Available online at http://rjas.rsu.ac.th

Rangsit Journal of Arts and Sciences, July-December 2016 RJAS Vol. 6 No. 2, pp. 109-116

ISSN2229-063X (Print)/ISSN2392-554X (Online)

A rough set control token leaky bucket in policing mechanism schemes over high speed network

Somchai Lekcharoen[1*] and Sumaman Pankham[2]

College of Information and Communication Technology, Rangsit University, Patumthani 12000, Thailand
[1]E-mail: somchai.l@rsu.ac.th; [2]E-mail: sumaman.p@rsu.ac.th

[*]Corresponding author

Submitted 6 March 2016; accepted in final form 15 August 2016
Available online 19 December 2016

Abstract

The research objective is to evaluate and compare the differences between the rough set token leaky bucket (RST) and the leaky bucket (LB) as a policing mechanism in reference to traffic fluctuations on data networks. The original policing mechanism scheme has LB for traffic with a nearly constant burst and silence, however, when overflow occurs in the buffer router, incoming frames are dropped. We propose an RST in policing mechanism to help prevent the drop of incoming frames and to aid in the detection of violations in parameter negotiation. A rough set converts knowledge, which is expressed in an uncertain form to a certain form. The simulation results show that in very-high-bit-rate digital subscriber line (VDSL) frames, the rough set control system helps improve the performance of our RST as a policing mechanism better than traditional policing mechanisms by about 12% in terms of conforming and non-conforming frames on various types of the burst/silence traffic generated.

Keywords: *policing mechanism, rough set, rough set token leaky bucket, token, token LB, LB, RST, TLB, VDSL*

1. Introduction

A high speed network device always has a limited buffer size when it receives more frames from a source device than it can send to a destination. When a buffer in a network device overflows, it will drop incoming frames called non-conforming frames which causes network congestion and degraded throughput because a source device must retransmit frames.

A very-high-bit-rate digital subscriber line (VDSL) is a broadband speed network in excess of 20 Mbps, yet it still encounters congestion when a source transmits at peak rate. The solution to this problem is to take precautions before the congestion occurs in the high-speed network by preserving the traffic parameters that interact with the other network, such as data rate, peak rate, burst/silence, etc. The mechanism used to take care of this problem is the policing mechanism scheme, with the original policing mechanism scheme having the leaky bucket (LB) prior buffer.

This paper aims to evaluate and compare between the rough set token leaky bucket (RST) and LB as a policing mechanism by applying the RST concepts to the network queue. There were many previous studies involving policing mechanisms (Maratsolas, Koutsakis, & Lazaris, 2014; Moraes, & Guardieiro, 2012; Wagner, 2014), token leaky bucket (TLB) (Aeron, 2010; Moraes, & Guardieiro, 2012), and rough set mechanisms (Mitra, Satapathy, & Paul, 2013). However, RST compared with the behavior of LB in terms of the policing mechanism is not mentioned. We therefore propose a performance comparison among LB and RST of the VDSL network.

This paper will be divided into the following sections:

1. Section 1 – Introduces a very-high-bit-rate digital subscriber line (VDSL)
2. Sectopm 2 – Overview of the most significant policing mechanism scheme, the token leaky bucket (TLB), an algorithm used in packet switched computer networks to control smooths traffic and to limit on bandwidth and burstiness in data transmissions, will be examined.
3. Section 3 – Information about traffic networks will be evaluated.
4. Section 4 – Defines the rough set theory.
5. Section 5 – Discusses the purpose of rough set controls prior to buffer.

6. Section 6 – Defines the simulation model.
7. Section 7 – Comprises a performance evaluation of the proposed solution and comparison between TLB and rough set controls TLB.
8. Section 8 – Provides the conclusion, discussion, and recommendations for future research.

2. Literature review

In the traffic policing mechanism, an LB is required to control the ingress traffic; therefore, a proposal is made for a TLB approach to control the traffic. The TLB has two buckets, one for storing incoming frames in a queue with a capacity of M bits, another one for storing a maximum of β called tokens. Each incoming bit wants to take out a token from the token bucket to be advanced and the token bucket is filled with a rate of ρ tokens per time unit. If the token bucket is full, no more tokens can be added and if the traffic queue is full, incoming frames will be dropped. Nevertheless, the committed sustainable bit rate is restricted by ρ (Aeron, 2010; Goswami, PattAnaik, Bharadwaj, & Bharti, 2014).

