Synthesis Algorithm for Layer 4 Dynamic Modulation Feedback (L4-DMF) Protocol in FA-WLAN

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Abstract— This paper presents a TCP heuristic algorithm referred to as Layer 4 Dynamic Modulation Feedback (L4-DMF) for congestion control in Flow Aware Wireless Local Area Network (FA-WLAN). The algorithm enhances self adaptive congestion control through utilization of fuzzy logic controller for dynamic modulation feedback in Layer-4. TCP layer-4 dynamic modulation feedback uses fuzzy logic ability to adapt to the dynamic conditions over the classical inflexible thresholds in access point (AP) buffer state under realistic load condition. With Mamdani fuzzy inference structure for the system algorithm developed, the fuzzy plots were generated for L4-DMF. In this context, this paper developed a new Fuzzy-Logic Adaptive Queuing Controller (FLAQC) with implicit modulation feedback at the base station in order to tune the average queue length and the wireless packet error. The proposed algorithm seeks to maintain small buffer size space over a time-varying channel which may exhibit significant degradation in the network bandwidth estimation. By using this algorithm, a heuristic TCP performance can be evaluated over a time-varying channel under different conditions of user's mobility.

Keywords— Adaptive, Dynamic Modulation, Fuzzy logic, Mamdani, TCP, L4-DMF

INTRODUCTION

SEVERAL WLAN congestion management schemes and issues have been proposed and studied in [1], [2], [3] and [4]. This work explains that a proposed TCP layer-4 DMF is a Fuzzy-Logic Adaptive Queuing (FLAQ) controller based on a classical Random Early Detection (RED) algorithm [1] and [2] with an implicit dynamic modulation feedback. As a variant of TCP FLAQS, this was adapted in FA-WLAN for congestion analysis. The fuzzy DMF controller predicts dynamically the packet dropping rate (joint scheduling and congestion control) and the corresponding average queue length. It relies on the average queue length at the base Access Point (AP) router and the packet loss rate caused by the channel variations in mobile environment; assuming there is no buffer overflow due to the congestion. Using this model, a heuristic TCP performance can be estimated over a time-varying channel under different conditions of user's mobility. When the arriving packets cannot be accommodated due to lack of network resources (bandwidth, buffer size, etc), this indicates occurring congestion at router buffers of networks. More specifically, a poor network performance due to congestion can be offered in terms of high packet dropping and queuing delay for packets, low throughput and not maintaining the average queue length which may not prevent the router buffers from building up, then dropping packets.

Moreover, congestion may also trigger an unbalanced share among the network sources [3]. However, congestion control mechanism implemented through intelligent Queue Management algorithms, is assumed to be the key factor to solve this problem keeping TCP/IP networks efficient and reliable from the user's viewpoint. The result of the proposed layer 4-DMF will show a significant improvement in TCP QoS (throughput, etc) performance considering the user's mobility and realistic traffic loads in the FA-WLAN.

The network model in this research is a common scenario of BSS (wireless-to-wired) unicast, and broadcast network topology model. The TCP layer-4DMF network models in Fig. 1, 2 and 3 seek to investigate the TCP performance over wireless link as shown in Fig. 3. The network model consists of a mobile host (FH) which is defined over the wired link via an AP and IP gateway through an IP cloud to a wireless last hop consisting of two pair of servers (FTP and HTTP servers). The process network model consists of a mobile host (MH) with an AP in a FA-wireless cellular network LAN. Within this model, the wireless channel in cooperates a DMF (dynamic modulation feedback) signal in terms of TCP ACK used to return back the estimation of congestion state and channel variations in terms of the wireless packet error rate (PER) over wireless channel.

Fuzzy logic controllers FLC, like expert systems, can be used to model intelligent decision-making behaviors. The conceptual components of a FLC basically consist of a fuzzifier, a defuzzifier, an inference engine and a rule base. Fig. 4 shows the Fuzzy Logic Controller architecture. Since in many fuzzy control applications, the input data are usually crisp, a fuzzification is necessary to convert the input crisp data into a suitable set of linguistic value that is needed in inference engine. Singleton fuzzifier maps the crisp input to a singleton fuzzy set.

