A MODEL OF FUZZY CONTROL BACKPRESSURE IN POLICING MECHANISMS FOR VDSL NETWORK

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ABSTRACT

With fuzzy logic it is possible to convert knowledge, which is expressed in an uncertain form, to an exact algorithm. Fuzzy control is based on fuzzy logic, which provides an efficient method to handle inexact information as a basis of reasoning. In fuzzy control, the controller can be represented with if-then rules. The interpretation of the controller is fuzzy but the controller is processing exact input-data and is producing exact output-data in a deterministic way. However, traditional policing mechanisms have proved to be inefficient in coping with the conflicting requirements of ideal policing mechanisms, that is, low dropping frames and high conforming frames. This led us to explore alternative solutions based on artificial intelligence techniques, specifically, in the field of fuzzy systems. In this paper, we propose a fuzzy control backpressure in policing mechanism that aims at detecting violations of parameter negotiated. We evaluate and compare the performance of the three fuzzy logic control backpressure in policing mechanisms, namely: Fuzzy backpressure Leaky Bucket(FBPLB), Fuzzy backpressure Jumping Window(FBPJW) and Fuzzy backpressure Triggered Jumping Window(FBPTJW) with conventional policing mechanisms, namely: Leaky Bucket(LB), Jumping Window(JW) and Triggered Jumping Window(TJW). Simulation results show that on VDSL frames, the fuzzy logic control scheme help improve performance of our fuzzy control backpressure in policing mechanisms much better than conventional policing one while various types of burst/silence traffic are generated.

KEYWORDS : VDSL, Fuzzy Control Backpressure and Policing Mechanisms.

1. INTRODUCTION

Video on demand, video conference and many other popular networking application services on the same telecommunication network are now common services on telecommunications network. To meet these demand for bandwidth, technology of choice used to deploy to next generation network is Very High Data Rate Digital Subscriber Line(VDSL) technology, which is a modem technology using existing twisted-pair telephone lines to transport high-bandwidth data, such as multimedia and video, to service subscribers. Recently, VDSL is very significant attention from implementers and service providers as it guarantees to deliver high-bandwidth data rates to dispersed locations with little changes to the existing infrastructure. VDSL services are dedicated, point-to-point, public network access over twisted-pair copper wire.

In VDSL networks, there is always chance that large number of traffic sources become temporarily active at the peak rate, or close to it, causing sever network congestion. To prevent this situation some congestion control mechanisms depend on type of source. Also, some policing mechanisms can degrade the main performance measures, such as non-conforming frame, bandwidth allocation, frame delay, throughput and other grade of service measures.

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Nowadays, we are faced with increasingly complex control problems .for which different modeling representations may be difficult to obtain. This difficulty has simulated the development of alternative modeling and control techniques which include fuzzy logic based ones. Fuzzy modeling methods may lead to models that describe the behavior of systems sufficiently well for their application in fuzzy control. Thus due to the demand for inexpensive but reliable models, the fuzzy modeling approach may turn out to be a useful complement to traditional modeling and control approaches when both the complexity and uncertainty about the system increases. This is of great practical significance, since modeling is usually the bottleneck for the application of effective control.

There are many previous studies involving traffic policing mechanism[1][2][3][4] however the behavior of fuzzy control policing with VDSL is not mention. In this paper, we proposed that the comparison the performance between policing mechanism and fuzzy control policing mechanism of VDSL network.

This paper is organized as follows. In Section II, an overview of the most significant traffic policing mechanisms already proposed in literature is proposed. Section III, we define the model of a fuzzy control policing mechanism. Section IV, we define the simulation model. Section V contains a performance evaluation of the proposed solution and comparison to traditional policing mechanisms. Section VI, some conclusion and recommendation for future research are draw].

2. DESCRIPTION AND MODELING OF TRAFFIC POLICING

2.1 Requirement for policing mechanism

Traffic policing allows us to control the maximum rate of traffic sent or received on an interface during the entire active phase and must operate in real time.

In addition to these requirements, mechanism of parameter violations must be short to avoid flooding of the relatively small buffers in the network. To meet these somewhat conflicting requirements, several policing mechanism have been proposed so far. Several mechanisms have been proposed which are described in following sections.

