Type-2 Fuzzy Logic Control Model for Traffic Shaping Using Backpressure over High Speed Networks

Somchai Lekcharoen

***Abstract*— Current, network has become a significant part of network and data communications. The crisis problem is that cannot properly shape incoming connection. A traffic shaper assists monitors the amount of egress traffic, and makes smooth the burst traffic rate. It wants the guarantee performance, lower delaying packet, and raises the serviceable bandwidth by packets that meet up certain criteria. As the major of networks has a limited amount of bandwidth. Network traffics are always to become so busy. It is leads to choking points. However, one way to solve this problem, we use type-2 fuzzy backpressure to control traffic shaping. In deed, the telecommunication network traffic always becomes fluctuation. Especially, various types of burst/silence traffic are being generated. A type-2 fuzzy control is suitable for uncertain traffic, especially in alternative burst and silence. The backpressure mechanism can control traffic and increases conforming frames. In this paper wants to evaluate and compare the performance of the three mechanisms in traffic shaping: type-2 fuzzy using backpressure (T2F), Fuzzy control (T1F) and conventional traffic shaping mechanism on Leaky Bucket (LB). Simulation results showed that the type-2 fuzzy using backpressure mechanism could help to improve the performance in traffic shaping much better than conventional traffic shaping one while various types of burst/silence traffic are being generated.**

***Index Terms*—type-2 fuzzy control, traffic shaping, congestion control**

I. INTRODUCTION

In the network traffic concerns with making a network run as smoothly as possible. In normally, we find a technique that can help smooth traffic is traffic shaping. If network traffic shaping done incorrectly, it is causing more problems such as unpleasant points. It makes to degrade the main performance measures such as dropped frame, bandwidth allocation, frame delay, throughput and other grade of service measures. There have been a lot of previous studies involving traffic shaping [1,2,3].

At present, the traffic shaping is widely used to control smooth traffic at an egress network. In the traffic network, an egress router is a router through which a packet leaves one network for another network. The previous papers have been proposed involving traffic shaping. They are difficult to obtain the proper and understandable modeling representations. This difficulty has simulated the development of alternative modeling and controls a technique that includes fuzzy logic based ones. Type-2 Fuzzy control may show the way to the models that express the behavior of systems suitably for their application in fuzzy control. Thus due to the requirement for low-cost but reliable models, the type-2 fuzzy modeling approach may be a useful complement to traditional modeling. The type-2 fuzzy control approach is suitable for both the complexity and uncertainty during the increase of the system. There are a number of previous studies involving fuzzy control traffic shaping.

In this paper, we have proposed a model for type-2 fuzzy control traffic shaping using backpressure over the high speed network that it is not mentioned. This paper is organized as follows. In Section II, we propose traffic shaping. Section III, we describe the model of backpressure algorithms. Section IV, we define the model of a type-2 fuzzy control traffic shaping. Section V, we define the model. Section VI contains a performance evaluation of the proposed solution and comparison to traffic shaping. Section VII, some conclusion and recommendation for future research are draw.

II. DESCRIPTION AND MODELING OF TRAFFIC SHAPING

Traffic shaping monitors the maximum rate of traffic sent out on an interface during the egress active phase and must operate in real time. In this section is described in traffic that it is used in the telecommunication network.

In addition to these requirements, mechanism of parameter violations must be short to avoid flooding of the relatively small buffers in the network. To eliminate these conflicting requirements, several traffic shaping have been proposed [1,2,3] as described in the following sections.

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A. Traffic source models

In the telecommunication, the network traffic transfers data in the form of the burst and silent period.

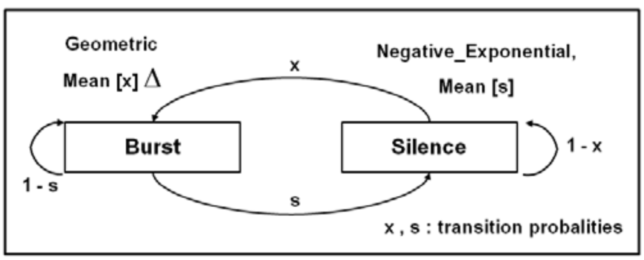

Figure 1.The burst/silence traffic model using in this study.

