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Efficient Fuzzy Traffic Adaptation Solution in Wireless Mesh Networks

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Abstract— ***As wireless communication gains more advancement, significant research has been developed and adapted to support real time transmission which strengthens quality of services. Requirement for wireless communication and application and technology. Wireless mesh networks (WMNs) are considered as the next step towards providing a high-bandwidth network over a specific coverage area. Because of their advantages over other wireless networks, WMNs are undergoing rapid progress and inspiring numerous multimedia applications such as video and audio real-time applications. These applications usually require time-bounded service and bandwidth guarantee. Therefore, there is a vital need to provide Quality of Service (QoS) support in order to assure better quality delivery. In communication this technology are accepted to provide a wide variety of real time application, hence there is a QoS is need to be maintained. One of the key mechanism is to support quality of service in traffic regulation at network state e.g. Load in order to adapt the rate flow. In this paper we proposed a novel model called fuzzy wireless mesh network, used to implement traffic adaptation in wireless mesh network. The objective of this model is to calculate the rate adaptation according to current network state. It depends on two parameter 1) Packet delay between source and destination, 2) buffer occupancy of network nodes.***
Keywords— ***Fuzzy, WMN, QoS, Delay, Buffer.***

I. INTRODUCTION

The last few years have witnessed a wealth of research ideas on Wireless Mesh Networks (WMNs) that are moving rapidly toward implemented standards. Omni present access to information anytime and anywhere will characterize new kinds of information system. This is made possible by advanced growth in communication system that evolved wireless technology. Wireless mesh networking represents a key component of these future wireless networks [1]. Wireless mesh networking consist of routers and client, where mesh routers have minimal mobility. It provides network access for both mesh and converting client. The integration of WMNs with other networks such as internet, cellular, IEEE 802.11, IEEE 802.15, IEEE 802.16 and sensor networks can be made possible through the gateway and bridging function in mesh router [2]. It is expected that WMNs will carry various kinds of multimedia services, e.g. Multimedia streaming and VOIP, characterized by their stringent QoS requirement [3]. Hence the mechanisms that provide QoS support must be deployed in WMNs. Adaptation of traffic is one of the key traffic management mechanisms that used for QoS support. The basic idea behind traffic regulation is to measure the networks state e.g. Load in order to adapt the rate of carefully selected application traffic flows [4]. In a network with shared resource it is necessary to adapt the traffic rate used by each transmitter in order to complete for bandwidth and not to overload the network. Traffic packets that arrive at intermediate nodes and cannot be reach at destination due to congestion at nodes they are dropped these packets might previously have travelled long way i.e. traversed nodes in the network and thus consumed unnecessarily bandwidth which result in network throughput and traffic delivery. While many traffic adaptation models e.g. [4, 8] have been proposed in the literature they are essentially based on traffic engineering mechanism which are based on TCP principle, end to end delay and packet loss rates, buffer occupancy in intermediate nodes.

In this paper, we propose a traffic adaptation model for WMNs named as fuzzy WMN [5]. This model is based on two parameters 1) packet delay measurement 2) Buffer occupancy in intermediate nodes. Due to the dynamic and unpredictable nature of traffic in the nodes we practise to develop intelligent learning theories such as fuzzy logic. The major component in a fuzzy logic system includes fuzzifier, inference engine, and defuzzifier. To design a fuzzy logic controller, a set of input and output parameter is required. My paper proposes a new way of using fuzzy logic in our contribution that the fuzzy logic theory is implemented as a full system,, our fuzzy traffic adaptation model is not only acts as controller tool to measure traffic rates for traffic sessions but it is also integrates with a decision making model that uses fuzzy petri nets modelling method for better result and better performance evaluation [6]. This method is best understood for the mechanism of traffic control rules and base results oriented proposed efficient traffic.

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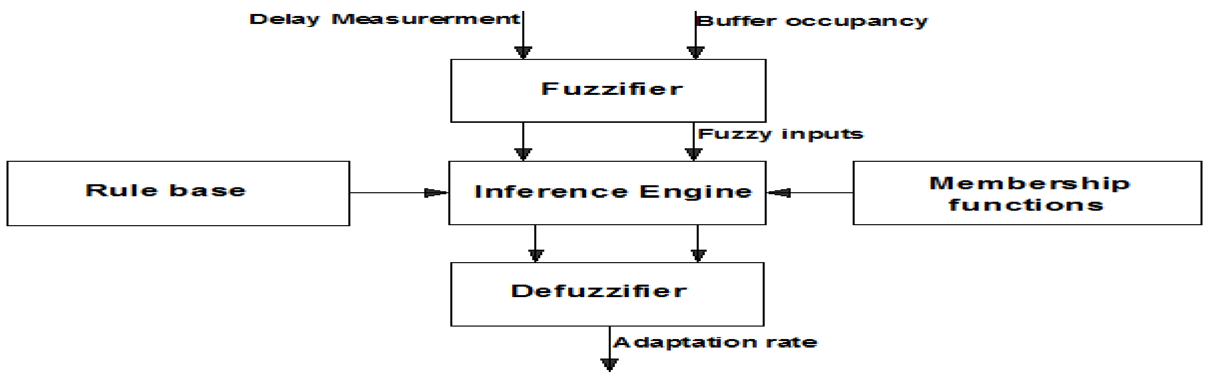
II. FUZZY TRAFFIC ADAPTATION MODEL



