.53A/W
A	1
Spectral range density of n_0	$10^{-21}A^2/H_2$
$T_s(\theta_{ki})$	1

Number of fixed users	10

The network scenarios are developed to be similar to each other in terms of coverage area of access points, type of access points, number of fixed users and several other parameters. This is done to serve as a premise for comparing existing bandwidth allocation and management schemes with the resulting scheme put forward by this study. However, the application layer and profile layer configurations for both scenarios are different. Deployment of the Fuzzification scheme consisting of 3 membership functions to one scenario and also the Fuzzification scheme consisting of 5 membership functions to the second network simulation scenario were carried out. The 3-memebership function scenario as well as the 5-membership function scenario employ the same fuzzy set ranges and the same parameters to differentiate all fixed users in the wireless network. The added membership functions are both average membership functions and can enhance the prediciton of channel gain, required data rate and blocking probability in calculating the user priority for bandwidth allocation.The developed approach is to run both bandwidth allocation schemes, compare the results, thereby defining by what extent the 5-memebership function bandwidth allocation approach actually enhances the network in managing bandwidth. A preset of poor input parameters over 9 fixed users; poor channel gain or high LOS link blocking probability and high data rates were inputted. These input values were fed into 3-membership and 5-membership functions to obtain the fuzzified outcome. Also fed were the fuzzy set, the rule base as well as thefuzzified values into the fuzzy inference engine in the riverbed modeler application tool. The 5-membership function enhances how the bandwidth allocation scheme interprets all fixed user input at different periods ranging around the average membership function thereby more accurately defining the user priority, if a particular user qualifies to receive bandwidth allocated to it or not. Figures 7 and 8 present the two-scenario simulation for testing the bandwidth allocation scheme in riverbed modeler.

Figure 7: First scenario simulation for bandwidth management scheme in riverbed modeler

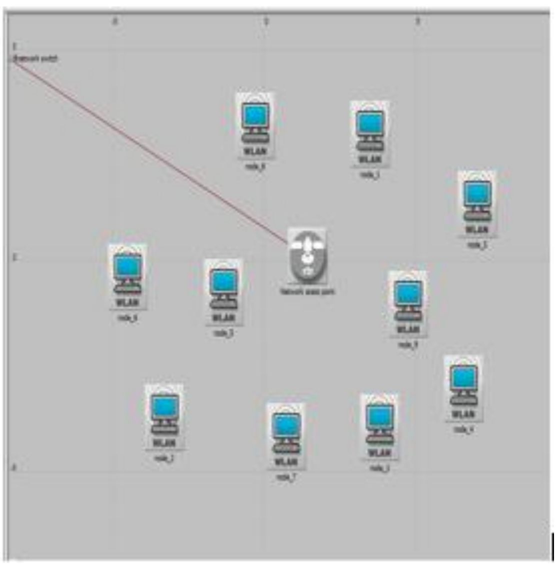

Figure 8: Second scenario simulation for bandwidth management scheme in riverbed modeler

III. RESULT AND DISCUSSION

The results from the bandwidth management and allocation simulation process are in two categories. They present and discuss the graphical results of the user priority simulation in the riverbed modeler, the bandwidth allocation outcome to different fixed users within the network and finally, in order to validate the enhancement in the scheme, the throughput for users with high priority score within the network is presented. This is to show that all fixed users who qualify (by reason of their user priority score estimated from the fuzzy inference engine in the river bird modeler) have higher throughput tendencies than users who did not receive allocations. This shows that the available bandwidth is properly managed.

A. User Priority Simulation in Riverbed modeler

The approach for obtaining the fixed user priority value is to simulate the network scenario (having fed in the dynamic user input) to generate a weight-value from the simulation dynamically for a given fixed user according to the user's channel gain, blocking probability and also the user required data rate. Since the approach is to carry out two simulation scenarios for the 3 Membership Function (MF) bandwidth allocation and the 5MF bandwidth allocations, two sets of tables for each scenario were presented. To do this, different input conditions for the different fixed users in the network werepreset as illustrated in tables 2 and 3.