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In this section, we describe the traffic model used in our model. The traffic source model is based on burst/silence traffic stream. A burst is the transfer of data without interruption from another. A silence is no data to transfer. The burst /silence ratio is strictly alternating.

The number of packets per burst is assumed to have a geometric distribution with mean E[X]; the duration of the silence phases is assumed to be distributed according to a negative-exponential distribution with mean E[S]; and inter-packet arrival time during a burst is given by Δ. With

$$\textit{mean burst duration} = E[X]\,\Delta \quad (1)$$

$$\textit{mean silence duration} = E[S] \quad (2)$$

$$\textit{mean cycle duration} = E[X]\,\Delta + E[S] \quad (3)$$

B. Traffic shaping models

The traffic shaping monitors a leaving traffic at the edges of the network for frame-based traffic. This mechanism decides whether to accept a unit of the conforming frame or remarked to a lower class of service (see Fig. 2). The traffic shaping allows us to control the average rate of traffic leaved during the active phase. So it preserves average data-rate connections from the source network transmission, and improves the quality of service (QOS).

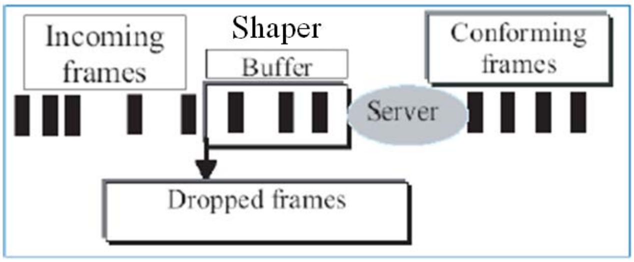

Figure2. The traffic shaping.

In the Fig. 3 illustrates the key of traffic shaping. The traffic shaping retains excess frames in a queue and then schedules the excess for later transmission over increments of time. The result of traffic shaping is a smoothed frame output rate.

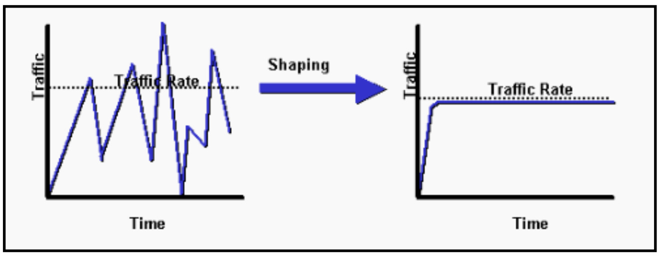

Figure3. The traffic shaping for a smoothed frame [11].

C. A model of a simple transmitter

The transmitter shows in Fig. 4. It consists of processor and a limited buffer to hold frames. An arrival frame is random and the inter-arrival time between frames follows a particular distribution function. Moreover, frames come in different sizes and the time to transmit a frame depends on its size. When a frame arrives at the transmitter, it can be done one of two cases. The first case, the frame is given to the processor, which immediately starts transmitting it. The last case, the frame is queued in the buffer behind other queued frames. While the buffer has many frames, the processor retrieves a frame at a time from the buffer in a first-in-first-out (FIFO) order and transmits it onto the link. If the buffer is filled up frames until over flow, then frames were dropped.

Our study considers the behavior of the transmitter using discrete event simulation. In particular, given a distribution of the frame inter-arrival times and a distribution of the frame transmission times we are interested in mean queue time and mean queue length of frames in the buffer, the total number of non-conforming frames, and the total number of conforming frames. The final is also referred to processor utilization.

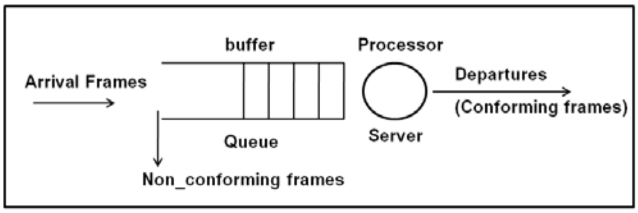

Figure4. A model of a simple transmitter.