The proposed fuzzy wireless mesh network model shown in figure 1 atoms to study the traffic adaptation with the objective of improving network performance which is based on packets delay measurement and buffer occupancy. The packet delay shows the time it takes to send a packet from the sours eth the destination. Where buffer occupancy has a major impact on QoS provided by the network. It has to be continuously monitored at each intermediate node, along the path from source to destination. When a packet arrives to a node with a lightly loaded buffer, it will rapidly forward to its next hop; if it arrives to node with a highly loaded buffer it has to wait until all existing packets are processed before forwarded. Thus by keeping buffer lightly loaded will load to bounded end to end delays. In order to update/adjust the sending rate, buffer occupancy along the path can be communicate to the source using either a) Time based scheme b) Decision based scheme. In (a) buffer occupancy is measured by nodes along the path and sent to the source periodically. But in this paper we use decision based scheme where each node, along the path measures its buffer occupancy but it notifies the source only when changes occur in the decision of its local fuzzy controller [7].

The Proposed traffic adaptation process is performed in following three steps: 1) Fuzzification 2) Rules evaluation 3) Defuzzification. In Fuzzification step, real numbers which represents the values of buffer occupancy and the delay measurement parameters are converted into linguistic values, each value is characterizes by its own membership function. In the next inference step, a set of rules called the rule base which enumerates the decision making process of a network, which is applied to the linguistic values of the inputs so as to regulate the output rate set. This output is then defuzzified to the actual traffic rate to be applied on the flow.

A. Fuzzification

The fuzzy inputs in this system are the buffer occupancy and the delay measurement; the traffic adaptation rate represents the fuzzy output. These two parameters have to be converted into fuzzy sets; in fuzzy theory, a fuzzy set may contain elements that have different degrees of membership in a set. A variety of membership functions may be applied, such as triangular, Gaussian, and trapezoidal functions. In our study, we have chosen triangular functions because of their computation simplicity. Note that a fuzzy set is an extension of a classical crisp set. A fuzzy set in the universe of discussion U, $U = \{u_1, u_2, \ldots, u_n\}$, can be described by a membership function u_A , u_A: U→[0,1], represented by:

$$a_{uk} = u_A(u_1)/u_1 + u_A(u_2)/u_2 + \ldots + u_A(u_n)/u_n \qquad (1)$$

$u_A(u_1)$ it indicates the grade of membership of u_i, in the fuzzy set A for eg. It indicates the buffer occupancy in the sets "not high", or " quite low".

A fuzzy number can be parameterized by a triplet (a_1, a_2, a_3), where the membership function of the fuzzy number is defined as follows [8]:

$$u_A(u) = \begin{cases} 0 & u < a_1 \\ (u-a_1)/(a_2-a_1), & a_1 \le u \le a_2 \\ (a_3-u)/(a_3-a_2), & a_2 \le u \le a_3 \\ & u \ge a_3 \end{cases} \qquad (2)$$

Some arithmetic operation between generalized trapezoidal fuzzy number are : let A and B be two fuzzy number parameterized by the triplets (a_1, a_2, a_3) and (b_1, b_2, b_3) respectively. The addition and multiplication operation of the fuzzy number A and B

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represented as;

$A \oplus B = (a_1, a_2, a_3) \oplus (b_1, b_2, b_3)$

$=(a_1 + b_1, a_2 + b_2, a_3 + b_3)$ (3)

$A \otimes B = (a_1, a_2, a_3) \otimes (b_1, b_2, b_3)$

$=(a_1 x\ b_1, a_2\ x\ b_2, a_3\ x\ b_3)$ (4)

When we observe the equation (3) both addition and multiplication of two fuzzy number A and B are achieved by summing and multiplying respectively the values of each triplet;

The maximum operation between A and B is defined as follows;

AΘB = [a1vb1,a2vb2,a3vb3] (5)

The maximum operation is used to obtain the maximum effect of two or more outputs fuzzy sets.

