

## Efficiency of Four Virtual LANs Switches with Equal Processing Times

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### ABSTRACT

Virtual LANs (VLANs) are introduced as some alternative switches to solve for the traffic problems of those LAN networks with Hubs. The idea is to create some collections in the whole LAN network, such collections are the so called VLANs. Appropriate switches (one switch or more of up to 24 ports) are designed to interconnect those VLANs. The design of such VLAN switches looks like the design of Look-Up tables to facilitate routing (similar to those used in CISCO networks). In this paper, an analytical model for such VLANs is proposed and then compared with single VLAN switch from the point of view of validity and speed characteristics.

**Keywords:** VLANs, CISCO network.

كفاءة أربع مبدلات شبكات محلية افتراضية بأوقات معالجة متساوية

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### المخلص

إن الشبكات الافتراضية تقدم بعض الخيارات البديلة كمبدلات شبكة لحل مشاكل المرور ضمن الشبكات المرتبطة عبر مقسم. الفكرة هي خلق بعض المجموعات ضمن الشبكة الواحدة والتي يمكن تسميتها بالشبكات المحلية الافتراضية أو VLANs. حيث صممت مبدلات شبكات مناسبة لربط هذه الشبكات الافتراضية تحوي على أكثر من 24 منفذ. إن تصميم الشبكات الافتراضية هذه تشبه إلى حد بعيد تصميم لوائح السحب والتوجيه المستخدمة في شركة سيسكو. هذا البحث يقدم نموذج تحليلي لأربع مبدلات شبكات افتراضية ويقارن صلاحيتها وسرعة أداءها مع صلاحية وسرعة أداء مبدل شبكة وحيد. الكلمات المفتاحية: الشبكات المحلية الافتراضية، شبكة CISCO.

## 1. Introduction

The whole idea of Virtual Local Area Network (VLAN) technology is to divide a LAN into logical, instead of physical, segments. A LAN can be divided into several logical LANs called VLANs. Each VLAN is a workgroup in the organization. If a person moves from one group to another, there is no need to change the physical configuration. The group membership in VLANs is defined by software, not hardware. Any station can be logically moved to another VLAN. All members belonging to a VLAN can receive broadcast messages sent to that particular VLAN [8]. Figure 1 shows a switched LAN containing 7 hosts grouped into two LANs that are connected by a switch. The first four hosts work together as the first group, the next three hosts work together as the second group. The LAN is configured to allow this arrangement [3].

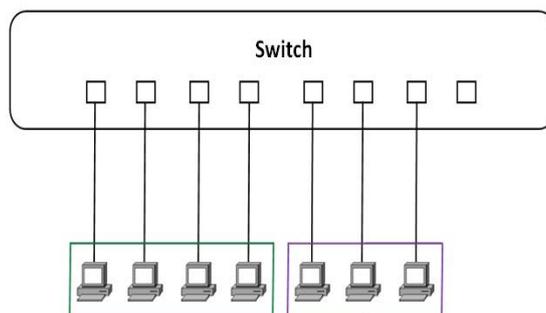
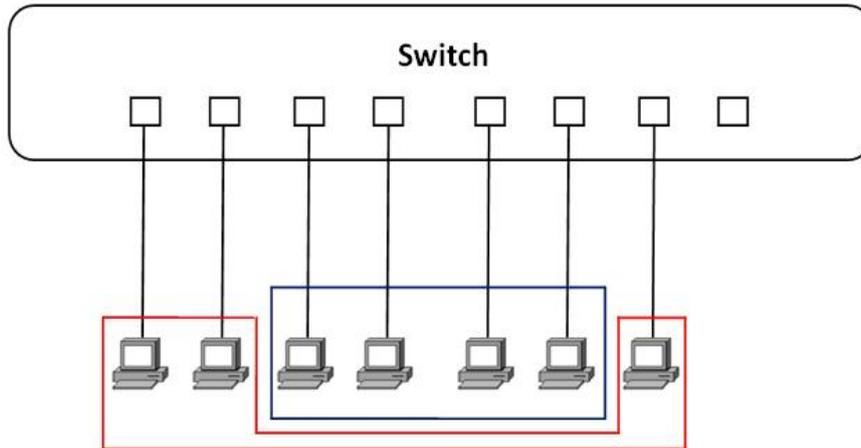