Table 2: 3MF Rule base fixed user input and user priority value

User data rate C_k	**User channel gain H_k**	**LOS blocking probability ρ_k**	**User priority**
Not high	High	Low	Positive
High	Med	Low	Average
med	Low	High	Negative
Not high	Med	Low	Average
High	Med	High	Negative
med	High	Low	Positive
med	High	High	Average
Not High	Med	High	Negative
med	Low	Low	Average
Not High	Low	High	Negative

Table 3: 5MF Rule base fixed user input and user priority value

C_k	H_k	ρ_k	**User priority (from 3MF)**
Low	High	Low	Positive
High	Low-Med	Low	Poorly Average
Low-med	Low	High	Negative
Low	High-Med	Low	High-Average
High	Med	High	Negative
med	High	Low	Positive
High-med	High	High	Poorly-Average
Not High	Low-Med	High	Negative
Low-med	Low	Low	Average
Not High	Low	High	Negative

Unique user input conditions were entered into 5-membership function Fuzzification block, generated fuzzy values and then fed the fuzzy values into the riverbed modeler and simulated the network scenario mapped with the rule base, the fuzzy set and the fuzzy values (generated from the 5-membership function) to get the user priority on a scale of 0 to 1. The network scenario data-rate was preset to 54MbPs in riverbed modeler as is shown figure 9

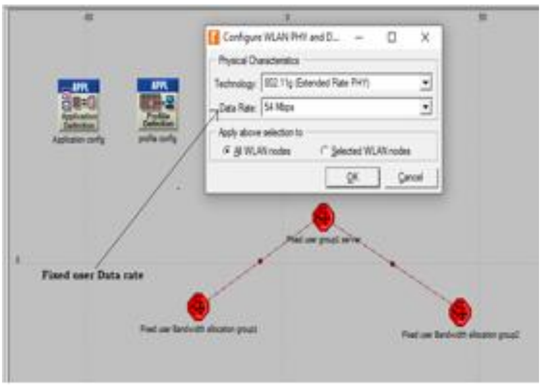

Figure 9: Network data rate configuration in riverbed modeler application tool

The user priority is classified into 5 different possible outcomes; negative, neutral and positive. The output priority score always ranges from 0 to 1.Figure 10 is an illustration detailing the user priority estimation for 3MF and 5MF.

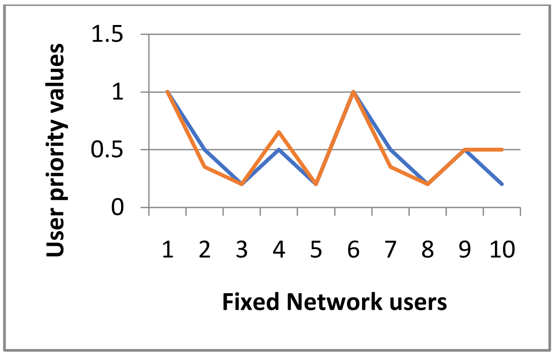

Figure 10: Comparison of user priority estimation for 3MF and 5MF

From figure 10, it is observed that for fixed users who highly qualify to receive bandwidth allocation or are highly disqualified from receiving bandwidth allocation, both signals agree, but for poorly average qualified users (from >0.35 upwards < 0.65) developed approach manages bandwidth allocation for users within that region better. This enhanced bandwidth management especially for fixed users not just within the qualified or disqualified user priority values but within the poorly average and average membership curve regions.

Figures 11, 12 and 13 show the fixed –user input based on a 5-element fuzzy set and then the fuzzy value results fed into the riverbed modeler.

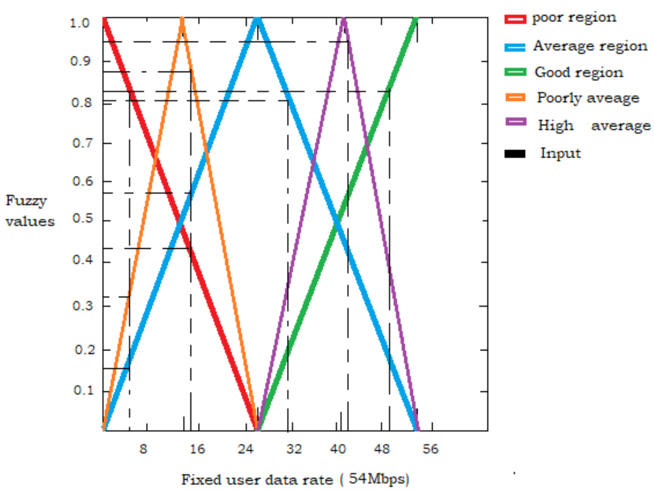

Figure 11: fixed –user data-rate input based on a 5-element fuzzy set and the fuzzy value results

The graphs show the relationship between the fuzzy values, the actual input parameters, the fuzzy set which determines how the inputs are ranged or interpreted and also the fuzzy values. The results indicated three fuzzy values per input as opposed to two fuzzy values per input. This was effectual in determining the poorly average qualified fixed users and allocating bandwidth to such users.