U	Universe of discussion which is the range of all possible values for an input or output to a fuzzy system.
u_A	A fuzzy set that allows its membership of universe in the fuzzy set A
$u_A(u_i)$	Indicates the grade of membership in the fuzzy seta) and (b1, b2,b3) resp.
A,B	Fuzzy numbers parameterized by the triplets (a1, a2, a3
Θ	Maximum operation between two fuzzy numbers.
⊕	Addition operation between two fuzzy numbers.
⊗	Multiplication operation between two fuzzy numbers.
V	Provides the maximum value of two fuzzy numbers.
R^k	The kth fuzzy rule includes a set of conditional statement.
X^k_1…….X^k_n	Input linguistic variable of rule k
Y^k_1…….Y^k_n	Output linguistic variable of rule k
$A^{(k)}_i, B^{(k)}_i$	Linguistic values of the variable Xik and Yik in the universe of discourse U.
DM	Delay measurement
AF	Buffer occupancy
TR	Traffic regulation rate

Table 1: Notation table

B. Defuzzification

In defuzzification step, the decision sets (i.e. increased, decreased, increased slowly, decreased slowly) concerning the traffic adaptation process are converted into precise quantities. The defuzzification chooses a representative value to the resulting fuzzy set as the final output. There exist several heuristic that allow performing defuzzification. Center of Area (CoA) (referred to as the Center of Gravity) computes and returns the center of gravity of the aggregated fuzzy set (the center is the centroid of the composite area representing the output fuzzy term). Center of Maximum (CoM) determines the numerical value of each scaled membership function; only the peaks of the membership functions are used, which are determined by finding the place where the weights are balanced. The output value is computed as a weighted mean of the term membership maxima, weighted by the inference results. Mean of maximum (MoM) computes the most plausible result which is obtained as the average of the elements that reach the maximum grade in a fuzzy set. In our proposed model, we use MoM as a defuzzifier because of its light computational complexity.

III. PERFORMANCE EVALUATION

In this section, we use IEEE 802.11.The simulations scenarios are based mainly on three criteria: topology type, network density and traffic model. We used two types of topologies: structured and random. The structured topologies are (inspired from [3]) were we have generated 4 architectures: chain, cross, grid, and star. We have generated random topologies using our simple topology generator that avoids the case of unreachable nodes. The network density (number of nodes per square meter) impacts directly the number of generated events (neighbours' interferences, reception of messages) and channel occupancy. Thus, to evaluate the performance of our

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approach in different conditions, we run our approach in 10, 30, 50, 70 and 90 nodes topologies. These nodes are deployed within a fixed area of 1000mx1000m square with equal radio range per node (250m). The traffic model is also a main key in the evaluation of any approach. We remember here that our proposed model is done to support multimedia traffic. Thus, we suppose video session of 200kbps and audio session of 80 kbps. We have also mixed both traffic model and network density in the random topologies, where we simulate the same quantity of exchanged information, separately from the number of nodes. notification value). Indeed, before starting the rate regulation operation, a source node waits for a short period (without this waiting period, the source node may react to all notifications sent by congested nodes). This period is useful to avoid unnecessary regulations that may happen due to the reception of multiple congestion notifications from multiple congested nodes of the same path. The value of this period is fixed to 150ms (a delay of 150ms is acceptable for high voice quality).