Fig. 1 Switched LAN containing 7 hosts grouped into two

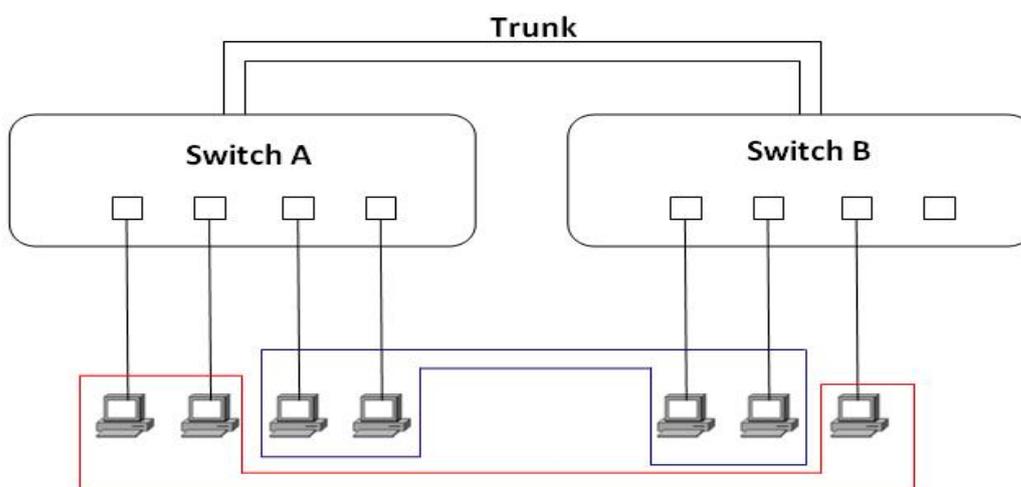
But what would happen if the administrators needed to make two hosts from the first group work with one host from the second group as one workgroup, and two hosts from first group with two hosts from second group as another workgroup, as shown Fig. 2. The LAN configuration would need to be changed. The network technician must rewire. The problem is repeated if, in another week, the administrators needed to make hosts back to their previous groups. In a switched LAN, changes in the work group mean physical changes in the network configuration [3].



**Fig. 2** Two hosts from the first group work with one host from the second group.

This means if a host moves from VLAN-1 to VLAN-2, it receives broadcast messages sent to VLAN-2, but no longer receives broadcast messages sent to VLAN-1. It is obvious that the problem in our previous example can easily be solved by using VLANs. Moving hosts from one group to another through software is easier than changing the configuration of the physical network.

VLAN technology even allows the grouping of stations connected to different switches in a VLAN. Figure 3 shows a backbone local area network with two switches and two VLANs. Stations from switches A and B belong to each VLAN [3].



**Fig. 3** Backbone local area network with two switches and two VLANs.

This is a good configuration for a company with two separate buildings. Each building can have its own switched LAN connected by a backbone. People in the first building and people in the second building can be in the same work group even though they are connected to different physical LANs.

There are many technique problems in VLANs, such as how to configure VLANs automatically, transfer membership information between switches, and combine VLANs with ATM networks. X. Wang, *et al.* in [15] proved that VLAN Based on service can not only timely dynamically configure VLAN but can also distribute administration right to owners of network resources. K. Okayama, *et al.* in [10] proposed a method for dynamic interconnection of VLANs for large scale VLAN environment and implemented the VLAN converter as a software program with enough performance. Recently, V. Mancuso and L. Monica shows that a quasi-static mesh access network can be endowed with dynamically- managed VLANs (controlled VLANs switching) in order to tackle the impairment caused by topology changes [13].