2.1.1 *Traffic source Models*

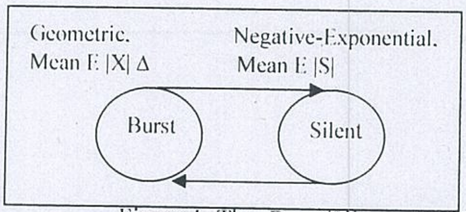

Figure 1. The Burst/Silence Traffic Model

In this section, we describe the traffic model, simulation method. In our simulation, a burst traffic stream from a single source is modeled as a Burst/Silence traffic stream. The Burst-period models a single flow and Silence-period models is silent. Burst-periods and Silence-periods are 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 time during a burst is given by Δ. With

$\alpha^{-1} = E[X] \times \Delta$
and
$\beta^{1} = E[S]$

2.1.2 Policing Mechanism Models

Various congestion control traffic policing mechanisms[1]. In this paper selected three policing mechanisms include the Leaky Bucket(LB), the Jumping Window Mechanism(JW) and The triggered jumping window(TJW).

The Leaky Bucket Mechanism

The most popular and simple policing mechanism is the leaky bucket (LB). 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 policing 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[1][5].

The Jumping Window Mechanism (JW)

The JW mechanism limits the maximum number of frames accepted from a source within a fixed time interval (window) to a maximum number N. The new interval starts immediately at the end of the preceding interval (jumping window) and the associated counter is restarted again with an initial value of zero. Therefore, the time interval during which a specific frame is influencing the counter value varies from zero to the window width. The implementation complexity of this mechanism is comparable to the complexity of the LB mechanism. Counters are needed to measure the interval T and to count the number of arrivals, and variables are needed for the counter limit and the interval length T. The probability that policing actions must be taken on a frame can be computed by using the counting process for the frame arrivals, which characterizes the number of arriving frames in an arbitrary time interval. For example, the counting process for negative-exponential inter-arrival times is a Poisson process.

The Triggered Jumping Window Mechanism (TJW)

The time window is not synchronized with source activity in the JW mechanism. To avoid the ambiguity problems arising from that fact, the "triggered jumping window" mechanism has been proposed, where the time windows are not consecutive but are triggered by the first arriving frame. The implementation complexity for this mechanism is comparable to the complexity of the mechanisms described above.[7]

2.2 Comparison of the mechanism

2.2.1 Definition of comparisons

A general framework for studying the performance of traffic policing is presented in this section. For constant rate traffic, the existing policing mechanism such as LB, JW, and TJW compare its performance. The source traffic is characterized by peak rate λp, average rate λa and delay variation (DV) parameters. The LB analogy refers to a bucket with a hole in the bottom that causes it to 'leak' at a certain rate corresponding to a peak rate (PR) parameter. The 'depth' of the bucket (B) corresponds to a delay variation parameter (DV), which can be calculated by $DV * PR$. While window mechanisms JW and TJW are given the ratio of maximum accepted number of frames per interval N and window width T by:

$$T = N / \lambda p$$

3. FUZZY CONTROL BACKPRESSURE IN POLICING MODEL

In this section, we will first describe a new fuzzy control policing mechanism which meets the requirements of performance, flexibility and cost-effective implementation of VDSL networks.

3.1 Fuzzy Control Theory Background.

Fuzzy logic is a method for representing information in way that resembles natural human communication, and for handling this information in a way that is similar to human reasoning. Concepts of fuzzy sets, fuzzy logic, and fuzzy logic control have been introduced and developed by Zedeh [8] [9] [10].

Fuzzy control denotes the field within control engineering or computer science in which fuzzy set theory and fuzzy inference are used to derive control law. It is especially useful for simulations in which either the system to be controlled or its input cannot be adequately modeled mathematically.

The concept of a fuzzy set is an extension of the concept of a tradition, or crisp, set. For a crisp set , an element either belongs to or does not. This relationship can also be expressed as a mapping whose domain is some characterization of possible elements of and whose range is the binary space . This mapping is called the characteristic function of the crisp set . A fuzzy set, on the other hand, is defined by a membership function whose range is the closed interval . Any value between 0 and 1 can express the degree of membership of a particular element in the fuzzy set. This concept of fuzzy sets makes it possible to use fuzzy inference, in which the knowledge of an expert in a field of application is expressed as a set of "IF–THEN" rules, leading to algorithms describing what action should be taken based on currently observed information, or in our case, on predicted future information. Fuzzy controllers are the applications of fuzzy sets and fuzzy inference in control theory. Their operation is typically divided into the following three phases[11] .

Fuzzifier: The fuzzifier converts the input system performance parameters into suitable linguistic values which are needed in the inference engine.