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Fig. 1: Unicast-Broadcast FA-WLAN model

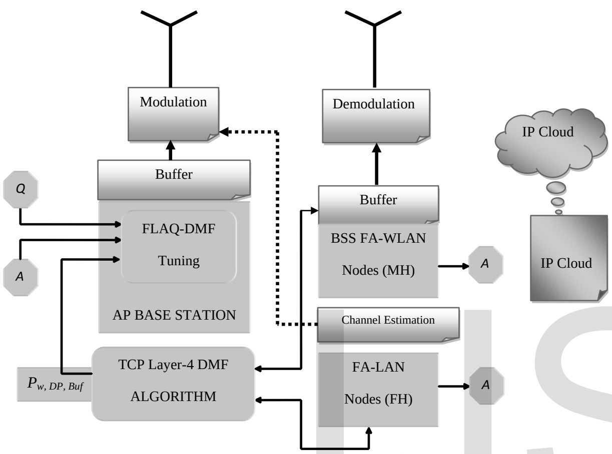

Fig.2: FA-WLAN Process Model

Fig.3: System Architecture for FA-WLAN

Fig.4: Proposed layer-4 DMF Fuzzy Logic Controller Architecture

In the rule-base of an FLC, a set of fuzzy control rules, which characterize the dynamic behaviour of system, are defined. The inference engine is used to form inferences and draw conclusions from the fuzzy control rules. The output of inference engine is sent to defuzzification unit as shown in Fig. 4.5. Defuzzification is a mapping from a space of fuzzy control actions into a space of crisp control actions.

To implement DMF scheme, this work used a combination of two methods [82] to construct the fuzzy linguistic rules: (1) The trail and error (Heuristics) and (2) The theory method.

This is because the first method depends on domain expert knowledge and experience, and the second method tunes the input and output linguistic parameters to accurate values. Thus using both methods together, the output D_P can be obtained in more accurate.

In proposed layer-4 DMF as depicted in Fig. 4.5, the FLC consists of (1) fuzzification (2) Rule base engine (3) Inference engine for aggregation the outputted rules, and (4) defuzzification, to compute the output *DMF_prediction* at the AP BS router queue. Then, the proposed layer-4 TCP DMF employs two input linguistic variables ($AVQL_{congestion}$, P_r) with aim to evaluate a single output linguistic variable *DMF_prediction*. The general bell membership function is used to represent all linguistic variables. The generalized bell function depends on three parameters *a*, *b*, and *c* as given by

$$f(x,a,c) = \frac{1}{1+\left|\frac{x-c}{a}\right|^{2b}} \quad \text{-------------} 1.0$$

The parameter *b* is usually positive and the parameter c locates the centre of the curve. Then, every linguistic variable is linked to a fuzzy set of the input and output linguistic variables as defined in Table 4.1.

Variable ranges	Linguistic Variables
$AVQL_{congestion}$ = 50kb-150kb [packet]	$AVQL_{congestion}$ = *{Low,Medium, High, Very, High}*
Pr = 5%-30%	*Pr = {Low,Medium,High,Very, High}*
Buffer Size = 8kb - 256kb	*Buffer = {Low, Medium ,High, Very, High}*
DMF_predict = 0% -30%	*DMF_prediction = {Low, Medium, High,Very, High}*

Basically, there are two types of fuzzy systems viz: Mamdani and Takagi-Sugeno-Kang (TSK) fuzzy systems [5]. An example of fuzzy rule for *m* inputs *(x1, x2… xm)* and only one output y (Multi Input Single Output (MISO) could be defined in many forms like:

- **Mamdani Type:** *R: If x1 is* μ*(x1) and x2 is* μ*(x2) and … and xm is* μ*(xm) then y is* μ*(y) … or*
- **Sugeno Type:** *R: If x1 is* μ*(x1) and x2 is* μ*(x2) and … and xm is* μ *(xm) then y = f(x1,.., xm)…*

Because *Buffer Size*, $AVQL_{congestion}$ *and Pr* has four membership functions, then there are 16 fuzzy rules can be generated as listed in Table 4.2. As a result, Fig. 4 depicts the details of the proposed Fuzzy-Logic Adaptive Queuing based RED scheme using Mamdani Fuzzy–Logic when General Bell function of (3) is considered. The memberships of linguistic variables of *AVQL*, *Pw* and *Dp* are adjusted depending on the wireless environment in order to introduce the resultant fuzzy logic system decision surface.

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in the previous sections: Membership functions, fuzzy logic operators, and if-then rules. There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type. These two types of inference systems vary somewhat in the way outputs are determined. References to descriptions of these two types of fuzzy inference systems can be found in the bibliography, [5], [6], [7]. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems. Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory [8]. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes [9]. Mamdani-type inference, as adopted form the MATLAB fuzzy Logic Toolbox, [10] expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification.

