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A model of Fuzzy Control Backoff Schemes in Telecommunication Networks

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Abstract:- Fuzzy control is based on fuzzy logic, which provides an efficient method 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 algorithm. 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, Backoff time computation schemes, namely: pseudorandom backoff (PB) time, exponential backoff (EB) time and random backoff (RB) time that are applicable in waiting time re-arrangement in queue. They have proved to be inefficient in coping with the conflicting requirements, that is, low dropping frames and high conforming frames. This led us to explore alternative solutions based on artificial intelligence techniques, specially, in the field of fuzzy logic. In this paper, we propose a fuzzy control backoff scheme that aims at detecting violations of parameter negotiated. We evaluate and compare the performance of fuzzy control backoff scheme (FB) with namely, pseudorandom backoff scheme (PB), random backoff scheme (RB) and exponential backoff scheme (EB). The performance of four backoff schemes have been investigated by the fluctuation of telecommunication traffic stream (burst/silent type). Simulation results show that the fuzzy control scheme helps improve performance of our re-arrangement waiting time in queue compared to other non-fuzzy backoff schemes.

Keywords: Backoff time computation, fuzzy control, policing mechanisms.

1 Introduction

Backoff computation, each source will delay the message whenever the transmission to next service fails. Backoff algorithms have introduced many techniques such as exponential backoff, random backoff, linear backoff and quadratic backoff as described in many papers [1],[2],[3]. For example, messages sent by senders in an Ethernet network may be retransmitted after T steps where T is selected randomly from $\{1,2,3, . . . ,2^{\min(10,b)}\}$ and b is the number of times the station has tried to send the packet but failed. This is one of an example of general application referred to exponential backoff.

In this paper, we apply backoff concepts to waiting time in the queue with policing mechanisms and evaluate the performance using a high speed network model.

1.1 Backoff algorithm

Many papers study the backoff algorithms in terms of their effect on network performance as the offered load increases. However, simplification or modification of backoff algorithm can lead to very different analytical results [3],[4]. Many backoff schemes have been proposed and studied.

1.1.1 Pseudorandom backoff

In pseudorandom backoff (PB) scheme, none of the computation is applicable but queue disciplines. They are FIFO, LIFO and priority. In this paper, the FIFO and the maximum queue size are preset.

1.1.2 Exponential backoff

Exponential backoff (EB) is an algorithm being widely used in traffic offered load. In EB, each node doubles the backoff time after each retry occurs (2x) but not above the maximum value (B_{max}), and decreases the backoff interval to the minimum value (B_{min}) after a successful retry. We summarize EB by the following set of equations:

$x \leftarrow \min(2x, B_{max})$ upon retry and
$x \leftarrow B_{min}$ upon successful transmission.

The x is the backoff interval value. The values of the B_{max} and B_{min} are predetermined, based on the possible range of number of active nodes and the traffic load of a network. For example, B_{max} and B_{min} are usually set to 1024 and 2, respectively. Although some researchers found that the channel throughput in the Ethernet network will be degraded as the backoff interval does not correctly represent the actual contention of the channel [5],[6],[7] but we experience somehow the EB can help improve the performance of the system regarding to the fluctuation of telecommunication traffic.

1.1.3 Random backoff

Another approach is the use of the random backoff (RB) technique. In order to avoid repeated retry by one particular node based upon the detection of non availability of transmission, the sender is required to wait for a random period of time before next retry. This random period is referred to as *retry delay* or simply *backoff*. Backoff algorithms, which usually adaptively change the retry delay according to the traffic load, are implemented to address the dynamic network conditions and to improve the performance of such system. In a backoff algorithm, the duration of the backoff is usually selected randomly in the range of 0 and some maximum time duration, which we refer to as the *backoff interval* (τ).

1.1.4 Backoff interval time essentials

The backoff interval is dynamically controlled by the backoff algorithms as described above. Setting the length of the backoff interval is, however, not a trivial task. On one hand, with a fixed number of ready nodes, small backoff intervals do not help reduce the correlation among the retrying nodes to any appropriate low levels. These results are moreover raising too high number future retries, lowering the channel throughput. On the other hand, large backoff intervals introduce unnecessary idle time on the channel (waiting time in queue), increase the average packet delay and unneeded preparation of buffer to handle the size of queue, also eventually would degrade the system's performance[8].

1.2 Waiting time in the queue

In this section, we describe our proposed queue policy, called threshold-based queue management in details. Consider a workstation that consists of a single machine M and an infinite buffer B . The average waiting time of lots in the buffer of single-machine station *BM* can be approximated by :

$$\phi q = \left(\frac{C_a^2 + C_e^2}{2} \right) \left(\frac{u}{1 - u^{t_e}} \right) \quad (1)$$

C_a = the coefficient of variation of the arrival times

C_e = the corresponding coefficient of variation

t_e = the mean processing time of station

u = utilization

Concepts of waiting time in the queue have been introduced and developed by [11].

