Int. J. Open Problems Compt. Math., Vol. 6, No. 3, September 2013
ISSN 1998-6262;
www.i-csrs.org

Improvement of forwarding mechanism with heterogeneous network links

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(*Communicated by Firas Ibrahim Alzobi*)

Abstract

Computer networks can use multiple heterogeneous communication channels. All the packets passing through a network facility, e.g. router or switch, must share the limited resources. These shared resources include the available bandwidth of linking channels, CPUs and the buffers. Packets will differently delay if multiple heterogeneous communication channels are used. Present paper aims at overcoming this delay problem for delivering data in case of existence of a number of heterogeneous linking channels by proposing the packet forwarding mechanism - Optimized Load Balancing. Also numerical results are obtained for Optimized Load Balancing mechanism that convince of the improvement of delays for proposed mechanism with multiple network links approach.

Keywords: *packet forwarding mechanism, multiple links, heterogeneous communication channels.*

1 Introduction

Connection between two separate computer networks can be established through two network facilities and multiple communication channels between them. If there are multiple paths to a destination in the routing table, then load balancing mechanism allows the router to use multiple links to a destination when forwarding packets. All the packets, passing through a network facility (e.g. router or switch) must share the limited resources. These shared resources include the available bandwidth of linking channels, CPUs and the buffers. Thus, packets will differently delay if multiple heterogeneous communication channels are used.

The load balancing guarantees equal load across these links, but the packets may arrive out of order at the destination [1] because differential delay may exist within the network buffers. In routers, the forwarding process determines the outgoing interface for each packet by looking up the routing table and picking the least used interface. This ensures equal utilization of the links, but is a processor intensive task and impacts the overall forwarding performance, i.e. this form of load balancing is not well suited for higher speed interfaces. Load balancing of communication channels is permitted in almost every standard routing protocol – Routing Information Protocol (RIP), Open Shortest Path First (OSPF), Interior Gateway Routing Protocol (IGRP), Enhanced Interior Gateway Routing Protocol (EIGRP) and in statically configured routes. A problem occurs [1],[4],[5] when communication channels have different speeds (heterogeneous communication channels). It is observed low performance in data transmission through TCP – Transmission Control Protocol in such conditions due to different delay of packets.

Round Robin means [3] that the network facility sends one packet for a destination over the first path, the second packet for the same destination over the second path, and so on.

In earlier work [4] an adaptive algorithm for the allocation of traffic was proposed. This algorithm is titled Rate Balance Algorithm and it is based on following principle – every packet is transmitted in that channel, which will deliver it earlier than all others channels. It uses formulae to determine the time of delivery of the packet over each channel, taking into account its time of the release. Thus the Rate Balance Algorithm selects this channel to deliver the packet which will deliver it earlier relative to the other channels.

The purpose of this paper is to propose modified packet forwarding mechanism which minimize the delay of packets in case of heterogeneous communication channels, and investigate its characteristics as well as comparing them with those of well-known forwarding mechanism.

2 Optimized Load Balancing

Below is proposed a forwarding mechanism titled Optimized Load Balancing mechanism that allows minimizing the waiting time of packets in network facilities interconnected with heterogeneous communication channels [7].

Keeping in mind that the algorithms for packet forwarding create extra load for CPU of the network facility, e.g. router, the computational complexity of these mechanisms should be minimal.

In Fig.1 it is shown the forwarding process of PDUs (Protocol Data Units) packaged as packets $D = \{dk\}$, $k \in (1, 2... \infty)$ which entering at the entrance of the network facility. Each packet is characterized by size lk $k \in (1, 2... \infty)$. Average value of packet's size is denoted with l. The proposed mechanism manages the N channel $C = (c1, c2... cN)$ forming virtual channel among source and destination.

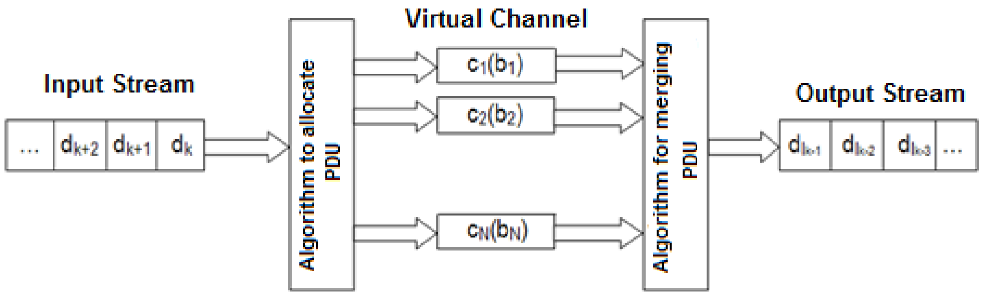

Fig. 1: Transfer of packets (PDUs).

For each channel $c_i \in C$, $i \in \{1,2,.. N\}$ its speed is known as b_i, in bps. Moreover $\sum\lambda_i=\lambda$, $i \in \{1, 2 \ldots N\}$. The input packet stream is forwarded to each channel with intensity λ_i, respectively, with probability $p_i=\lambda_i/\lambda$, $i \in \{1,2,.. N\}$.