Many attempts are carried out recently to create analytical models for a single VLAN, two and three VLANs [1, 16]. In this paper, another analytical model for four VLANs is proposed and then compared with single VLAN switch from the point of view of validity and speed characteristics.

This paper is divided into five major sections. Besides this introductory section, the next section reviews the VLAN characteristics and advantages. In section 3, the communication between VLAN switches is described. The proposed four VLANs switch network model is presented in section 4 with the derivations of the average number of frames and the total time delay. Comparisons of such model with a single VLAN switch model from the point of view of validity and speed characteristics are also included. Finally, section 5 highlights some conclusions.

## **2. VLAN Characteristics and Advantages**

### **2.1 VLAN characteristics**

The followings are the two main VLANs characteristics.

#### **i) VLAN-s create broadcast domains**

VLANs group stations belonging to one or more physical LANs into broadcast domains. The stations in a VLAN communicate with one another as though they belonged to a physical segment.

#### **ii) Membership**

To group stations in a VLAN, vendors use different characteristics such as port numbers, MAC addresses, IP addresses, IP multicast addresses, or a combination of two or more of these [4, 11].

##### **a. Port Numbers:**

This is also called static VLAN. (all other types of VLAN are called dynamic VLAN). Some VLAN vendors use switch port numbers as a membership characteristic. For example, the administrator can define that stations connecting to ports 1, 2, 3, and 7 belong to VLAN-1; stations connecting to ports 4, 10, and 12 belong to VLAN-2; and so on.

##### **b. MAC Addresses:**

Some VLAN vendors use the 48-bit MAC address as a membership characteristic. For example, the administrator can stipulate that stations having MAC

addresses E21342A12330 and F2A123BCD311 belong to VLAN-1, and stipulate that stations having MAC addresses E21342A12333 and F2A123BCD341 belong to VLAN-2 [2].

**c. IP Addresses:**

Some VLAN vendors use the 32-bit IP address as a membership characteristic. For example, the administrator can stipulate that stations having IP addresses 181.34.23.62, 181.34.23.63, 181.34.23.64, and 181.34.23.65 belong to VLAN-1, and stipulate that stations having IP addresses 181.34.23.71, 181.34.23.72, 181.34.23.73, and 181.34.23.74 belong to VLAN-2 [12].

**d. Multicast IP Addresses:**

Some VLAN vendors use the multicast IP address as a membership characteristic. Multicasting at the IP layer is now translated to multicasting at the data link layer [2].

**e. Combinations:**

Recently, the software available from some vendors allows all these characteristics to be combined. The administrator can choose one or more characteristics when installing the software. In addition, the software can be reconfigured to change the settings [2].

## 2.2. Advantages of VLANs

There are several advantages to using VLANs:

**i) Cost and Time Reduction:**

VLANs can reduce the migration cost of stations going from one group to another. Physical reconfiguration takes time and is costly. Instead of physically moving one station to another segment or even to another switch, it is much easier and quicker to move it using software [14].

**ii) Creating Virtual Work Groups:**

VLANs can be used to create virtual work groups. For example, in a campus environment, professors working on the same project can send broadcast messages to one another without the necessity of belonging to the same department. This can reduce traffic if the multicasting capability of IP was previously used [5].

**iii) Security:**

VLANs provide an extra measure of security. People belonging to the same group can send broadcast messages with the guaranteed assurance that users in other groups will not receive these messages [8].

## 3. Communication Between Switches

In a multi-switched backbone, each switch must know not only which station belongs to which VLAN, but also the membership of stations connected to other switches. For example, in Fig. 3, switch A must know the membership status of stations connected to switch B, and switch B must know the same about switch A. Three methods have been devised for this purpose [12]: *table maintenance*, *frame tagging*, and *time-division multiplexing*.

**i) Table Maintenance:**

In this method, when a station sends a broadcast frame to its group members, the switch creates an entry in a table and records station membership. The switches send their tables to one another periodically for updating [12].