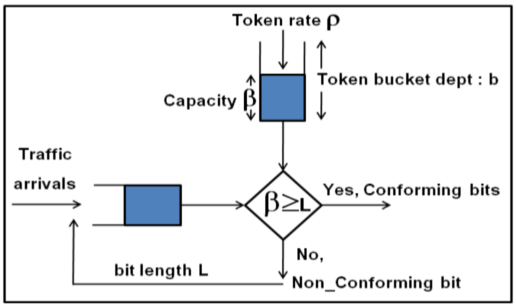

Figure 1 TLB mechanism

3. Modeling of network traffic

The policing mechanism monitors the maximum rate of traffic led into an interface during the ingress active phase and needed function in real time. This is described and measured by traffic flow.

In addition to these requirements the mechanism of parameter violations must be used to avoid overflowing the relatively small buffers in the network. To remove these conflicting requirements, a policing mechanism scheme has been proposed (Vieira, Santos, & Cardoso, 2013) and is described in the following sections.

3.1 Traffic source models

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

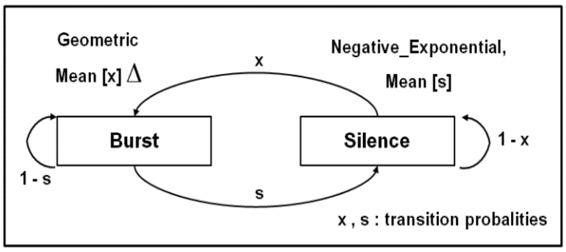

Figure 2 The burst/silence traffic model used in this study.

The traffic source model used as the example is founded on burst/silence traffic stream. A burst is a transfer of data without disturbance from another source and a silence is no transmission of data. The burst /silence ratio is strictly alternating.

The amount of frames per burst is estimated to have a geometric distribution with mean E[X]; the period of the silence phases is expected to be distributed according to a negative-exponential distribution with mean E[S]; and inter-packet arrival time throughout a burst is given by Δ. With

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

$$\text{mean silence duration} = E[S] \qquad (2)$$

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

3.2 The Network traffic models

The policing mechanism monitors the incoming traffic at the edges of the network for frame-based traffic. This mechanism decides whether to accept a unit of incoming traffic; either sending it as smooth traffic or marking the frame as a non-conforming frame, therefore, preserving data-rate connections from the source network transmission improving the Quality of Service (QoS).

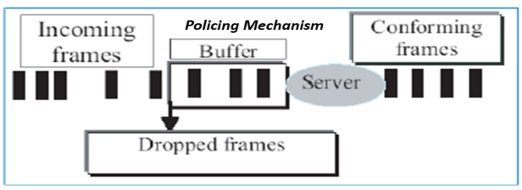

Figure 3 The traffic policing mechanism

3.3 A model of a simple transmitter

The transmitter shown in Figure 3 consists of a processor and a limited buffer to hold frames.

An arrival frame is arbitrary and the inter-arrival time among frames follows a particular distribution function. Moreover, frames come in different sizes, affecting the transmitting time. When a frame arrives at the transmitter, it can be processed using one of two methods. In the first method, the frame is given to the processor, which immediately starts transmitting it. The second method will queue the frame in the buffer behind other queued frames. While the buffer has many frames, the processor retrieves one 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 full, incoming frames will overflow and be 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. Principally of interest is the mean waiting time, mean queue length of frames in the buffer, the total number of non-conforming frames, and the total number of conforming frames. The final step is also referred to as processor utilization.

The mean queue length defined by the formula below states that the mean queue length L is given by Pollaczek–Khinchine_formula (Fares & Woodward, 2009).

$$L=\rho + \frac{\rho^2+\lambda^2 Var(S)}{2(1-\rho)} \qquad (4)$$

where

Arrival rate = λ

Departure rate = μ

Utilization rate $\rho = \frac{\lambda}{\mu}$

Var (S) is the variance of the service time distribution S.
Mean waiting time is defined by the formula given by Pollaczek–Khinchine_formula (Fares & Woodward, 2009).