Fuzzy Rule Base: The fuzzy rule base contains a set of fuzzy control rules, defined in a linguistic way, to describe the control policy.

Inference Engine: The inference engine infers the fuzzy control action under the fuzzy control rules and the related input linguistic parameters.

Defuzzifier: The defuzzifier converts the inferred fuzzy control action into a nonfuzzy control action under a defuzzification strategy.

To summarize, a fuzzy inference engine maps fuzzy sets to fuzzy sets. In control engineering applications we almost always deal with numerical values. The Fuzzifier and Defuzzifier modules act as interfaces between linguistic world of the fuzzy inference engine and numerical world. The Fuzzifier module takes a numerical value and maps it to a fuzzy set, while the Defuzzifier module takes a fuzzy set and produces a non-fuzzy output whose objective is to represent the possibility distribution of the inference[12][13][14][15].

3.1.1 Regulator Input Fuzzification

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

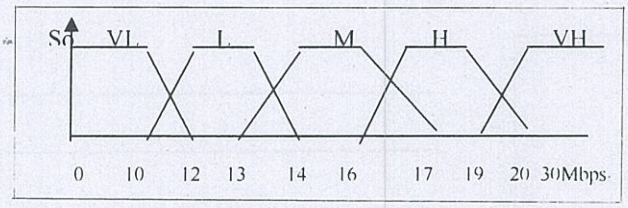

Figure 2. Library of fuzzy sets used in the fuzzification process
(The term set of the input variable So)

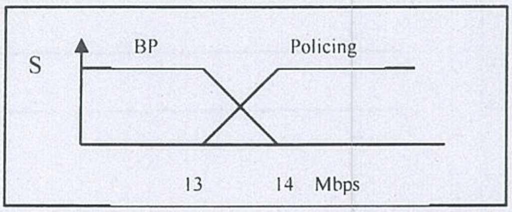

Figure 3.The term set of output variable S

3.1.2 Inference, Fuzzy Rules and Defuzzification

Fuzzy set s are involved only in rule premises. Rule consequences are crisp functions of the output variables (usually linear functions). It is robust because few rules are needed for control. There is no separate defuzzification step. Based on our defined measurement input variables and their membership functions, the fuzzy system is described by five fuzzy IF-THEN rules, each of which locally represents a linear input-output relation for the regulator. In Figure 4. shows the fuzzy rules that are used to be implement our research.

IF So is VeryLow (VL)	THEN S is BP
IF So is Low (L)	THEN S is BP
IF So is Medium (M)	THEN S is Policer
IF So is High (H)	THEN S is Policer
IF So is VeryHigh (VH)	THEN S is Policer

Figure 4. The fuzzy rules

Figure 2 and Figure 3 respectively show the membership functions of the linguistic values the input variable So and the output variable S can take. Analysis of the fuzzy system rules (Figure 4) shows that if Sources are Very Low and Low (So is VeryLow or Low) then sources go directly to server. If sources are Medium, High and Very High (So is Medium, High or VeryHigh) then sources go to policer mechanism.

In our models, fuzzy control policing mechanism uses a set of linquistic rules (Figure 2,3,4). The selection of rule base is based on our experience and beliefs on how the system should behave. Recently, in the fuzzy control literature, some formal techniques for obtaining a rule base by using artificial neural networks or genetic algorithms has appeared. Nevertheless, we have used the conventional trial and error approach [16]. Input traffics allow a burst traffic stream (ON/OFF stream) to fluctuate our VDSL network which they are controlled by Fuzzy controller.

In fuzzy control backpressure in leaky bucket model (FBPLB), if source traffic is very low or low then it goes directly to server. If source traffic is medium or high or very high then it goes to leaky bucket.

In fuzzy control backpressure in jumping window model (FBPJW), if source traffic is very low or low then it goes directly to server. If source traffic is medium or high or very high then it goes to jumping window.

In fuzzy control backpressure in triggered jumping window model (FBPTJW), if source traffic is very low or low then it goes directly to server. If source traffic is medium or high or very high then it goes to triggered jumping window.

Fuzzy logic controller design is implemented using MATLAB 6.1 version. Whenever there is a change in the arrival rate only some rules are fired leading to changes in the indices which in turn changes a way to go to server or policing mechanism.

4. SIMULATION MODEL

The following figure 5 shows a simulation model used in this paper.