METHODOLOGY

The methodology adopted in this paper in view of the modeling, involves both literal rule base description (algorithm) Fuzzy and Process modeling with MATLAB Simulink blockset design tools. We employed a literal algorithm to design the L4-DMF fuzzy logic controller which optimizes the inference rules, membership functions while scaling gains of this controller by using parameters of the intelligent algorithm. The performance of the Intelligent Algorithm Optimized Fuzzy Logic controller is presented afterwards. Outlined below are the step by step modeling approaches in the L4-DMF model.

- Step 1. Fuzzification of Inputs (Process variables)
- Step 2. Application of the Fuzzy Operator
- Step 3. Application of the Implication Method in the Rule Editor
- Step 4. Aggregation of All Outputs
- Step 5. Defuzzification

A System Assumptions

The proposed TCP layer 4 DMF models are shown in Fig.s 4.4a, 4.4b and 4.4c. From Fig. 4.4b, the considered key preliminaries required to predict the congestion (packet dropping rate) based on the fuzzy logic adaptive queuing controller in the FA-WLAN and Rayleigh fading channel is as follows:

- Multiple TCP flow traffic is considered for all mobile receivers.
- The network is assumed to be stable without heavy or bursty TCP traffic.
- The TCP packet error rate (PER), (i.e., *Pr)*, is caused by the variations of wireless channel when only highly bit errors occurs during traffic transmission. Assuming there is no congestion at the router buffer of AP base station.
- *Pr is* measured by the channel estimator at mobile receiver and returned back via the ACK feedback of the round trip of TCP to indicate the sender about the channel bit errors, so we assumed Pr changes from 5% to 30%.
- The TCP rate regulator at the AP router queue of the AP base station is required *if and only if* multiple TCP flows are present. This rate regulator is mainly used to distinguish the packet error (dropping) due to the variations of wireless channel and the packet loss due to congestion of buffer overflow. In our assumption, there could be packet dropping due to AP buffer overflow is extreme congestion. So, the link could be under or over utilizing bandwidth and the queue threshold of the APs could be exceeded. At the AP base station (BS), we consider the following assumptions:
- Let the buffer size = 256kb packets
- The AP router queue with *Qmin* = 50kb [packet], and *Qmax* =150kb [packet]
- If the average queue length is less than 50kb, no packets are dropped➔No TCP congestion
- If the average queue length is more than 150kb, all the arriving packets are queued while DMF regulates the feedback flows to and from the MH or MNs.
- If the average queue length is between *Qmin* and *Qmax*, then the packets should be controlled by the fuzzy logic controller depending on to inputs ($AVQL_{congestion}$, P_r)
- Packet loss rate at AP base station is compensated by DMF algorithm (hence, there is no packet loss at the event of congestion) under realistic loads.

B L4-DMF Synthesis Algorithm

INPUT: $Buffr\_{Size}$, $AVQL_{\_congestion}$, P_{r_rate}.
OUTPUT: *DMF_predicted*
Procedure {begin}:

If ($Buffr\_{Size}$ is low) and ($AVQL_{\_congestion}$ is low) and (P_{r_rate} is low) then (*DMF_predicted* is very_low)

If ($Buffr\_{Size}$ is low) and ($AVQL_{\_congestion}$ is medium) and (P_{r_rate} is medium) then (*DMF_predicted* is very_low)

If ($Buffr\_{Size}$ is low) and ($AVQL_{\_congestion}$ is high) and (P_{r_rate} is high) then (*DMF_predicted* is very_high)

If ($Buffr\_{Size}$ is low) and ($AVQL_{\_congestion}$ is very_high) and (P_{r_rate} is very_High) then (*DMF_predicted* is very_high)

If ($Buffr\_{Size}$ is medium) and ($AVQL_{\_congestion}$ is low) and (P_{r_rate} is low) then (*DMF_predicted* is very_low)

If ($Buffr\_{Size}$ is medium) and ($AVQL_{\_congestion}$ is medium) and (P_{r_rate} is medium) then (*DMF_predicted* is medium)