The proposed approach in this paper for the traffic forwarding so as to minimize the waiting time of packets in network facilities for heterogeneous communication channels use mathematics method [9], [10], and more precisely the method of Lagrange with undetermined coefficients and the well-known formula for the waiting time in the M/M/1 queuing system [8]: $t_i = \frac{1}{\mu_i - \lambda_i}$, where μ_i - the transmission speed of the packets and λ_i - the intensity of arrival of packets in channel c_i, $i \in \{1, 2\ldots N\}$ and $\mu_i>\lambda_i$.

The mechanism for traffic forwarding allocates PDUs, Vd_k, $k \in (1,2 ,..., \infty)$ for each channel that is available, $c_i \in C$, with probability p_i, so as to minimize the waiting time of packets:

(1) $\sum\lambda_i t_i \to \min$.

According to the method of Lagrange:

(2)
$$\begin{cases} \dfrac{\partial \sum_{i=1}^{N} \lambda_i t_i}{\partial \lambda_1} + \lambda\xi = 0 \\ \dfrac{\partial \sum_{i=1}^{N} \lambda_i t_i}{\partial \lambda_2} + \lambda\xi = 0 \\ \ldots \\ \dfrac{\partial \sum_{i=1}^{N} \lambda_i t_i}{\partial \lambda_i} + \lambda\xi = 0 \\ \ldots \\ \sum_{i=1}^{N} \lambda_i = \lambda \text{ ,} i \in \{1,2,..\text{N}\} \end{cases}$$

Or

(3)
$$\begin{cases} \dfrac{\partial \sum_{i=1}^{N} \frac{\lambda_i}{\mu_i - \lambda_i}}{\partial \lambda_1} + \lambda\xi = 0 \\ \dfrac{\partial \sum_{i=1}^{N} \frac{\lambda_i}{\mu_i - \lambda_i}}{\partial \lambda_2} + \lambda\xi = 0 \\ \dots \\ \dfrac{\partial \sum_{i=1}^{N} \frac{\lambda_i}{\mu_i - \lambda_i}}{\partial \lambda_i} + \lambda\xi = 0 \\ \dots \\ \sum_{i=1}^{N} \lambda_i = \lambda \text{ , } i \in \{1,2,..N\} \end{cases}$$

Whence for λ_ι:

(4)
$$\frac{\mu_i}{(\mu_i - \lambda_i)^2} + \lambda\xi = 0$$

Or

(5)
$$\mu_i + \lambda\xi(\mu_i - \lambda_i)^2 = 0$$

Solving equation (5), we obtain the desired intensity-λ_ι **:**

(6)
$$\lambda_i = \mu_i - \left(\sum_{j=1}^{N} \mu_j - \lambda \right) \frac{\sqrt{\mu_i}}{\sum_{j=1}^{N} \sqrt{\mu_j}}$$

Finally, taking into account, that $\mu_i = b_i/l$, in pkts/s, the intensity with which the algorithm forwards data to each channel c_i , λ_ι, i ∈ {1,2,.. N} is obtained:

(7)
$$\lambda_i = \frac{b_i}{l} - \left(\sum_{j=1}^{N} \frac{b_j}{l} - \lambda \right) \frac{\sqrt{b_i}}{\sum_{j=1}^{N} \sqrt{b_j}}$$

respectively the probability p_i is obtained:

(8)
$$p_i = \frac{b_i}{\lambda l} + \left(1 - \frac{1}{\lambda l} \sum_{j=1}^{N} b_j \right) \frac{\sqrt{b_i}}{\sum_{j=1}^{N} \sqrt{b_j}}$$

If it happens $\lambda_\iota<0$, then it should be equated to 0 and the optimization problem must be resolved again, taking in mind the constraint $\lambda_\iota=0$.

Proposed mechanism forwards the PDUs to one of the channels by drawing a random number in the interval (0,1) and determines in which interval the number falls {(0, p_1), (p_1, p_1+ p_2),… , (p_1+ p_2+...,1)}.

3 Numerical Example

Below is given a numerical example. Calculations are made [6] with the following input data:

- Number of channels is N=2;
- Speed of the first channel is four times slower than the speed of the second channel (b_1=100Mbps and b_2=400Mbps);
- Mean length of packet is 500 B;
- Intensity of arrival of packets λ is chosen 50, 150, 250, 350, and 450 Mbps.

Note, intensity of arrival of packets varies between 0.1 and 0.9 of the overall speed of the channels (b_1+ b_2=500Mbps), i.e. it is 0.1, 0.3, 0.5, 0.7, and 0.9.

Using (7) for each of these values of intensity of arrival of packets λ={50, 150, 250, 350, and 450 Mbps} are calculated optimal intensities with which the mechanism forwards data to both channels- λ_1, and λ_2. Results are shown in Table 1.