D. The Leaky Bucket mechanism

In the traffic shaping mechanism, we need a leaky bucket to control the smooth traffic. It is based on the concept of pseudo-queue, and consists of a counter increased on the arrival of the frames and decreased (if positive) at a constant frequency λ_e. When the counter exceeds a pre-established threshold N (length of the pseudo-queue or the counter limit), the frames are detected as excessive and the traffic shaping action agreed on is taken.

The parameters for the sizing of the LB are the threshold N and the depletion rate λ_e. The choice of N plays an important role. As certain statistical fluctuations around the average value negotiated are allowed in the frame rate, N has to be long enough to reduce the false alarm probability, that is the probability of detecting some frames of a non- violating source as excessive. This requirement is met when N values are high, but the reaction time of the mechanism grows excessively. From the analysis, it has emerged that in order to achieve greater flexibility in size and reduce the probability of false alarms, it is necessary to introduce an over dimensioning factor C (C>1) between the negotiated frame rate λ_n and that which is really policed λ_p; it follows that $\lambda_e = \lambda_p = C\lambda_n$. On the other hand, this artifice reduces the capacity to detect violation over a long term. In spite of its pitfalls, the LB mechanism is still regarded as particularly attractive due to its simplicity of implementation [4,5].

III. Backpressure Algorithm

The backpressure algorithm works like XON/XOFF techniques with a purpose to avoid buffer overflows and temporary network congestion. The XOFF flow control message is sent to source when the buffer of destination is filled up frame until overflow. When the Source receives a

XOFF message, it stops sending frames until it receives a XON message from the same destination. The XON message is triggered when the buffer of destination has decreased below the lower threshold.

In the backpressure algorithms, when frames arrive at destination' buffer, the backpressure algorithm is activated. If destination' buffer is below the threshold, it sends a message to the source. The source can increase a half the transmission rate. If destination' buffer reaches the upper threshold, then destination sends a message to source to reduce a half the transmission rate. The backpressure is suitable for a connection-oriented network that allows hop-by-hop flow control. The backpressure algorithm is shown with the pseudo code as follows.

The goal of backpressure algorithm wants to control the traffic rate. If the buffer is filled up frames until reaching threshold then the destination hop sends the message to the source and it reduces to half transmission rate.

```
Start Check:

IF buffer of destination exceeds the upper threshold

THEN GOTO Stop:

ELSE {

        IF QDESTN >= QTHRESHOLD

         THEN Destination  sends feedback to source and
              source reduces traffic rate to half.

              GOTO Start Check:

         ELSE  Destination  sends feedback to source and
              source increases  traffic rate to half.

              GOTO Start Check:

      }

   Stop:
```

IV. Type-2 Fuzzy control prior buffer

In this section, we initially first describe the concept of type-2 fuzzy and type-2 fuzzy control prior buffer in the shaper which meets the requirements of performance implementation of high speed networks.

A. Basic concepts of type-2 fuzzy set [6, 7].

The type-2 fuzzy set appears to be handled more uncertainly than fuzzy set. A type-2 fuzzy set incorporates uncertainly with the membership function into the fuzzy set theory. If there is no uncertainty, then a type-2 fuzzy set will reduce to a type-1 fuzzy set. In order to distinguish between a type-1 fuzzy set and a type-2 fuzzy set, A denotes a type-1 fuzzy set, whereas Ã denotes the comparable type-2 fuzzy set. The feature of Ã versus A is the membership function values. They have a continuous range of values between 0 and 1.

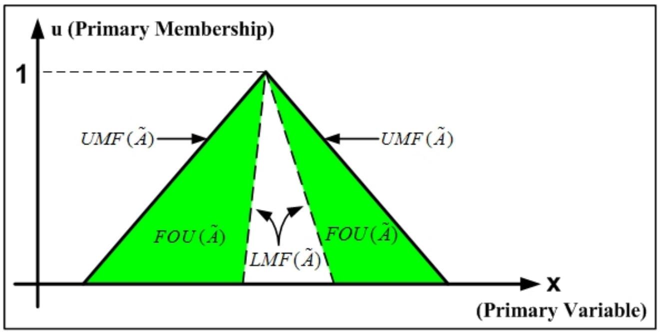

Figure 5. FOU for an interval type-2 fuzzy set. Many other shapes are also possible for the FOU [12].

