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Performance Evaluation of VDSL Network with Fuzzy Control Policing Mechanisms

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Abstract

Fuzzy control is based on fuzzy logic, which provides a most efficient way to handle inexact information as a basis of reasoning. With fuzzy logic it is possible to convert knowledge, which is expressed in an uncertain form, to an exact and precise output for uncertain systems. In fuzzy control, the controller can be simply represented by if-then-else rules. The interpretation of the controller is fuzzy but the controller will process an input-data then produce an 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 due to the adjustment of unpredictable input data rates. This will lead us to explore alternative solutions based on artificial intelligence techniques, specifically, in the field of fuzzy systems. In this paper, we propose a fuzzy logic to control policing mechanisms that aim at detecting violations of negotiated parameters such as input data rates, token rates and etc. We evaluate and compare the performance of the three fuzzy logic control policing mechanisms, namely: Fuzzy Leaky Bucket (FLB), Fuzzy Jumping Window (FJW) and Fuzzy Triggered Jumping Window (FTJW) 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 policing mechanisms much better than conventional policing ones while various types of burst/silence traffic are employed

Keywords: *Fuzzy logi, dropping frames, conforming frames, artificial intelligence.*

Introduction

In VDSL networks, large number of traffic sources becomes an active load at the peak rate, or close to it, causing all processing units a congestion. To prevent this situation, some congestion control mechanisms are developed. Although, policing mechanisms may drop or affect somehow the system performance due to the processing time caused by the policer, but they help increase the main performance measures such as conforming frames, end-to-end delay, throughput and other grade of service measures in return.

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At current time, we are faced with increasingly complicated control problems at the level of different input data rates (McDysan 2000). This difficulty has a way out by simulating the alternative input models and control techniques, based upon fuzzy logic rules.

There are many previous studies involving traffic policing mechanism, however, the behavior of fuzzy control policing in VDSL network is not mentioned. In this paper, we proposed fuzzy control policing mechanism in the VDSL network. The paper is organized as follows. Section II describes an overview of the most significant traffic policing mechanisms. The model of a fuzzy control policing mechanism will be explained in a later section. The simulation model used in our experiment will also be cited. Finally, simulation results and analysis including the suggestion for future work will be discussed.

Modeling of Traffic and Policing

Traffic Source Model

Traffic policing allows us to control the maximum rate of traffic sent or received by an interface during the entire active transmission process. 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 as described in following sections.

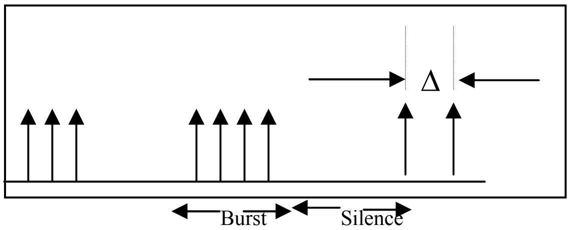

Fig. 1. The Burst/Silence traffic model.

In this section, we describe the traffic model used in simulation method. In our simulation, a burst traffic stream as shown in Fig. 1, from a single source is employed. Burst 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

$\beta^{1} = E[S]$

Policing Mechanism Models

Various congestion control traffic policing mechanisms have been introduced by Pitiporn (2002). However, in this paper, only underlying three policing mechanisms have been adopted, including Leaky Bucket (LB), Jumping Window (JW) and Triggered Jumping Window (TJW).

Fuzzy Control 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 for VDSL network.

Fuzzy logic is a method for representing information in a way that resembles natural human communication, and for handling this information in the way that is similar to human reasoning. Concepts of fuzzy sets, fuzzy logic, and fuzzy logic control have been introduced and developed by (Hu and Peter 2000).

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, the 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.

Fuzzifier

The fuzzifier converts the input system performance parameters into suitable values that are needed in the inference engine.

***Fuzzy Rule Base*:** The fuzzy rule base contains a set of fuzzy control rules, defined in such a 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 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 numerical nonfuzzy sets. In control engineering applications we always deal with numerical values. The *Fuzzifier* and *Defuzzifier* modules act as interfaces between the world of the fuzzy inference engine and the world of numerical values. 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.