λ	50	150	250	350	450
λ_1	-50	-16.67	16.67	50	83.33
λ_2	100	166.67	233.33	300	366.67

Table1. First results for the optimal intensities

As can see in Table 1 when λ=50 and 150 Mbps, the calculated values for optimal intensity λ_1 are negative numbers. Therefore, it should be equated to 0 and values for intensity λ_2 must be recalculated, taking in mind the constraint λ_1=0. Final results of this iteration process calculating optimal intensities are shown in Table 2

λ	50	150	250	350	450
λ_1	0	0	16.67	50	83.33
λ_2	50	150	233.33	300	366.67

Table2. Final numerical results for the optimal intensities

In order to determine the mean waiting time of forwarded packets in network facilities with heterogeneous communication channels is used the well-known formula in queuing system theory:

(9) $T=\sum p_i t_i$,

where p_i is the probabilities obtained by formula (8) and t_i is waiting time in the M/M/1 queuing system respectively.

The obtained in this manner numerical results for waiting times are shown graphically.

Figure 2 shows the numerical results obtained for the waiting time (in μs) at different intensities of arrival of packets for Optimized Load Balancing mechanism as well as Load Balancing mechanism. Intensity of arrival of packets varies between 0.1 and 0.9 of the overall speed of the channels (b_1+ b_2=500Mbps), and more precisely it is chosen 0.1, 0.3, 0.5, 0.7, and 0.9.

As the name suggests, in Load Balancing, packets are forwarded to each of the channels (with constant probabilities p_1=0.2 and p_2=0.8), so that their load is the same, i.e. in this case the Load Balancing mechanism will forward to the second channel four times more packets than to the first channel.

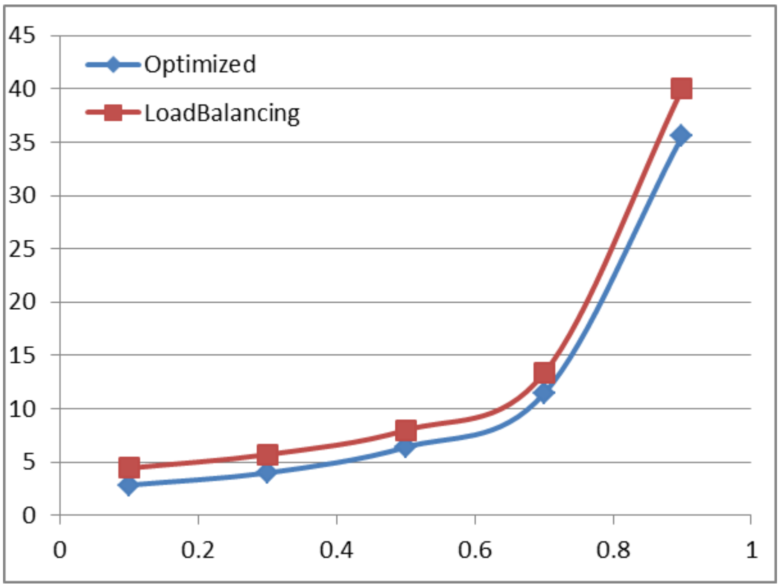

Fig. 2: Numerical results for Optimized Load Balancing and Load Balancing.

By comparing the results (fig. 2) for Optimized Load Balancing and Load Balancing mechanisms it can be concluded, that the proposed mechanism is better, because it permits minimization of the waiting time of packets in routers in case of heterogeneous communication channels

4 Conclusion

In this paper few different forwarding mechanism are analyzed and a comparison is made between them for the case of heterogeneous (with different speed) communication channels.

A modified forwarding mechanism - OptimizedLoadBalancing is proposed. It allows minimizing the waiting time of packets in network facilities for heterogeneous communication channels. The proposed approach to minimize the waiting time of forwarded packets in case of heterogeneous communication channels uses the method of Lagrange with undetermined coefficients. Through a numerical example, and more precisely using numerical results for the performance of Optimized Load Balancing and Load Balancing mechanisms are obtained, which convince of improvement of proposed forwarding mechanism with multiple network links.

5 Open Problem

In this article OptimizedLoadBalancing mechanism has been presented, as well as its performance has been investigated trough an analytic model based on well-known formula for waiting time in M/M/1 queuing system. As it is known this formula gives right waiting times only for SMTP traffic. But today Internet Traffic is mix of HTTP, FTP, Telnet, SMTP and others type packets. Thus in common case (real Internet traffic) it needs to use formulas for G/G/1 system. Unfortunately there are only approximately and enough complicated formulas which make hardly or even impossible to use the method of Lagrange with undetermined coefficients. As a whole the Evolutionary Computing and more specially genetic algorithms assures the overcoming of the above problem. In this context the next steps will be to:

- develop a calculator of genetic algorithms means for easily creation of more complicated genetic algorithms (for example with functional relations between genes and etc.);
- using the calculator of genetic algorithms to research over the influence of the parameters and characteristics of the real Internet traffic on delays of this packet forwarding mechanism;
- use the calculator of genetic algorithms for solving of different optimization problems, especially in the field of data computer networks

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