The FOU is described by its two bounding functions (Fig. 5), a lower membership function (LMF) and an upper membership function (UMF), both of which are type-1 fuzzy sets. We can use type-1 fuzzy set mathematics to characterize and work with interval type-2 fuzzy sets. It can be said that Type-2 Fuzzy Sets are suitable for ***rule-based fuzzy logic systems*** (FLSs) because they can handle uncertainties whereas Type-1 fuzzy cannot handle uncertainties. A diagram of a type-2 FLS is depicted in Fig. 6.

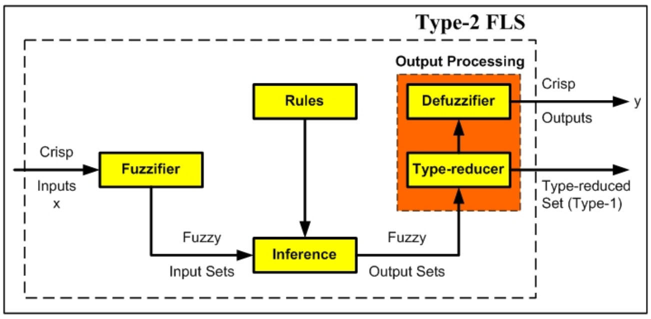

Figure 6. Type-2 Fuzzy Logic Systems [12].

Fuzzy sets are associated with the terms of IF THEN ELSE rules, and with the inputs to and the outputs of the Fuzzy set. Membership functions are used to describe these fuzzy sets. The Type-2 Fuzzy sets have interval membership functions.

In output processing of a type-1 Fuzzy Sets which is called ***Defuzzification*** maps a type-1 fuzzy set into a number. Nevertheless, it is more complicated for an interval type-2 Fuzzy Set because it is going from an interval type-2 fuzzy set to a number which (usually) requires two steps (Fig. 6). The first step, called ***type-reduction*** is where an interval type-2 fuzzy set is reduced to an interval-valued type-1 fuzzy set. There are as many type-reduction methods as there are in type-1 defuzzification methods. The second step of Output Processing, which occurs after type-reduction, is still called ***defuzzification***. Since a type-reduced set of an interval type-2 fuzzy set is always a finite interval of numbers, the defuzzified value is just the average of the two end-points of this interval.

B. Regulator input fuzzification

Input variables are transformed into fuzzy set (fuzzification) and manipulated by a collection of IF-THEN fuzzy rules, assembled in what is known as the fuzzy inference engine, as shown in the Fig. 7.

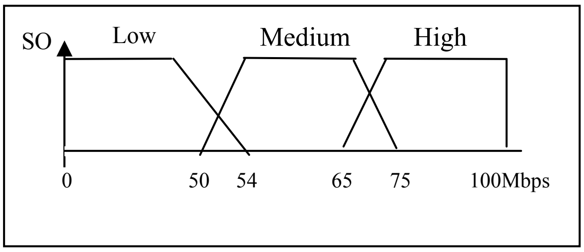

Figure 7. Membership function of SO input variable.

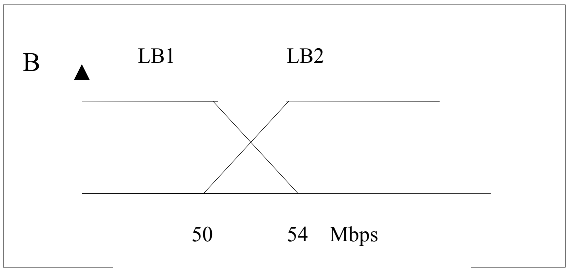

Figure 8. Membership function of B output variable.