If ($Buffr\_{Size}$ is medium) and ($AVQL\_{congestion}$ is high) and (P_{r_rate} is high) then ($DMF\_predicted$ is high)
If ($Buffr\_{Size}$ is medium) and ($AVQL\_{congestion}$ is very_high) and (P_{r_rate} is very_high) then
($DMF\_predicted$ is high)
If ($Buffr\_{Size}$ is high) and ($AVQL\_{congestion}$ is low) and (P_{r_rate} is low) then ($DMF\_predicted$ is high)
If ($Buffr\_{Size}$ is high) and ($AVQL\_{congestion}$ is medium) and (P_{r_rate} is medium) then ($DMF\_predicted$ is low)
If ($Buffr\_{Size}$ is high) and ($AVQL\_{congestion}$ is high) and (P_{r_rate} is high) then ($DMF\_predicted$ is medium)
If ($Buffr\_{Size}$ is high) and ($AVQL\_{congestion}$ is very_high) and (P_{r_rate} is very_high) then ($DMF\_predicted$ is high)
If ($Buffr\_{Size}$ is very_high) and ($AVQL\_{congestion}$ is low) and (P_{r_rate} is low) then ($DMF\_predicted$ is low)
If ($Buffr\_{Size}$ is very_high) and ($AVQL\_{congestion}$ is medium) and (P_{r_rate} is medium) then ($DMF\_predicted$ is medium)
If ($Buffr\_{Size}$ is very_high) and ($AVQL\_{congestion}$ is high) and (P_{r_rate} is high) then ($DMF\_predicted$ is high)
If ($Buffr\_{Size}$ is very_high) and ($AVQL\_{congestion}$ is very_high) and (P_{r_rate} is very_high) then
($DMF\_predicted$ is very_high)
End;

MAMDANI FUZZY INFERENCE SYSTEM FOR L4-DMF ALGORITHM

In implementing the Algorithm II, this work used fuzzy Logic Toolbox in MATLAB 7.9.0 version R2009b software designed to work in Simulink environment. Algorithm II shows the general rule base conditions for the proposed TCP algorithm. After creating the fuzzy systems using the GUI tools, the system is then ready to be embedded directly into a simulation following its surface diagram plots. The FIS Editor displays general information about a fuzzy inference system. Mamdani-type inference, as we have defined it for the Fuzzy Logic toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification. In the Fuzzy Logic Toolbox, there are five parts of the fuzzy inference process:

1. Fuzzification of the input variables (*buffer_sizes*, $AVQL\_{congestion}$ *and Pr_rate*)
2. Application of the fuzzy operator (AND) in the antecedent
3. Implication from the antecedent to the consequent,
4. Aggregation of the consequents across the rules.
5. Defuzzification.

The above component is summarized in Fig. 4.6 considering the look up table for the linguistic variable Table 4.1.

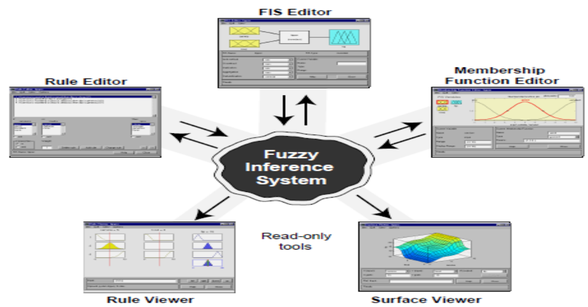

Fig. 4.6a: Mamdani Inference System [41]

A three-input, one-output, and nine-rule base algorithm II is shown in Fig. 4.6 mamdani inference system. The basic structure of this case is shown in Table 4.1 with the variable ranges and its linguistic variables labeled as the TCP-layer-DMF algorithm fuzzy sets viz: *Low, Medium, High and Very High*. Information flows from left to right, from three inputs to a single output (*DMF_predicted*). The parallel nature of the rules is one of the more important aspects of fuzzy logic systems.

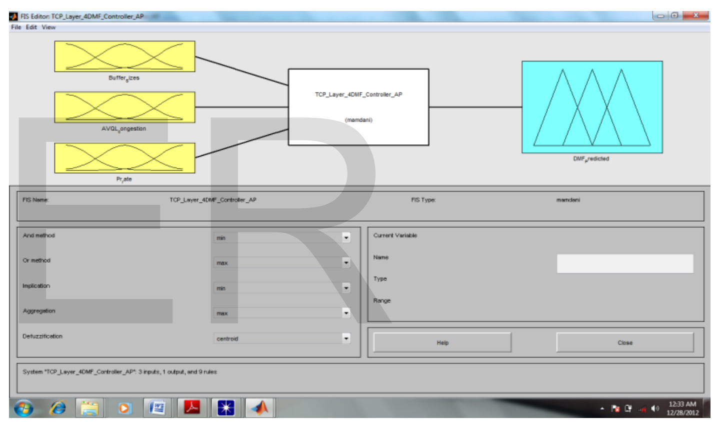

Fig. 4.6b: TCP layer-4DMF mamdani fuzzy inference engine

Fig. 4.7a shows the TCP layer-4DMF membership function for AP controller Buffer port. The buffer port is designated with three membership degrees viz: low, medium, high and very high. The AP buffer conditions shows fairness from the predicted output and satisfies the requirement of large packet size fragmentation.