$$L=\lambda W \qquad (5)$$

where

L is the mean queue length

λ is the arrival rate of the Poisson process

W is the mean time spent at queue

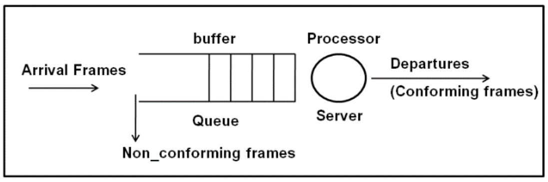

Figure 4 A model of a simple transmitter

4. Rough set theory and rough set control prior buffer

First the idea of rough set control prior to buffer in policer, which meets the requirements of performance implantation of high speed networks, will be described. Second, classification as an important task in data communication research facilitating analysis of a large amount of speed of packets will be examined. Rough set theory proposed by Pawlak (1982) is an approach to computing deals with vagueness and uncertainty in classification of the speed of the network. However, prior to applying rough set, data sets are discrete and have an impact on classification.

Rough set represents a data set as an information system that is comprised of rows and columns. Each row shows an object and each column indicates an attribute which assists the discovery of the decision rules. In the following sections, we will define the terms and sets needed to better understand rough set theory and depict a model for easier visualization.

4.1 Basic concepts of the rough set theory

4.1.1 Information system

To present the ideas of rough sets, begin with an information system (IS) data table *(IS)* with rows representing a set of objects in the universe (e.g. teacher, student, network traffic, etc.) and columns representing a set of attributes that describe the objects (e.g. name, color, age, burst/silence etc.), formally *IS= (U, A)*, where U is the set of objects and *A* is the set of attributes. Every attribute $a \in A$ has a set of values V_a called "Domain of a" such that $a: U \rightarrow V_a$. The information table assigns a value $a(x)$ from V_a to each attribute a and each object $\boldsymbol{x}$ in the universe ***U***. If V_a contains missing values for at least one attribute *a*, then *IS* is called an incomplete information table, otherwise it is complete (Mitra, Satapathy,& Paul, 2013 ;Shang, Zhou, Ye, & Wang, 2012; Zhai, Wan, & Zhang, 2015).

4.1.2 Indiscernibility relation

For every set of attributes B ⊂ A, an indiscernibility relation IND (B) is defined in the following way: if objects, x_i and y_j, are indiscernible by the set of attributes B in A, if $b(x_i)=b(y_j)$ for very b y⊂ B. The relation IND (b) is called a B-indiscernibility relation.

4.1.3 Lower and upper approximations

Let X denote the subset of elements of the Universe U (X⊂ U). The lower approximation of X in B (B⊆A), denoted as $\underline{BX}$, is defined as the union of all elementary sets which are contained in X.

$$\underline{BX} = \{x_i \in U \mid [x_i]\, Ind(B) \subset X\} \qquad (6)$$

The upper approximation of the set X, denoted as $\overline{BX}$, is the union of these elementary sets, which have a non-empty intersection with X:

$$\overline{BX} = \{x_i \in U \mid [x_i]\, Ind(B) \cap X \neq 0\} \qquad (7)$$

The boundary (BNX) of X in U, defined as the difference between the upper and lower approximations.

$$BNX = \overline{BX} - \underline{BX} \qquad (8)$$

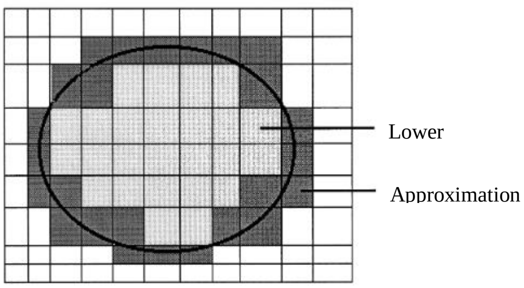

Figure 5 A model of a rough set

5. Rough set control prior Buffer

Describing a new rough set control prior in policer which meets the requirements of performance implementation of VDSL network will be discussed in this section. Consider a data set of network traffic containing groups of objects based on two variables of network parameters and one decision attribute.

The results are displayed in Table 1 with the rough set divided into three groups. The first group is composed of X1and X2 and is the lower approximate, the second group is composed of X3and X4 and is the uncertain group and the final group, composed of X5and X6 is upper approximate.