C. *Inference, Fuzzy Rules and Defuzzification*

Fuzzy sets are involved only in rule premises. Rule consequences are crisp functions of the output variables. There is no separate defuzzification step. Based on our defined measurement of input variables and their membership functions, the fuzzy system can be described by five fuzzy IF-THEN rules, each of which locally represents a linear input-output relation for the regulator. In Fig. 9, it shows simple fuzzy rules used in the experiment.

```
IF   So is Low (L) AND various types of burst/silence
          are narrow THEN   go to LB1
ELSE IF   So is Low (L) AND various types of
          burst/silence are wide THEN   go to LB2
ELSE IF   So is High (H)    THEN   go to LB2
END IF
```

Figure 9. The fuzzy rules.

Fig. 7 and 8 respectively show the membership functions of the linguistic values of the input variables So and also the output variable's B being taken. Analysis of the fuzzy system rules (Fig. 9) shows that sources are Low (L) and various types of burst/silence is narrow THEN they go to LB1(leaky bucket). If sources are Low (L) and various types of burst/silence is wider THEN they go to LB2(leaky bucket). If sources are High (H) THEN they go to LB2(leaky bucket).

In our models, Type-2 Fuzzy Control (T2F) uses a set of rules (Fig. 7, 8 and 9). The selection of basic rules is based on our experience and beliefs on how the system should carry out. Input traffics allow a burst traffic stream (burst/silence stream) to fluctuate within the network controlled by fuzzy controller.

V. Simulation Model

The following Fig. 10 shows a simulation model used in this paper.

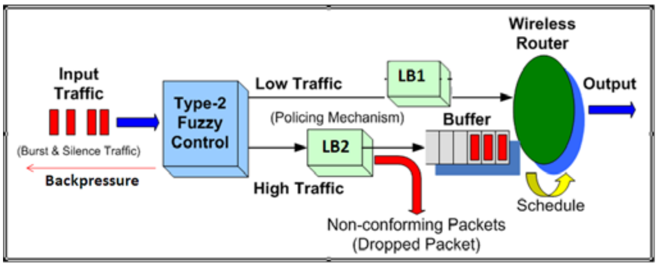

Figure 10. Simulation model.

Input traffic goes to type-2 fuzzy control. Sources are low speed and various types of the burst/silence are narrow then they go to LB1. If sources are Low speed and various types of burst/silence are wide then they go to LB2. If sources are high speed then they go to LB2.

The source transmits frames into the link and a finite buffer to hold frames. Frame arrival process is random and the inter-arrival time between frames follow a particular distribution function. Furthermore, the arriving frame is given to the link processor, which immediately starts transmitting the frame, while the buffer is not empty, the link processor retrieves a frame at a time from the buffer in a first-in-first-out (FIFO) order and transmits it onto the link. The link processor is never idle when there has been a frame waiting in the buffer.

This research confines the discussion, mainly on data. Data sources are generally bursty in nature, whereas voice and video sources can be continuous or bursty, depending on the compression and coding techniques used.

B. Characteristics of Queuing Network Model

There are three components with certain characteristics that must be examined before the simulation models are developed.

1) Arrival characteristics

The pattern of arrival input traffic mostly is characterized to be *Poisson Arrival Processes* [8]. Like several random events, Poisson's arrivals occur such a manner that for each increment of time (*T*), no matter how large or small, the probability of arrival is independent of any previous history. These events may be individual labels, a burst of labels, label or packet service completions, or other arbitrary events.

The following formulae give the resulting probability density function (pdf), which the inter-arrival time *t* is larger than some value *x* when the average arrival rate is ¸ events per second:

$$f_x(t) = \begin{cases} e^{-\lambda t}, \ for \quad t \ge 0 \\ \ 0, \ for \quad t < 0 \end{cases} \qquad (1)$$

$$F_x(t) = P(X \le t) = \int_0^t e^{-\lambda x} dx \qquad (2)$$

2) Service facility characteristics

In this paper, service times are randomly distributed by the *exponential probability distribution*. This is a mathematically convenient assumption if arrival rates are Poisson distributed. In order to examine the traffic congestion at output of wireless router (54Mbps) [9], the service time in the simulation model is specified by the speed of output link, giving that a service time is 42.65 µs per frame where the frame size is 2346 bytes [10].