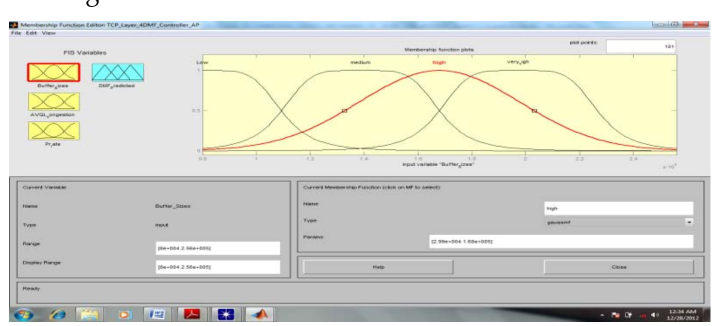

Fig. 4.7a: TCP layer-4DMF memberships function for AP controller Buffer port.

Fig. 4.7b shows the surface diagram of average queuing length variation. Fig. 4.7c shows the TCP layer-4DMF membership function for AP controller for PER. Fig. 4.6 shows the TCP layer-4DMF membership function for AP controller DMF_prediction output.

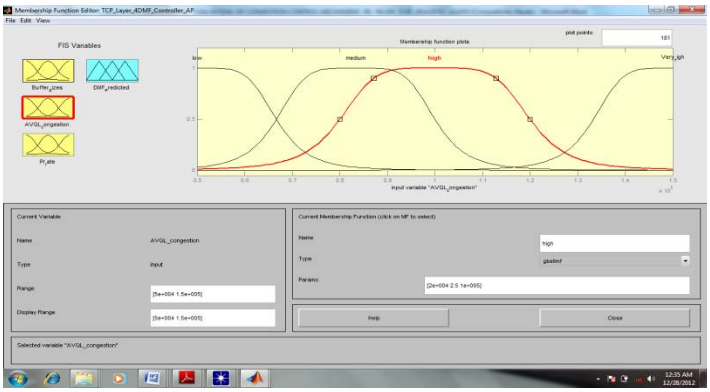

Fig. 4.7c: TCP layer-4DMF membership function for AP controller PER

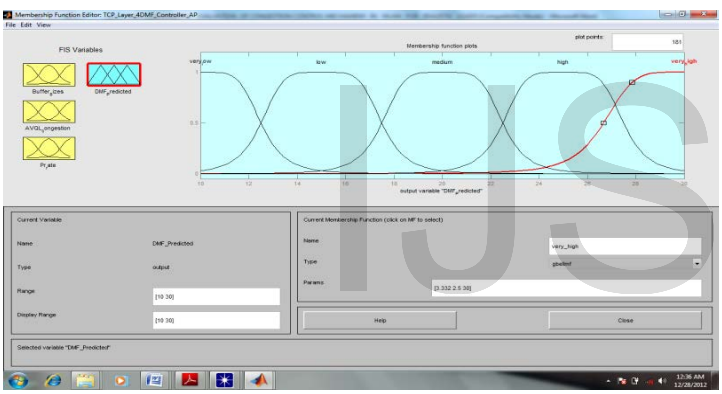

Fig. 4.6: TCP layer-4DMF membership function for AP controller DMF_prediction output

Fig. 4.8 shows the TCP layer-4DMF Rule editor for AP controller using mamdani FIS. The basic functionalities of the AP controller show that the system can be adapted into varying network conditions.