This result rough set can help make the decision. These are six types of undefinable sets in U:

IF speed <11 Mbs and burst/silence <100 µs
THEN traffic go to server
IF speed <11 Mbs and burst/silence >100 µs
THEN traffic go to server
IF speed 12 Mbs and burst/silence <100 µs
THEN traffic go to token LB
IF speed 12 Mbs and burst/silence >100 µs
THEN traffic go to token LB
IF speed >12 Mbs and burst/silence <100 µs
THEN traffic go to token LB
IF speed >12 Mbs and burst/silence >100 µs
THEN traffic go to token LB

Table 1 Network parameter attribute

U	speed	Burst/silence	decision
X1	<11 Mbs	<100 µs	low
X2	<11 Mbs	>100 µs	low
X3	12 Mbs	<100 µs	low
X4	12 Mbs	<100 µs	high
X5	>12 Mbs	<100 µs	high
X6	>12 Mbs	>100 µs	high

6. Simulation model

Figure 6 shows our model in this paper.

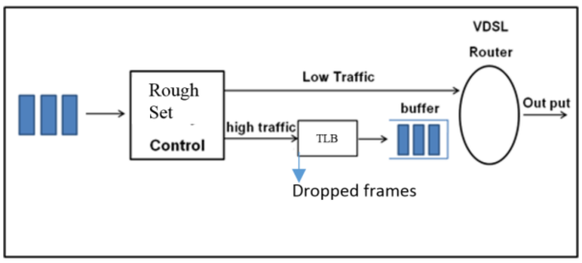

Figure 6 Simulation model

The transmitter sends traffic to the receiver which has a mechanism to shape smooth traffic when the input traffic arrives at the receiver, with the rough set making a decision. A low traffic is sent to the server and a high traffic is routed to the first TLB sending it to buffer. If the first TLB is full with frames to overflowing, frames will be dropped to the second TLB before progressing to the buffer.

6.1 Input traffic

This paper confines the discussion mainly to data. Data sources are generally bursty in nature (Kim & Suh, 2015; Kim, Wang, & Suh, 2015).

6.2 Characteristics of queuing network model

The following three mechanisms; arrival characteristics, service facility characteristics and a source traffic descriptor, each with unique characteristics will be reviewed prior to the development of the models.

6.2.1 Arrival characteristics

The pattern of arrival input traffic is frequently characterized to be a Poisson Arrival Processes (Mneimneh, 2016). Like several random events, Poisson arrivals occur in such a manner that for each increment of time (*T*), no matter how major or minor, the probability of arrival is autonomous of any previous history. These events may be individual labels, a burst of labels, packet service completions, or other arbitrary events. The probability of the inter-arrival time among events is defined by the inter-arrival time Probability Density Function (PDF). The following formula gives the ensuing PDF, when the inter-arrival time *t* is larger than some value *x* when the average arrival rate is λ events per second:

$$F_x(t) = P(X \le t) = \int_0^t e^{-\lambda x} dx \qquad (9)$$

$$f_x(t) = \begin{cases} e^{-\lambda t}, \ for \ t \ge 0 \\ 0, \ for \ t < 0 \end{cases} \qquad (10)$$

This paper adopts the ON/OFF burst/silence model.

6.2.2 Service facility characteristics

The study of service times arbitrarily distributed by the exponential probability distribution usefully assesses the mathematical assumption that coming rates are Poisson distributed. In order to examine the traffic congestion at crop of the VDSL downstream link (15Mbps) (D-Link Corporation, 2016) , the service time in the simulation model is indicated by the speed of the output link, given that a service time is 216 µs per frame where the frame size is 405 bytes.

6.2.3 Source traffic descriptor

The source traffic descriptor is the subset of traffic parameters demanded by the source, which characterizes traffic that should be submitted during the connection. The traffic parameter used in this model is defined as; PFR (peak frame rate) = λa = 1/*T* in units of frames/second, where *T* is the minimum inter-frame in seconds.

7. Result and analysis

The comparison between LB and RST is shown in Figures 7-11, indicating the simulation results from the LB and RST performance. The input frames (frame rate varies from 0 Mbps to 100 Mbps) with various types of burst/silence performed simulation results are shown in Figure 7. It obviously determines that the RST is the best of throughput guarantees. A throughput is one of the foundations of QoS to help guarantee higher reliability of network performance. Based on this information, a deduction can be made that the RST may assure higher reliability to handle uncertain traffic compared to the LB.