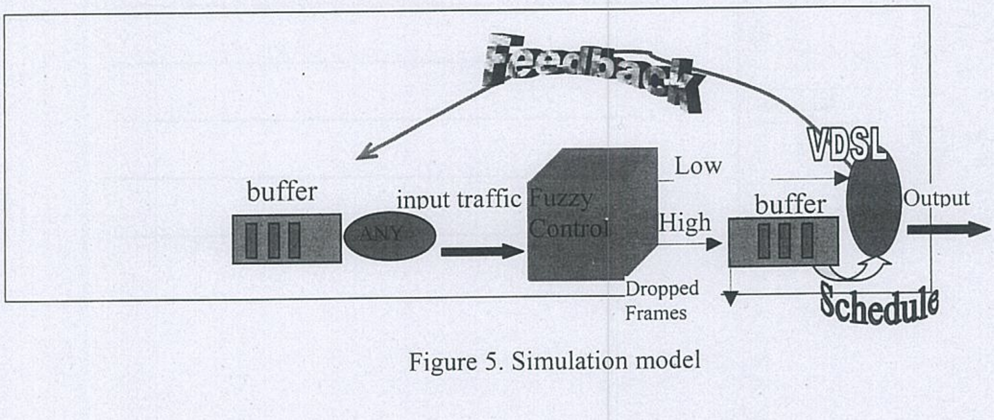

Figure 5. Simulation model

4.1 Input traffic

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

4.2 CHARACTERISTICS OF QUEUING NETWORK MODEL

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

4.2.1 Arrival Characteristics

The pattern of arrivals input traffic mostly is characterized to be *Poisson arrival processes*[8]. Like many random events, Poisson arrivals occur such 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 probability of the inter-arrival time between event t, is defined by the ***inter-arrival time probability density function (pdf)***. The following formula gives the resulting probability density function (pdf), which the inter-arrival time t is larger than some value x when the average arrival rate is λ events per second:

$$fx(t) = \begin{cases} e^{-\lambda t}, for & t \geq 0 \\ 0 \quad , for & t < 0 \end{cases}$$

$$p(t \leq x) = Fx(x) = \int_0^x e^{-\lambda x} dx = 1 - \lambda e^{-\lambda x}$$

$$p(t > x) = 1 - Fx(x) = \lambda e^{-\lambda x}$$

In this paper, we adopt the ON/OFF bursty model rather than Markov Modulated Poisson Process (MMPP) then the burstiness is varied by altering the ON and OFF [7],[16].

4.2.2 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 VDSL downstream link (15Mbps)[17], the service time in the simulation model is specified by the speed of this VDSL link, resulting that a service time is set to be exponential distribution with mean 216 µs ,where the frame size is 405 bytes[18]. Buffer size prior to the policing unit is identical to 20 frames while the buffer size at the entrance to VDSL network is set to be 1,024 frames [17]. Once it is exceeding the buffer size then it is considered to be a non-conforming frames (or dropped frames).

4.2.3 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)= λa = $1/T$ in units of frames/second, where T is the minimum inter-frame spacing in seconds. This paper focuses on :

PFR = λa = 10Mbps(3086.42 frames/s)
Hence, T=324 µs (1/3086.42 s).

5. RESULTS AND ANALYSIS

The comparison between existing policing mechanism (LB, JW, TJW) and fuzzy control backpressure in policing mechanisms (FBPLB, FBPJW, FBPTJW) is shown in figure 6-10.

5.1 The comparison between policing mechanism and fuzzy control backpressure in policing mechanism

This section focuses on the simulation results as LB, JW, TJW, FBPLB, FBPJW and FBPTJW performance will be compared. The input frames (frame rate varies from 5 Mbps to 29 Mbps) with burst/silence ratio of 100:300 performed simulation results as shown in Figure 6. It clearly determines that the fuzzy control backpressure in policing mechanism (FBPLB, FBPJW, FBPTJW) is better than traditional policing mechanism (LB, JW, TJW).

In Figure 7. demonstrates that we can help conserve the conforming frames by reducing dropped frames. The highest number of dropped frames as shown in this figure is traditional policing mechanisms. Compared to other fuzzy control backpressure in policing mechanisms with burst/silence ratio as of 100:300.

In Figure 8. the simulation result determines more utilization of fuzzy control backpressure in policing mechanisms comparing to traditional policing mechanisms with burst/silence ratio of 100:300. It is not problem about network congestion because the utilization is less than 80 %.

In Figure 9. shows that all fuzzy control backpressure in policing mechanisms, all frames have to wait longer in the buffer next to the entrance of VDSL network. The consequence of long waiting hour is compatible to results shown in Figure 10. We can observe many more frames in average reside in the queue prior to the entrance of VDSL network. We can solve this problem by increasing data rate of VDSL.