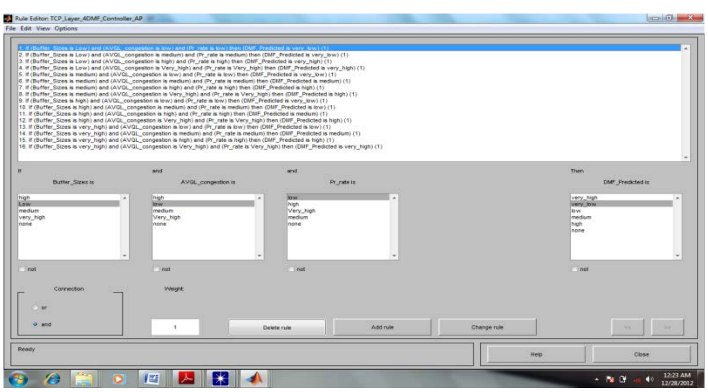

Fig. 4.8: TCP layer-4DMF Rule editor for AP controller in mamdani FIS

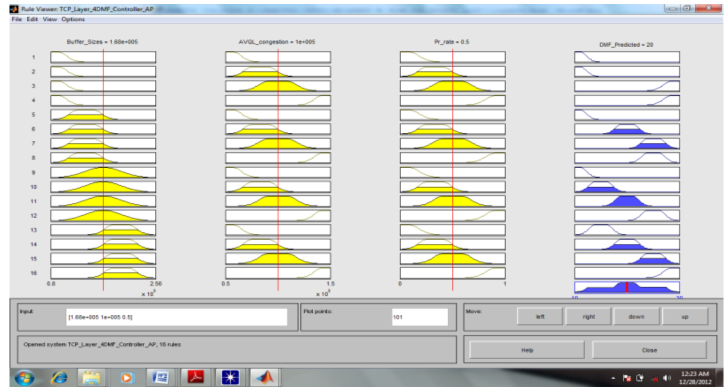

Fig. 4.9: TCP layer-4DMF Rule editor for AP controller process variables

In this work, the MATLAB rule viewer and surface viewer was used for the result analysis after configuring the algorithm in the rule editor in Fig. 4.8. But the rule viewer in Fig. 4.9 is a MATLAB based display for the fuzzy inference system as shown in Fig. 4.6a and 4.6b. Used as a diagnostic, it shows which rules are active and how individual membership function shapes are influencing the results of the proposed TCP layer-4 DMF algorithm II. The surface viewer is used to display the dependency of one of the outputs on any one or two of the inputs—that is, it generates and plots an output surface map for the system. Following the fuzzy rules base formulations for the proposed TCP layer-4 DMF algorithm II,

Fig. 4.10- 4.18 shows the MATLAB fuzzy surface viewer plots of the proposed layer-4 DMF algorithm under analysis. These plots are forms the key criteria for the effective network performance. Fig. 4.11 shows the TCP layer-4DMF surface viewer plots for the process variable (AVQL_congestion, Buffer_sizes) and control variable (DMF_Predicted). The network uses DMF_Predicted to control network saturation as depicted by the 3D plot trend of Fig. 4.11.This is a typical response of carrier Sense Multiple Access/collision Avoidance, CSMA/CA in wireless networks.

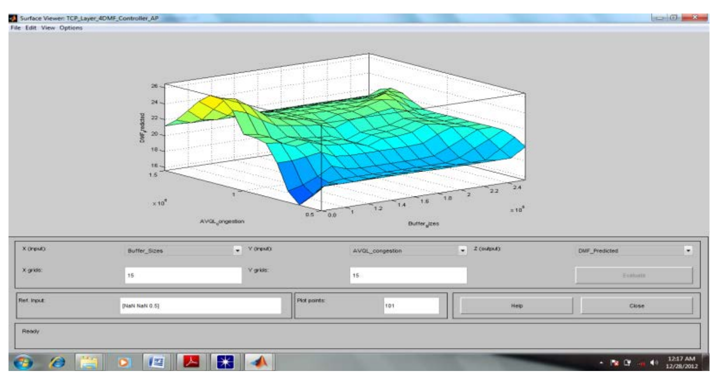

Fig. 4.11: TCP layer-4DMF surface viewer plots for the process variable (*AVQL_congestion*, *Buffer_sizes*) and control variable (*DMF_Predicted*).

Fig. 4.12 represents the TCP layer-4DMF surface viewer plots for the process variable-*AVQL_congestion*, against *Buffer_sizes*). There no significant difference between the average congestion window vis-à-vis buffered size. When the buffer size is less than the average congestion traffic, the AP dynamical adjusts the buffer so as to avoid packet drop scenario using fuzzy algorithm.