There are many previous studies involving backoff algorithms [1],[2],[3],[4] however, the behavior of backoff concept applicable to waiting time in the queue with policing mechanisms is nevertheless investigated. In this paper, we proposed comparisons of the performance between pseudorandom backoff (PB), exponential backoff (EB) and random backoff (RB) with leaky bucket policing mechanism.

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. 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.

2.1.1Traffic source models

In our simulation, a burst traffic stream from a single source is modeled as an 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.[8]

2.1.2 Policing mechanism models

Various congestion control traffic policing mechanisms[1]. In this paper selected policing mechanisms include the Leaky Bucket(LB)[8][9].

3 Fuzzy control prior buffer

In this section, we will first describe a new fuzzy control prior buffer in policer which meets the requirements of performance implementation of 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 [3].

3.1 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 figure.

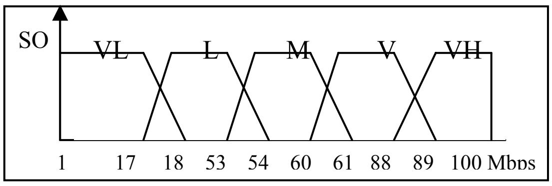

Fig 1 : Membership function of SO input variable

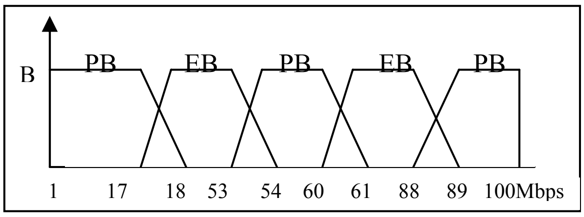

Fig 2 : Membership function of B output variable

3.2 Inference, Fuzzy Rules and Defuzzification

Fuzzy sets are involved only in rule premises. Rules 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 Fig. 3 shows simple fuzzy rules used in the experiment.

IF	So is VeryLow (VL)	THEN	B is PB
IF	So is Low (L)	THEN	B is EB
IF	So is Medium (M)	THEN	B is PB
IF	So is High (H)	THEN	B is EB
IF	So is VeryHigh (VH)	THEN	B is PB

Fig 3 :The fuzzy rules

Figure 1 and 2 respectively show the membership functions of the linguistic values the input variables So and the output variables B can take. Analysis of the fuzzy system rules (Fig. 3) shows that sources are very low then maximum waiting time in queue uses pseudorandom backoff scheme. If sources are low then maximum waiting time in queue uses exponential backoff scheme. If sources are medium then maximum waiting time in queue uses pseudorandom backoff scheme. If sources are high then maximum waiting time in queue uses exponential backoff scheme and If sources are very high then maximum waiting time in queue uses pseudorandom backoff scheme.

In our models, fuzzy control backoff scheme (FB) uses a set of rules (Fig.1,2,3). The selection of rules base is based on our experience and beliefs on how the system should behave. Input traffics allow a burst traffic stream (burst/silent stream) to fluctuate the VDSL network controlled by fuzzy controller.

Fuzzy logic controller design is implemented using MATLABv6.1. 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 backoff scheme.

4. Simulation model

The following Fig 4. shows a simulation model used in this paper.

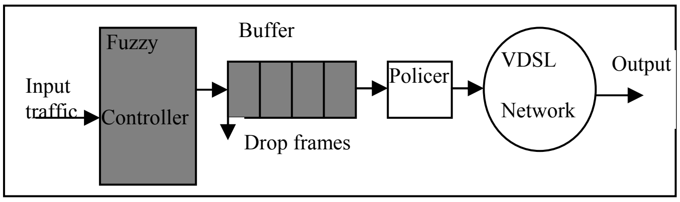

Fig 4. Simulation model

4.1 Input traffic

This research 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 [8].

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* [9]. 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.

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) [10], the service time in the simulation model is specified by the speed of output link, giving that a service time is 216 μs per frame where the frame size is 405 bytes[11].

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

PFR = λa = 9 Mbps(~2,778 frames/s)

Hence, T=360 μsec.

5. Results and analysis

The comparison between fuzzy control backoff, pseudorandom backoff, exponential backoff and random backoff is shown in figures below.