IV. SIMULATION RESULT

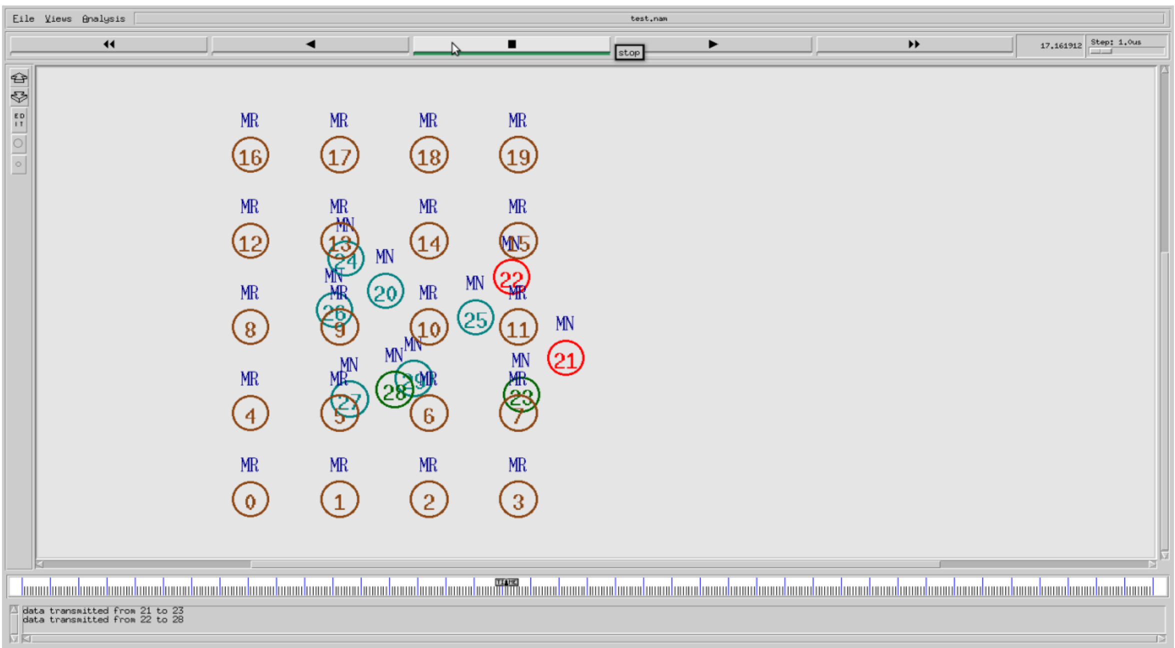

Figure 1: Nam file for Delay.

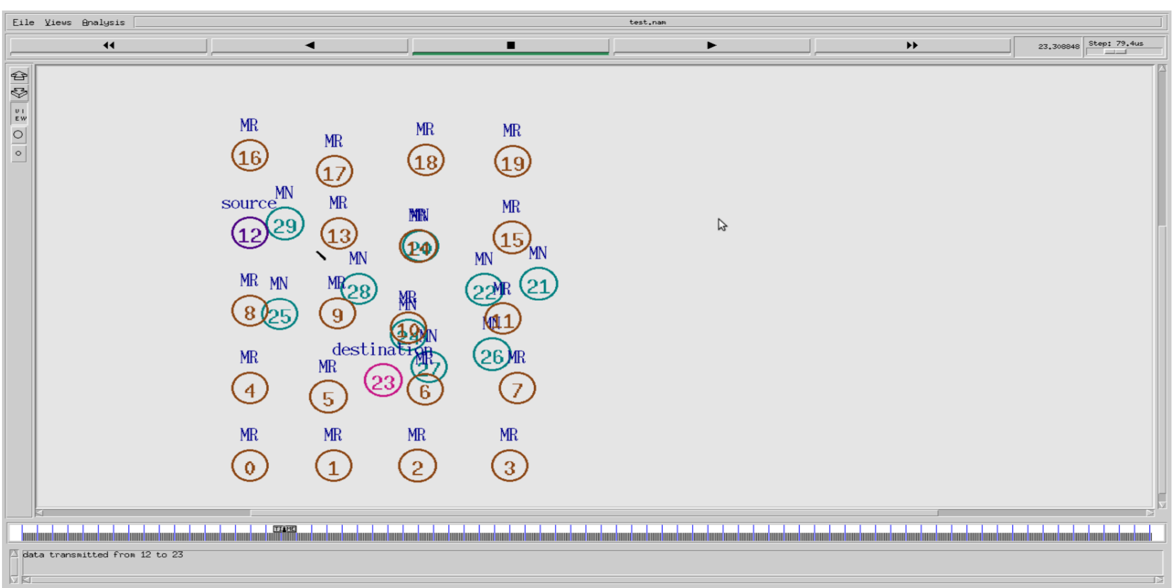

Figure 2: Nam file for AIMD.

A. Simulation Parameter For Analysis

SIMULATOR	Network Simulator 2
NUMBER OF NODES	Random
TOPOLOGY	fixed mesh routers, mobile users
INTERFACE TYPE	Physical / WirelessPhy
MAC TYPE	802.11
QUEUE TYPE	Droptail/Priority Queue
QUEUE LENGTH	50 Packets
ANTENNA TYPE	Omni Antenna
PROPAGATION TYPE	Two ray Ground
ROUTING PROTOCOL	AODV
TRANSPORT AGENT	UDP
APPLICATION AGENT	CBR
SIMULATION TIME	50seconds

V. CONCLUSION

In this paper, I have introduced a new traffic adaptation model in WMNs based on fuzzy logic theory. The model, called, Fuzzy WMN aims to regulate traffic to adapt to the network state (delay between sources and destinations and buffer occupancy of nodes) with the objective to improve the performance. Partial simulations show that Fuzzy WMN Outperforms AIMD with respect to delay, throughout and packet delivery ratio. This confirms our belief that fuzzy theory based design of QoS aware protocols provides an efficient solution and constitute a good alternative to some conventional methods based on complex optimization and/ or high overload traffic engineering mechanisms. For future work, I plan to improve / extend the proposed model by investigating the practicality of combining multiple learning methods on different layers; for example, using, genetic algorithm to select the best path for data delivery, and fuzzy logic to perform traffic regulation to get performance result with quality of service by reducing the packet loss ratio.

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