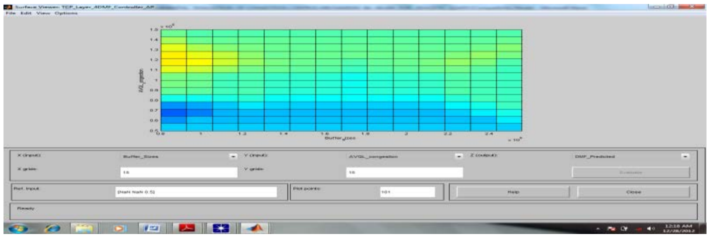

Fig. 4.12: TCP layer-4DMF surface viewer plots for the process variable-*AVQL_congestion,* against *Buffer_sizes*)

Fig. 4.13 depicts the TCP layer-4DMF surface viewer plots for the control variable *DMF_Predicted* against Buffer_sizes). This response gives the compact view as shown in Fig. 4.13 and shares the similar characteristics with Fig. 4.12.

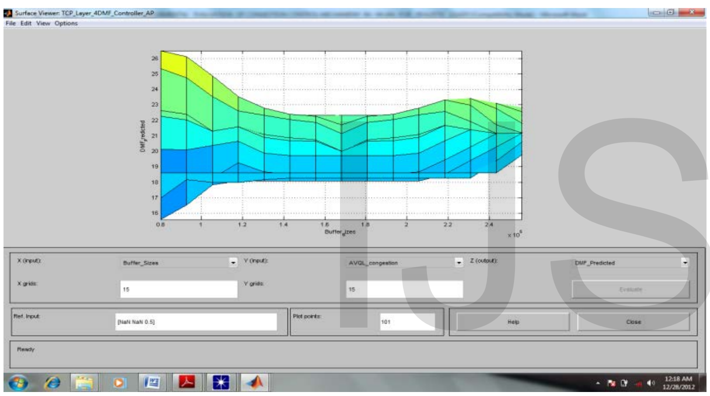

Fig. 4.13: TCP layer-4DMF surface viewer plots for the control variable *DMF_Predicted* against buffer_*sizes*)

Fig. 4.14 shows the TCP layer-4DMF surface viewer plots for the process variable *(Pr_rate, AVQL_congestion* and control variable (*DMF_Predicted*). The plot shows that average congestion traffic and packet rate ratio constitute a vital metric for network output prediction. Increase in congestion traffic with corresponding increase in packet rate ratio has no significant impact on the network state using the fuzzy algorithm.

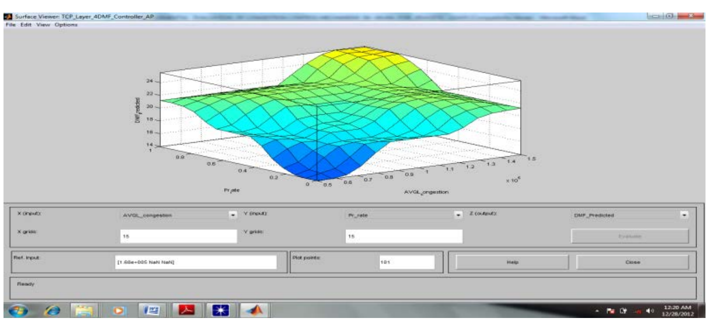

Fig. 4.14: TCP layer-4DMF surface viewer plots for the process variable *(Pr_rate, AVQL_congestion* and control variable (*DMF_Predicted*).

At peak congestion, Fig. 4.17 represents the TCP layer-4DMF surface viewer plots for the process variable *Buffer_sizes*, *Pr_rate* and control variable (*DMF_Predicted*). Optimization at peak congestion regulation is centered on the layered patterns and curves with the fuzzy algorithm.

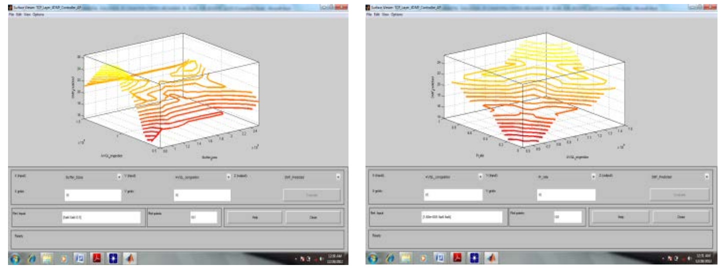

Fig. 4.15: TCP layer-4DMF surface viewer plots for the process variable *Buffer_sizes*, *Pr_rate* and control variable (*DMF_Predicted*) at peak congestion regulation.