1. 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 Fig. 2.

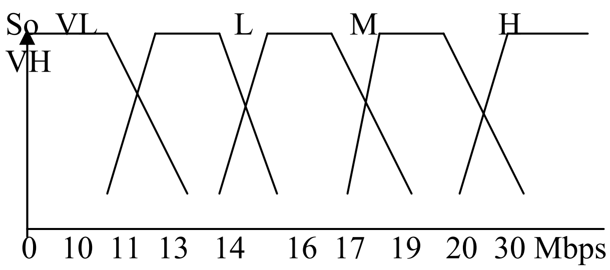

Fig. 2. Library of fuzzy sets used in the fuzzification process (So is set of the input variable)

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

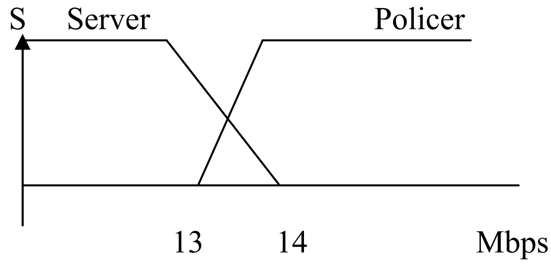

Fig. 3. The set of output variable S.

described by five fuzzy IF-THEN rules, each of which locally represents a linear input-output relation for the regulator. Fig. 4. shows the fuzzy rules used in our research.

IF So is Very Low (VL)	THEN S is Server
IF So is Low (L)	THEN S is Server
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

Fig. 4. The fuzzy rules

Fig. 2 shows the membership function of all values for the input variable So. Fig. 3 demonstrates the output variable S. The fuzzy system rules, as shown in Fig. 4, predict that If Source (So) is Very Low or Low Then source selects to forward all inputs directly to server. But If source is Medium or High or Very High Then source will decide to forward all inputs to policing mechanism instead.

In our models, fuzzy control policing mechanism is based upon a set of fuzzy rules. The selection of rule base is based on experiences 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 been developed. Nevertheless, we have employed the conventional trial and error approach. Input traffics allow a burst traffic stream (ON/OFF stream) to fluctuate the VDSL network that is controlled by fuzzy controller.

In fuzzy control leaky bucket model (FLB), fuzzy control jumping window model (FJW) and fuzzy control triggered jumping window model (FTJW), we use the same fuzzy rules as described above. Fuzzy logic controller design is implemented by using Simulink imbedded in 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 direct all inputs to either server or policing mechanism.

Simulation Model

Fig. 5 shows a simulation model used in the paper.

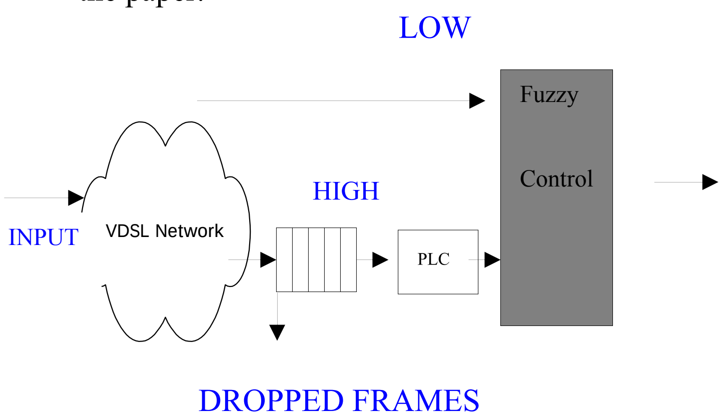

Fig. 5. Simulation model.

Input traffic to VDSL network

This paper confines the discussion mainly on telecommunications traffic. Telecommuni-cation traffic sources are generally bursting in nature whereas other types of video sources can be continuous or bursting, depending on the compression and coding techniques used.

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 arrivals input traffic mostly is characterized to be *Poisson arrival processes.* 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 (http://www.dlink.pl/docs/datenblatt/DEV3001_datasheet_en.pdf.).