Figure 8 shows the results that RST will generate the lower dropped frames more effectively than LB. A network with a poor QoS will have a greater non-conforming or dropped frames ratio due to its inability to protect the conforming frames and reduce the number of dropped frames.

Figure 9 demonstrates that the results of the utilization of the LB scheme are the lowest. From this viewpoint, the processing unit will be available for other sources in terms of sharing. The outcome is in the line of low processing power required by LB because LB is likely to crop fewer conforming frames and higher dropped frames. A maximum number of frames is discarded before transferring (entering the network) to the entrance of the network. LB seems to create a minimal congestion, but will reflect the lower throughput in return. The RST result maintains a higher utilization factor, but the figure does not go beyond the saturation point. The reason is because both schemes make more conforming frames as well as a higher number in successful retries.

Figure 10 displays that RST has to make all frames wait longer in the queue at the sender and next to the entrance of the network. This is due to fewer frames dropped and higher numbers of conforming frames. It shows that the mean queue length of RST is higher in general while LB appears to be lower.

Figures 11 shows that RST has frames delayed longer in the queue at the sender. This is due to fewer frames dropped and higher numbers of conforming frames. It shows that the mean queue time of RST is higher than LB.

Optimistically, with the same size of buffer, the RST is confirmed to be high-risk-high-return.

Figure 7 Illustrates conforming frames comparison among LB and RST

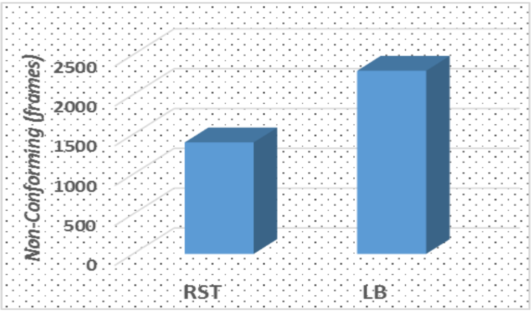

Figure 8 Illustrates non-conforming frames comparison among LB and RST

Figure 9 Illustrates the utilization comparison among LB and RST

Figure 10 Illustrates the mean queue length comparison among LB and RST

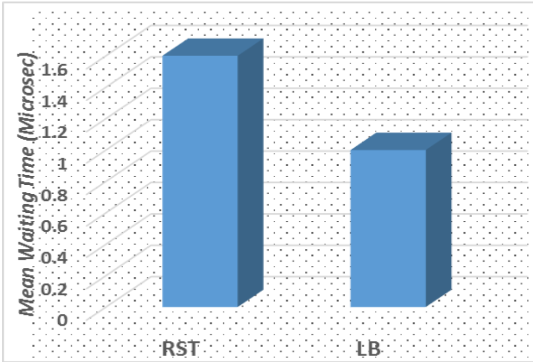

Figure 11 Illustrates the mean queue time comparison among LB and RST

8. Conclusion and discussion

In conclusion, the rough set control traffic was applied over the high speed network using the TLB technique. The results show that the RST in policing mechanism schemes over a high speed network appears to be the best outperforming compared to the traditional traffic LB in terms of maximizing the number of conforming frames; less non-conforming frames or dropped frames. It clearly determines that RST is the best of throughput guarantees, as throughput is one of the conditions QoS employs to help guarantee higher reliability of network performance, with RST generating lower dropped frames. A regular network may cause a poor QoS to have higher dropped frames. The utilization of the LB scheme is lower than the RST with the processing unit 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. It appears that LB creates less congestion, but it will reflect the lower throughput in return. The RST causes all frames to wait longer in the queue at the sender and next to the entrance of network, respectively, due to fewer frames being dropped. It is apparent that both the mean queue length and the mean queue time are high in general, while LB minimizes this. Optimistically, with the same size of buffer, RST is confirmed to be high-risk-high-return. We also believed that the rough set control in network traffic seems to be suitable for data under various types of burst/silence traffic conditions. The traditional policing mechanism is not concerned with the various types of burst/silence traffic conditions, instead, it determines speed of traffic only. In fact, various types of burst/silence traffic conditions are very important because of the effect on conforming and dropped frames. This is particularly apparent when the destination drops multiple frames and the source must retransmit these frames causing significant network delay time.

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

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