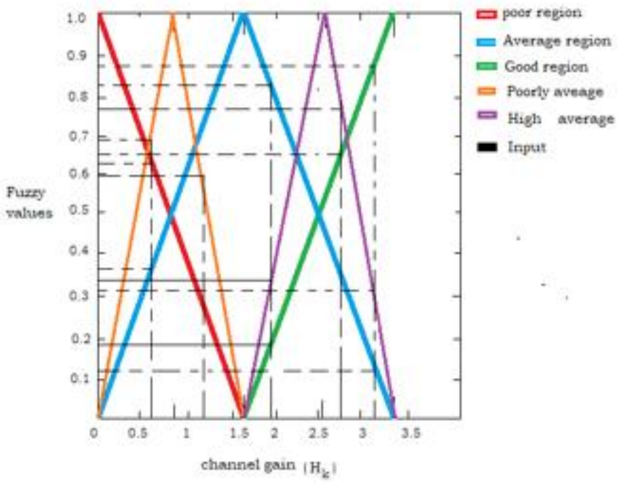

Figure 12: fixed –user channel gain input based on a 5-element fuzzy set and the fuzzy value results

The impact of any channel gain input or blocking probability input within the different ranges in the fuzzy set is already captured in the rule base with which the riverbed modeler is able to generate user priority scores relating to channel gain and blocking tendencies as is observed in figures 12 and figure 13.

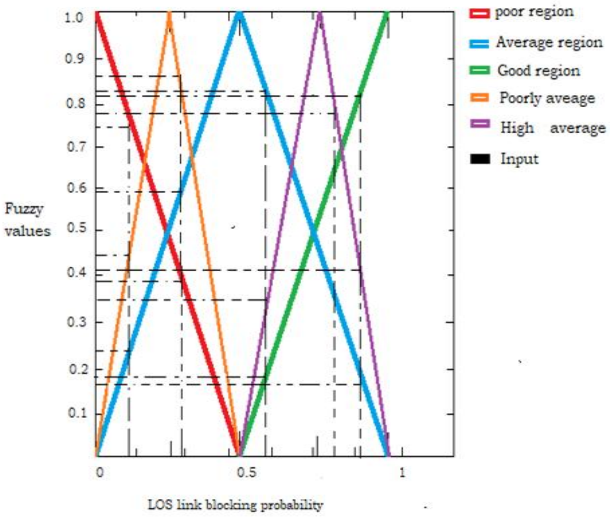

Figure 13: fixed –user blocking probability input based on a 5-element fuzzy set and the fuzzy value results

Tables 4 and 5 are updated forms of tables 2 and 3 featuring user priority score outcomes from the riverbed modeler tool.

Conclusively, user priority estimation and bandwidth allocation based on 3 membership functions deliver good results for obviously qualified or disqualified fixed users based on their priority score obtained from the fuzzy inference engine in the riverbed modeler application tool and displayed incompetence in overall fairness and unbiased allocation for fixed users who qualify for allocation but with a poorly average user priority score. However, the 5-membership functions display a better performance with ability to accommodate qualified users with somewhat of low user priority score.

Table 4: 3MF Rule base fixed user input and user priority value updated with user priority values from fuzzy inference engine in riverbed modeler

User data rate C_k	**User channel gain H_k**	**LOS blocking probability ρ_k**	**User priority**	**priority value (from 3MF)**
Not high	High	Low	Positive	1.0
High	Med	Low	Average	0.5
med	Low	High	Negative	0.2
Not high	Med	Low	Average	0.5
High	Med	High	Negative	0.2
med	High	Low	Positive	1.0
med	High	High	Average	0.5
Not High	Med	High	Negative	0.2
med	Low	Low	Average	0.5
Not High	Low	High	Negative	0.2

Table 5: 5MF Rule base fixed user input and user priority value updated with user priority values from fuzzy inference engine in riverbed modeler

C_k	H_k	ρ_k	**User priority (from riverbed)**	**priority value (from 5MF)**
Low	High	Low	Positive	1.0
High	Low-Med	Low	Poorly Average	0.35
Low-med	Low	High	Negative	0.2
Low	High-Med	Low	High-Average	0.65
High	Med	High	Negative	0.2
med	High	Low	Positive	1.0
High-med	High	High	Poorly-Average	0.35
Not High	Low-Med	High	Negative	0.2
Low-med	Low	Low	Average	0.5
Not High	Low	High	Negative	0.5

Figures 14 and 15 illustrate the difference of the 3-membership function and the 5-membership function allocation approaches in response to fixed user priority scores for qualified, unqualified average or poorly qualified users