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

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

PFR = λp = 10Mbps(3086.42 frames/s)

Hence, T=324 μs (1/3086.42 s).

Result and Analysis

The comparison between existing policing mechanism (LB, JW, TJW) and fuzzy control policing mechanism (FLB, FJW, FTJW) is shown in Figs. 6-9.

The simulation results as of LB, JW, TJW and FLB, FJW, FTJW will be compared. The input frames (varying from 5 to 29 Mbps) with burst/silence ratio of 100:300 are performed by simulation and results are shown in Fig. 6. It clearly determines that the fuzzy control policing mechanism (FLB, FJW, FTJW) is much better than traditional policing mechanism (LB, JW, TJW) if the conforming frames are taken into account. The increment of conforming frames will help boost up the performance level and help guarantee higher reliability of the VDSL network as such due to more frames traversing from source to destination.

Fig. 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 with burst/silence ratio as of 100:300. Results assure that as far as we can eliminate the problem of dropped frames, in return we can gain a higher conforming frame. The non-conforming frames are major factor of improving the system performance.

In Fig. 8, the simulation result determines more utilization of fuzzy control policing mechanisms comparing to traditional policing mechanisms with burst/silence ratio of 100:300. The increment of utilization factor seems not to be relevant to the performance improvement. The higher utilization may cause an approach of bottleneck situation, which can in general boggle down the system. In fact the step up from 79 to 83% in FLB will not affect the situation of bottleneck as a little higher compared to the utilization factor of LB. Positively this factor will improve the cost effectiveness of the VDSL devices rather.

Fig. 9 shows that all fuzzy control 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 a higher situation of utilization factor found in Fig. 8. We can observe many more frames in average reside in the queue prior to the entrance of VDSL network. We can help ease this congestion by increasing the data rate in VDSL network to be higher.

We found out that, from simulation result in general the fuzzy control policing mechanisms are better than traditional policing mechanisms various bursty/silence sources. The fuzzy control policing mechanisms will also help ease the tremendous amount of traffic fluctuate into the VDSL network and prevent the network from bottleneck with the 5-20% reduction of traffic load as shown in Figs. 6 and 7. Fuzzy control mechanisms can guarantee that they are better than traditional policing mechanisms.

In the future work, we will focus on the investigation of the back-off schemes (both random and exponential scheme applied at the buffer).

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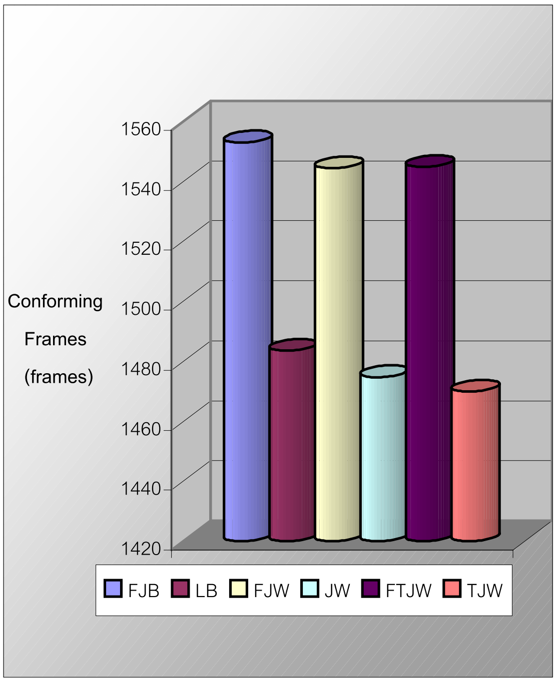

Fig. 6. The conforming frames comparison between FLB, LB, FJW, JW, FTJW and TJW at burst: silence = 100:300