In conclusion, fuzzy control backpressure in policing mechanisms perform better than traditional policing mechanisms in from of conforming and non-conforming frames.

6. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

In this paper, we carried out a comprehensive study to investigate the performance of three selected traditional policing mechanisms: namely LB, JW, TJW and fuzzy control backpressure in policing mechanism: namely FBPLB, FBPJW, FBPTJW with various bursty/silence sources. This study was accomplished through simulation. A simulation model was developed.

We found out that, from simulation result in general the fuzzy control backpressure in policing mechanisms are better than traditional policing mechanisms various bursty/silence sources. The fuzzy control backpressure in policing mechanisms will also help ease the tremendous amount of traffic fluctuate into the VDSL network and prevent the network from bottleneck with the 10%-30% reduction of traffic load as shown 6 and 7. Fuzzy control mechanisms can guarantee that they are better than traditional policing mechanisms.

In the future work, we will extend into two areas, first we intend to investigate the back-off schemes (both random and exponential scheme applied at the buffer and we will apply the fuzzy logic to find the better solution among our different policing mechanisms. The performance of difference input parameters has been obtained by solely simulation. It will be perform better if we can derive some mathematic equations for our analytical models by approximation method to analyze the performance at different level of input parameters.

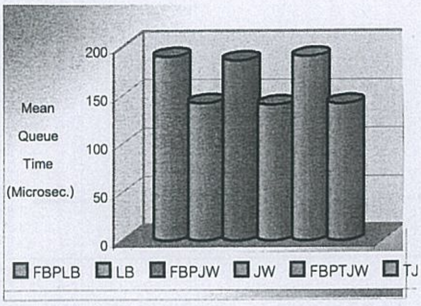

Figure 6 illustrates the comparison between conforming frames in FBPLB. LB. FBPJW. JW. FBPTJW and TJW at burst : silence = 100:300

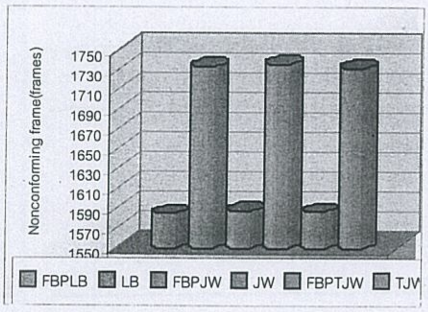

Figure 7 illustrates the comparison between non-conforming frames in FBPLB. LB. FBPJW. JW. FBPTJW and TJW at burst : silence = 100:300.

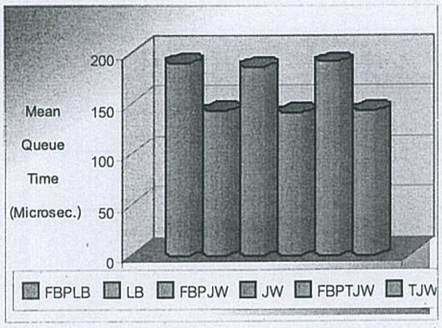

Figure 8 illustrates the utilization comparison between FBPLB. LB. FBPJW. JW. FBPTJW and TJW at burst : silence = 100:300.

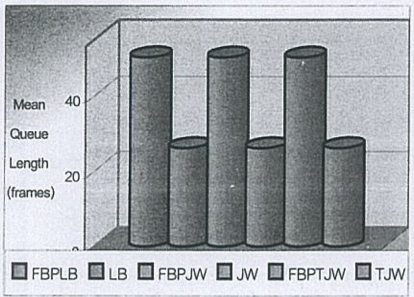

Figure 9 illustrates the mean queue length comparison between FBPLB. LB. FBPJW. JW. FBPTJW and TJW at burst : silence = 100:300.

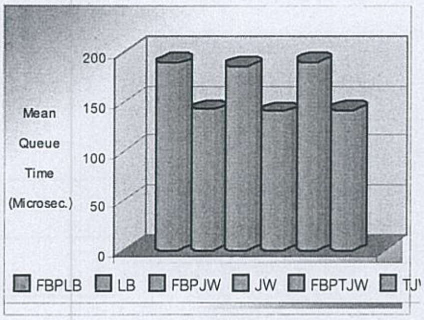

Figure 10 illustrates the mean time in queue comparison between FBPLB. LB. FBPJW. JW. FBPTJW and JW at burst : silence = 100:300

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