**ii) Frame Tagging:**

By such method, when a frame is traveling between switches, an extra header is added to the MAC frame to define the destination VLAN. The frame tag is used by the receiving switches to determine the VLANs to be receiving the broadcast message [12].

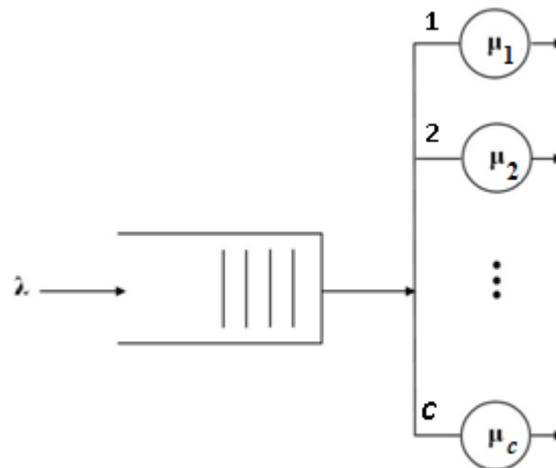
**iii) Time-Division Multiplexing (TDM):**

Using this method, the connection (trunk) between switches is divided into time shared channels. For example, if the total number of VLANs in a backbone is five, each trunk is divided into five channels. The traffic destined for VLAN-1 travels in channel, the traffic destined for VLAN-2 travels in channel 2, and so on. The receiving switch determines the destination VLAN by checking the channel from which the frame arrived [1].

In the next section, an analytical model for four VLANs is proposed and then compared with single VLAN switch from the point of view of validity and speed characteristics.

**4. Four VLANs Switch Network Model**

For the case of four VLANs, an analytical model for such VLANs is proposed here. The M/M/c queuing system can similarly be modeled as in the single VLAN case, except that the number of servers is greater than one bus, *i. e.*, has a *maximum* of  $c = 4$  buses as shown in Fig. 4.



**Fig. 4** A Simple representation of an M/M/c queue.

The proposed M/M/c queuing model represents  $c$  processors in a single switch with  $c = 4$ . The traffic intensity can be written as

$$\rho = \frac{\lambda}{\mu} = \frac{\lambda}{\min(\mu_i)} < 1 \quad \text{for } i = 1, \dots, 4 \quad (1)$$

where  $\lambda$  = average arrival rate of frames, mean processing time of VLAN-1 =  $\frac{1}{\mu_1}$ ,

mean processing time of VLAN-2 =  $\frac{1}{\mu_2}$ , mean processing time of VLAN-3 =  $\frac{1}{\mu_3}$ , and mean processing time of VLAN-4 =  $\frac{1}{\mu_4}$ .

To drive the average number of frames  $N$  in the buffer of the four-processor switch, the distribution of the number frame  $N$  is determined first. In the proposed model, it is considered that for the four VLANs, the four processors in the VLAN switch are of the same processing time with [6, 7, 9], then

$$P_n = \frac{(c\rho)^n}{n!} P_0, \quad \text{for } c = 4 \quad (2)$$

where

$P_n$  : probability of frames in the buffer.

$c$ : number of servers.

$$P_0 = \left[ \sum_{n=0}^{4-1} \frac{(4\rho)^n}{n!} + \frac{(4\rho)^4}{4!} * \frac{1}{1-\rho} \right]^{-1} = \left[ \frac{1+3\rho+4\rho^2+2.667\rho^3}{1-\rho} \right]^{-1}$$

$$\circ \circ P_0 = \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right] \quad (3)$$

$$\circ \circ P_n = \frac{(4\rho)^n}{n!} * \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right] \quad (4)$$

So, for a system in equilibrium state as the diagram shown in Fig. 5, it can be shown that

$$\lambda P_{n-1} = \min(n,c) \mu P_n$$

$$P_n = \frac{\lambda}{\min(n,c) \mu} * P_{n-1}, \quad \text{for } n \geq 1$$

$$P_1 = \frac{\lambda}{\mu} P_0 \quad \text{and} \quad P_n = \rho^{n-1} * \frac{\lambda}{\mu} P_0$$

$$\circ \circ P_n = \rho^{n-1} * \frac{\lambda}{\mu} \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right] \quad (5)$$