3) Source traffic descriptor

The source traffic descriptor is the subset of traffic parameters requested by the source (user), which characterizes the traffic that will (or should) be submitted during the connection. The relation of each traffic parameter used in the simulation model is defined below.

PFR(peak frame rate) = $\lambda a = 1/T$ in units of frames/second, where T is the minimum inter-frame spacing in seconds. This research focuses on:

PFR = λa = (20 Mbps)

Hence, T = 117.30 µsec.

VI. Results And Analysis

The comparison among leaky bucket, type-1 fuzzy and type2-fuzzy using backpressure are shown in Fig. 11-15.

This part indicates simulation results from the leaky bucket, Type1 fuzzy and type2 fuzzy using backpressure performance will be compared. The input frames (frame rate varies from 0 Mbps to 100 Mbps) with various types of burst/silence performed simulation results are shown in Fig. 11. It obviously determines that the type-2 fuzzy (T2F) is the best of throughput guarantee. Throughput is one of the causes of QoS to help guarantee higher reliability of network performance. In conclusion, the T2F may assure higher reliability to handle uncertain traffics compared to the other type-1 fuzzy (T1F) and leaky bucket (LB).

Fig. 12 shows the results that T2F will generate the lowest dropped frames compared to the other mechanisms. We can help protect the conforming frames by reducing the number of dropped frames. A regular network may cause a poor QoS by higher non-conforming or dropped frames.

Fig. 13, the result shows that the utilization of the LB scheme is the lowest. From this viewpoint, the processing unit will be available for other sources in terms of sharing. The result is in the line of low processing power required by LB because LB is likely to produce fewer conforming frames and higher dropped frames. Most frames are discarded before transferring (entering the network) to the entrance of the network. It seems like LB makes less congestion, but it will reflect the lower throughput in return. Both T1F and T2F result higher in utilization factor, but the figure does not go beyond the saturated point. It is because both schemes make more conforming frames as well as the higher number in successful retries.

Fig. 14 and 15 show that T2F has to make all frames wait longer in the queue at the sender and next to the entrance of network, respectively. It is due to fewer packets dropped and higher numbers of successful retry (make all possible retransmission). It is apparent that both mean queue length and mean queue time for both schemes are higher in general while LB makes less. Optimistically, with the same size of the buffer, T2F is confirmed to be high-risk-high-return while LB seems to be a traditional scheme.

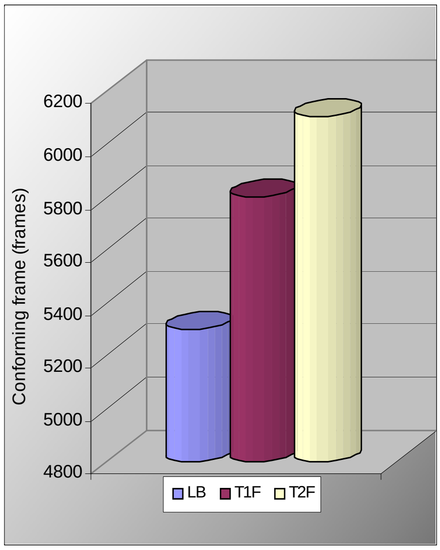

Figure 11. Illustrates conforming frames comparison among leaky bucket (LB), Type-1 Fuzzy (T1F), and Type-2 Fuzzy (T2F).

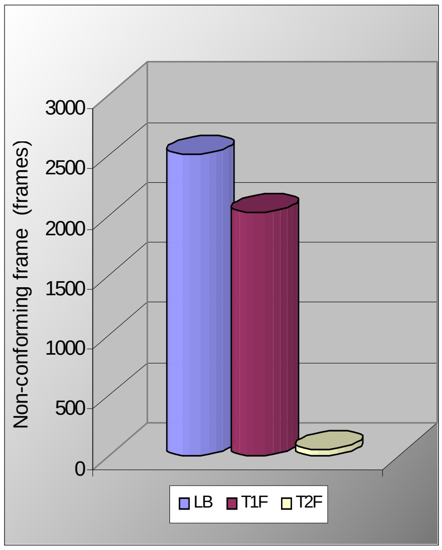

Figure 12. Ilustrates non-conforming frames comparison among leaky bucket (LB), Type-1 Fuzzy (T1F), and Type-2 Fuzzy (T2F).