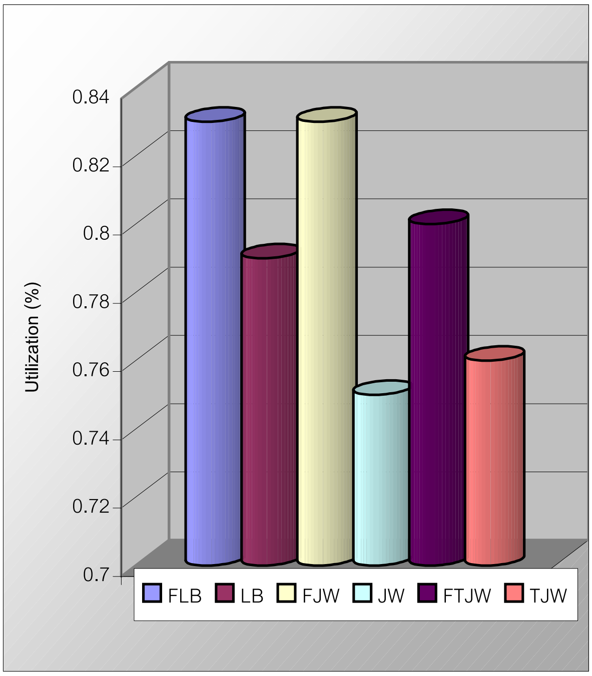

Fig. 8. The utilization comparison between FLB, LB, FJW, JW, FTJW and TJW at burst: silence = 100:300.

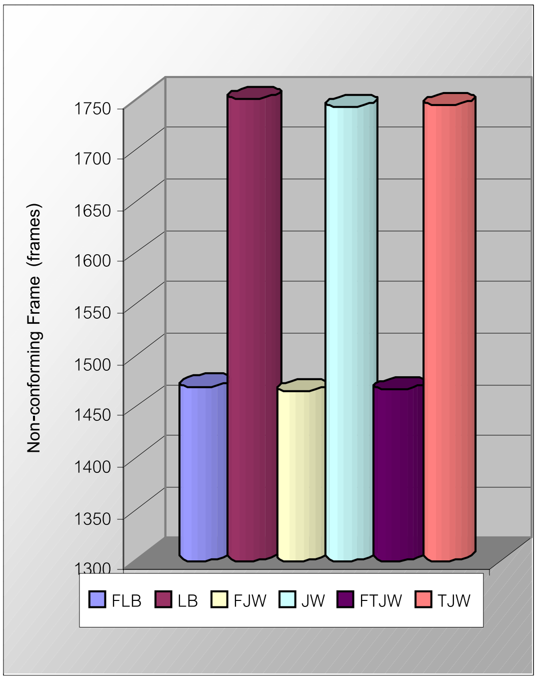

Fig. 7. The non-conforming frames comparison between FLB, LB, FJW, JW, FTJW and TJW at burst: silence = 100:300.

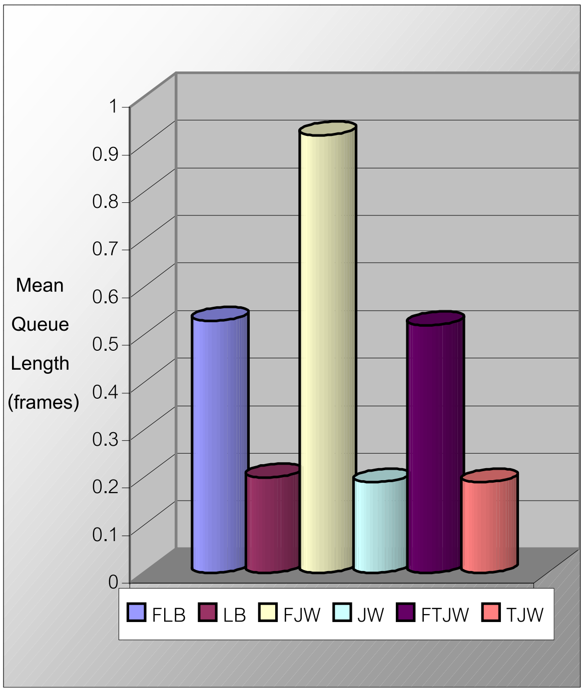

Fig. 9. Mean queue length comparison between FLB, LB, FJW, JW, FTJW and TJW at burst: silence = 100:300.