5.1 The comparison between fuzzy control, exponential, pseudorandom and random backoff

This section indicates simulation results from all backoff algorithms, that are, FB, EB, PB and RB performance will be compared. The input frames (frame rate varies from 5 Mbps to 100 Mbps) with burst/silence ratio of 100:100 performed simulation results as shown in Fig 5. It clearly determines that the FB scheme is the best of throughput guarantee. Throughput is one of factor of QoS to help guarantee higher reliability of network performance. In conclusion, the FB may assure higher reliability to handle real time applications such as multimedia traffics compared to other EB, PB and RB.

Fig. 5 complies with Fig. 6 results in the sense that FB will produce lowest dropped frames compared to other three schemes. In other words, we can help conserve the conforming frames by reducing number of dropped frames. A regular network may cause a poor QoS by higher non-conforming or dropped frames. Especially, a quality of multimedia traffics such as video during the online display mode may drop or cause a threat for the viewer while the quality of audio traffics may have less impact since the unclear situation would be ironed out by hearing intelligent function of human being. We can somehow broaden the usage of PB (after the better EB) in the case of audio traffic. But the matter of fact is that high dropped frames may cause high retransmission, which leads to higher delay time. For this reason, it is apparently seen that RB is not worth employing for any kinds of traffics.

In Fig. 7, the result determines that the utilization of the RB 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 RB because RB produces less conforming frames and higher dropped frames. Most frames are discarded before transferring (entering the network) to the entrance of the VDSL network. It seems like RB makes less congestion but it will reflect the lower throughput in return. Both FB, EB and PB result higher in utilization factor but the figure does not go beyond the saturated point (as high as 58%). It is because both schemes make more conforming frames as well as higher number in successful retries.

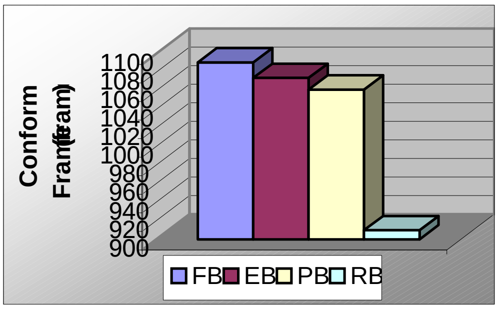

Fig 5 illustrates conforming frames comparison between fuzzy control, exponential, pseudorandom and random backoff time with variable input rate, τ=1260 microsec and burst : silence =100:100.

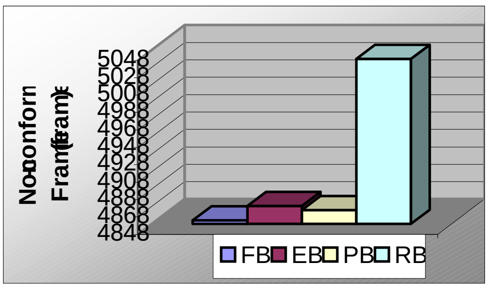

Fig 6 illustrates non-conforming frames comparison between fuzzy control, exponential, pseudorandom and random backoff time with variable input rate, τ=1260 microsec. and burst : silence =100:100.

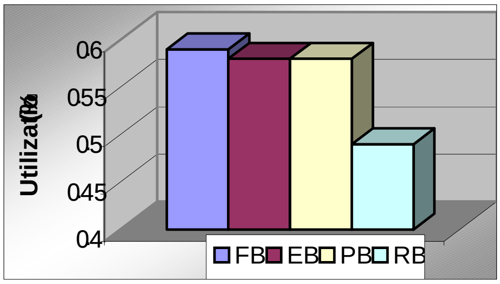

Fig 7 illustrates the utilization comparison between fuzzy control, exponential, pseudorandom and random backoff time with variable input rate, τ= =1260 microsec. and burst : silence =100:100.

6. Conclusions and recommendations for future research

In this paper, we carried out a comprehensive study to investigate the performance of four selected fuzzy control, exponential, pseudorandom and random backoff schemes with fixed types of traffic. The study was accomplished through simulation after developing an analytical queueing model.

We found that based on simulation results in general, the fuzzy control backoff scheme is the best outperforming compared to others (exponential, pseudorandom and random backoff). Only the case that the network seeks for sharing or availability of the utilization, random backoff scheme will be the only choice. Both fuzzy control, exponential backoff and pseudorandom backoff schemes are suitable for multimedia traffics such as voice, video and data but fuzzy control backoff is the best for real time application. The tradeoff between the employment of FB, EB and PB is that the former one is sender-oriented (distributed control) with given exponential backoff time while the latter is centralized- control (by the VDSL network).

In the future work, we will focus on the investigation of fuzzy control queueing system and deplete rate with policing mechanism . Also a network of queue (NoQ) for central pool prior to the VDSL network is currently under the implementation.

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