Fig. 4.16 represents TCP layer-4DMF surface viewer plots for the process variable *Buffer_sizes*, *Pr_rate* and control variable (*DMF_Predicted*) under optimization from un-optimization. Our fuzzy algorithm can be modulated depending on the network conditions to yield either optimality (maximum threshold) or minimal threshold for end user experience.

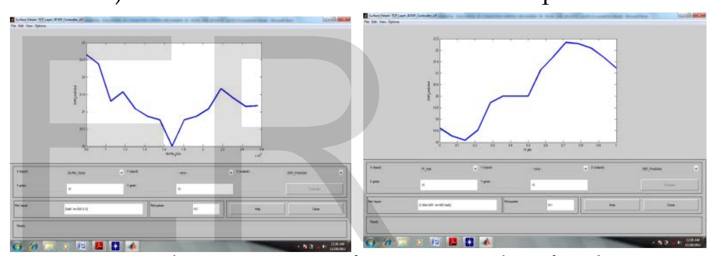

Fig. 4.16: TCP layer-4DMF surface viewer plots for the process variable *Buffer_sizes*, *Pr_rate* and control variable (*DMF_Predicted*) under optimization from un-optimization.

Conclusion and future Works

This paper has discussed a BSS wireless network model using a heuristic TCP performance that can be estimated over a time-varying channel under different conditions of user's mobility. Congestion can occur at the buffers of networks core devices making for high packet drops, packet queuing delay, low throughput and other unwanted network problem. This work showed fuzzy logic congestion control mechanism implemented through intelligent Queue Management algorithm (layer 4-DMF). The result of our surface diagrams for layer 4-DMF algorithm shows a significant improvement in TCP QoS metrics performance considering the user's mobility and realistic traffic loads in the FA-WLAN by leveraging the 3D surface diagrams.

Future work will carry out a realistic performance evaluation with other generic TCP algorithms using micro and macro mobility scenarios for mobile user

REFERENCES

[1] Yung Yi and Sanjay Shakkottai,"Hop-by-hop Congestion Control over a Wireless Multi-hop Network"

[2] Ziyu Shao et al, " Cross-layer Optimization for Wireless Networks with Deterministic Channel Models"

[3] Alessandro abate, minghua chen, Shankar sastry, "New congestion control schemes over wireless networks: delay Sensitivity analysis and simulations"

[4] Yuan Xue Hoang Nguyen and Klara Nahrstedt, CA-AQM: Channel-Aware Active Queue Management for Wireless Networks

[5] S. Floyd and V. Jacobson, "Random Early Detection Gateways for Congestion Avoidance", IEEE/ACM Transactions on Networking, 1(4):397- 413. (1993).

[6] H. Abdel-Jaber, M. Mahafzah, F. Thabtah, and M. Woodward, (2008), "Fuzzy Logic Controller of Random Early Detection based on Average Queue Length and Packet Loss Rate", *Proc. Of SPECTS* 2008.

[7] K. Zhou, K. L., Yeung, and V. O.K. Li, (2006), "Nonlinear RED: A Simple Yet Efficient Active Queue Management Scheme," Computer Networks, vol. 50, pp. 3784-3794.

[8] H. Abdel-Jaber, M. Mahafzah, F. Thabtah, and M. Woodward, (2008), "Fuzzy Logic Controller of Random Early Detection based on Average Queue Length and Packet Loss Rate", *Proc. Of SPECTS* 2008.

[9] K. Michels, F. Klawonn, R. Kruse, A. Nürnberger, (2006), "Fuzzy Control: Fundamentals, Stability and Design of Fuzzy Controllers", *Springer-Verlag Berlin Heidelberg*.

[10] Mamdani, E.H. and S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller", International Journal of Man-Machine Studies. 7: pp 1-13, 1975.

[11] Sugeno, M., Industrial applications of fuzzy control, Elsevier Science Pub. Co., 1985.

[12] Fuzzy logic toolbox for use with MATLAB. User's guide version 2 Foundations of fuzzylogicwith-MATLAB.pdfwww.mathwork.com http://www.phys.ufl.edu/docs/matlab/pdf_doc/fuzzy/fuzzy_tb.pdf.

[13] Zadeh, L.A., "Outline of a new approach to the analysis of complex systems and decision processes," *IEEE Transactions on Systems, Man, and Cybernetics*, Vol. 3, No. 1, pp. 28-44, Jan. 1973.

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