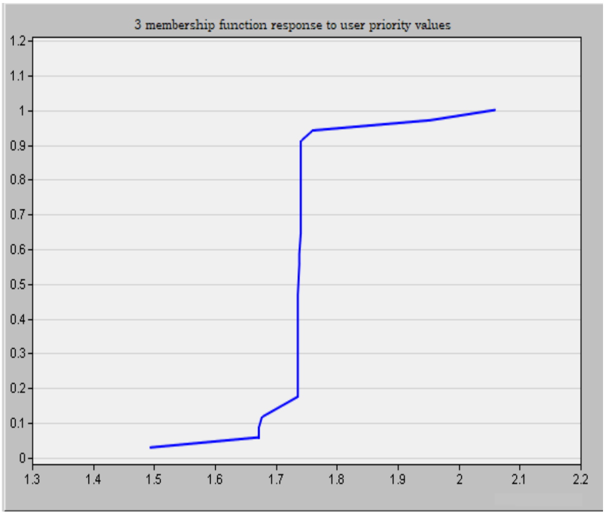

Fig 14: 3-membership function allocation response to fixed users with qualified, unqualified and poorly qualified user priority scores

From figure 14, the 3MF graph shows little or no response to user priority within the average zones. The response curve dwells more within the under qualified and qualified user priority score zones.

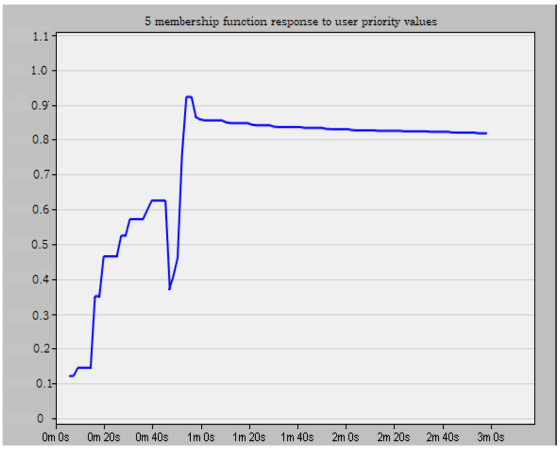

Fig 15: 5-membership function allocation response to fixed users with qualified, unqualified and poorly qualified user priority scores

In figure 15, the response curve illustrates an enhanced response to poorly qualified user priority score, the response curve graduates between the poorly average regions into the average and high average zones as well. Table 6 presents a tabulated comparison of 3 membership and 5 membership network resource management schemes

Table 6: Tabulated comparison of 3 membership and 5 membership network resource management schemes

3Membership function scheme (existing)	5Membership function scheme (Proposed)
Imprecise interpretation of estimated average range user input data	Enhanced interpretation of estimated average range user input data using added membership functions
Reduced fairness for lowly qualified users Availability of primary fuzzy set only	Enhanced fairness for lowly qualified users Availability of primary and secondary fuzzy sets
Reduced adaptability of rule base to dynamic nature of fixed user input	Enhanced fuzzy set and Rule base; easier to adapt to dynamic nature of estimated user input

This study does not propose the replacement of 3 membership curve allocation approach with the 5-membership curve allocation, but rather an enhanced bandwidth management and allocation scheme featuring both the 3MF and the 5MF bandwidth management and allocation approaches.

IV. CONCLUSION

The enhancement of wireless network resource management with particular interest on bandwidth has been considered in this study. The study aimed at upholding an enhanced fairness policy in the bandwidth allocation scheme for fixed users who qualify for resource allocation by a slim chance as this is the limitation of existing traditional bandwidth management schemes. The approach employed centered on three core fixed network user parameters which included; the position of fixed users, the probability of LOS blocking and the required data rate for different fixed users. The position of different fixed users was necessary to obtain the channel gain. The blocking probability parameter provided information of the LOS link between the network access point and fixed users while the required data rate was based on the application that a fixed user wanted to initiate at any time in the network. A guide set as to how these input parameters were fed into the Fuzzification block referred to as the fuzzy set was enhanced from the traditional three membership function approach to five membership. After the enhancement, the input parameters were fed into the Fuzzification block for better interpretation of input ranges in terms of five membership functions to obtain fuzzified values. Also, a rule base was developed and deployed into the riverbed modeler application tool. The rule base served as the instruction set for the bandwidth allocation scheme. The approach was to input the fuzzified values (resulting from the input), the fuzzy set and the rule base into the riverbed modeler and wait for the modeler to generate user priority values. In the study implementation, two different scenarios of the fixed network with 10 users each at different positions within the network were simulated. The different scenarios were each simulated based on the traditional three membership function and the enhanced five membership function presented in this study. The study outcome showed that both 3MF and 5MF curves performed similarly for out-rightly disqualified or qualified fixed users within the network. However, for fixed users who have their user priority estimation value from the riverbed modeler greater than 0.35 and less than the average value (i.e., fixed users who qualified with a slim chance), the 5 - membership function performed better than the 3-membership function by being able to show better fairness in the bandwidth allocation for such users.

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