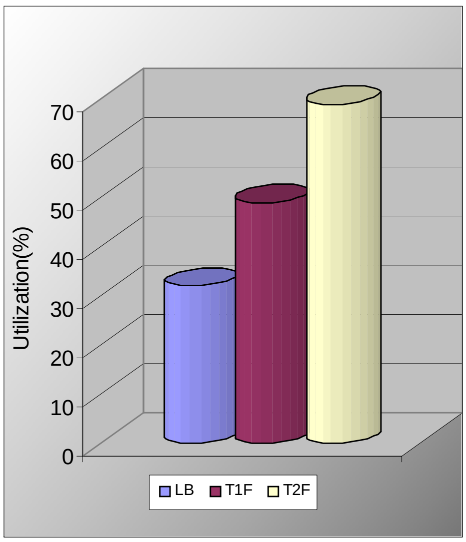

Figure 13. Illustrates the utilization comparison among leaky bucket (LB), Type-1 Fuzzy (T1F), and Type-2 Fuzzy (T2F).

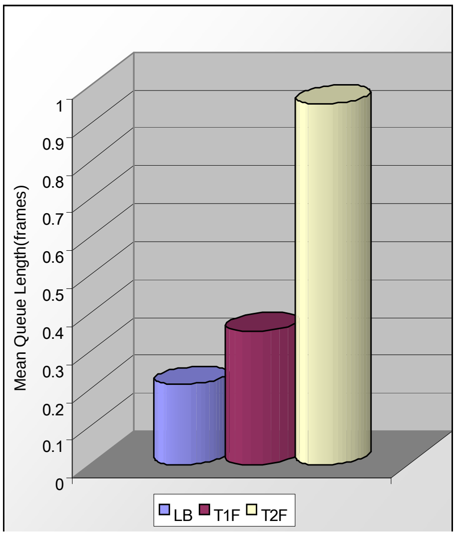

Figure 14. Illustrates the mean queue length comparison among leaky bucket (LB), Type-1 Fuzzy (T1F), and Type-2 Fuzzy (T2F).

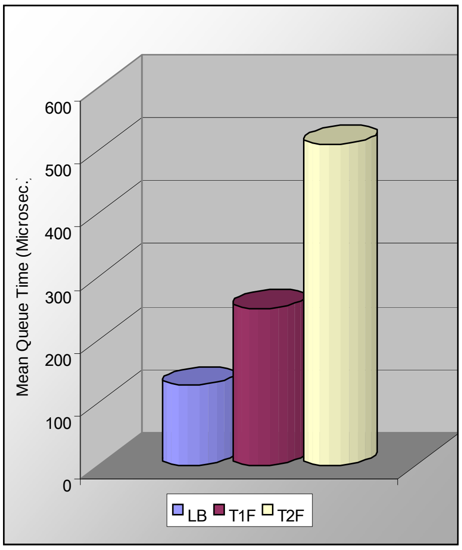

Figure 15. Illustrates the mean queue time comparison among leaky bucket (LB), Type-1 Fuzzy (T1F), and Type-2 Fuzzy (T2F).

VII. Conclusions And Recommendations For Future Research

In this paper, we carried out a comprehensive study to investigate the performance of three selected traffic shaping mechanisms, type-1 fuzzy control and type-2 fuzzy control with various types of burst/silence traffic. The study was accomplished through simulation after developing an analytical queuing model.

We found that based on simulation results in general, the type-2 fuzzy using backpressure control traffic shaping mechanism appeared to be the best outperforming compared to the others (type-1 fuzzy control and traditional traffic shaping mechanism) in terms of maximizing the number of conforming frames; less non-conforming frame. It is also believed that type-2 fuzzy control in traffic shaping mechanism seem to be suitable for data and multimedia under various types of the burst/silence traffic conditions.

In the future research, we will focus on the investigation of neural fuzzy control queueing system and deplete rate with the traffic mechanism.

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