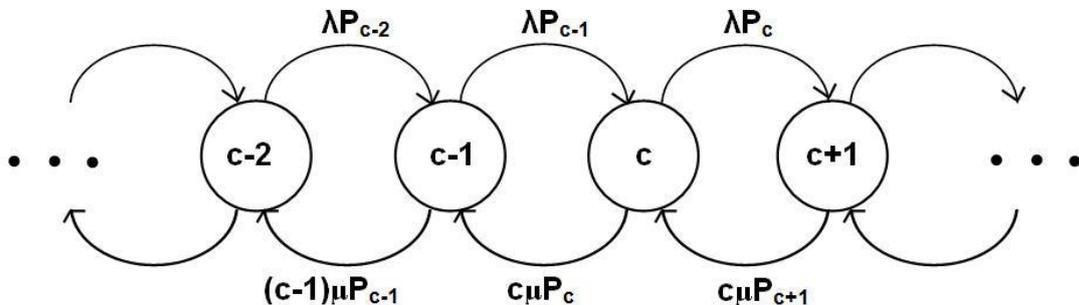


Fig. 5 A system in equilibrium.

To determine number of frames  $N$  in the buffer, it is used that [7]

$$\begin{aligned}
 N &= \sum_{n=1}^{\infty} n P_n \\
 &= \sum_{n=1}^{\infty} n \rho^{n-1} * \frac{\lambda}{\mu} \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right] \\
 &= \frac{\lambda}{\mu} \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right] \sum_{n=1}^{\infty} n \rho^{n-1} \\
 \therefore \sum_{n=1}^{\infty} n \rho^{n-1} &= \frac{1}{(1-\rho)^2} \tag{6}
 \end{aligned}$$

$$\begin{aligned}
 \therefore N &= \frac{\lambda}{\mu} \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right] * \frac{1}{(1-\rho)^2} \\
 \therefore N &= \left[ \frac{1}{1+3\rho+4\rho^2+2.667\rho^3} \right] * \frac{\rho}{1-\rho} \tag{7}
 \end{aligned}$$

The plot against traffic intensity, of average number of frames  $N$  in the buffer for the single VLAN model of *Ref.* [1] and 4 VLANs, in Eq. (7) is shown in Fig. 6. From Fig. 6, it can be seen that, traffic intensity can more efficiently be increased with minimum average number frames in the buffer for the case of equi-processing time four VLANs than a single VLAN case.

Also for determining the total time delay  $T$ , it can be derived that [7]

$$T_w = \frac{P_c}{1-\rho} = \frac{P_4}{1-\rho} \tag{8}$$

where  $T_w$  is the waiting time in the buffer.

$$\text{Since } P_4 = \frac{(4\rho)^4}{4!} P_0 \quad \text{and} \quad P_0 = \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right]$$

$$\therefore P_4 = \frac{(4\rho)^4}{4!} * \left[ \frac{1-\rho}{1+3\rho+4\rho^2+2.667\rho^3} \right]$$

$$\text{So, } T = T_w * \frac{1}{1-\rho} * \frac{1}{c\mu} \tag{9}$$

$$\text{or } T = \frac{P_4}{1-\rho} * \frac{1}{1-\rho} * \frac{1}{4\mu}$$

$$\therefore T = 10.667 \rho^4 * \frac{1}{(1+3\rho+4\rho^2+2.667\rho^3)*(1-\rho)*(4\mu)} \tag{10}$$

The plot of the time delay  $T$  versus traffic intensity for single VLAN model of *Ref.* [1] and 4 VLANs model in Eq. (10), is shown in Fig. 7. From Fig. 7 it can be seen that, traffic intensity can more efficiently be increased with minimum time delay in the buffer for the case of equi-processing time four VLANs than a single VLAN case.

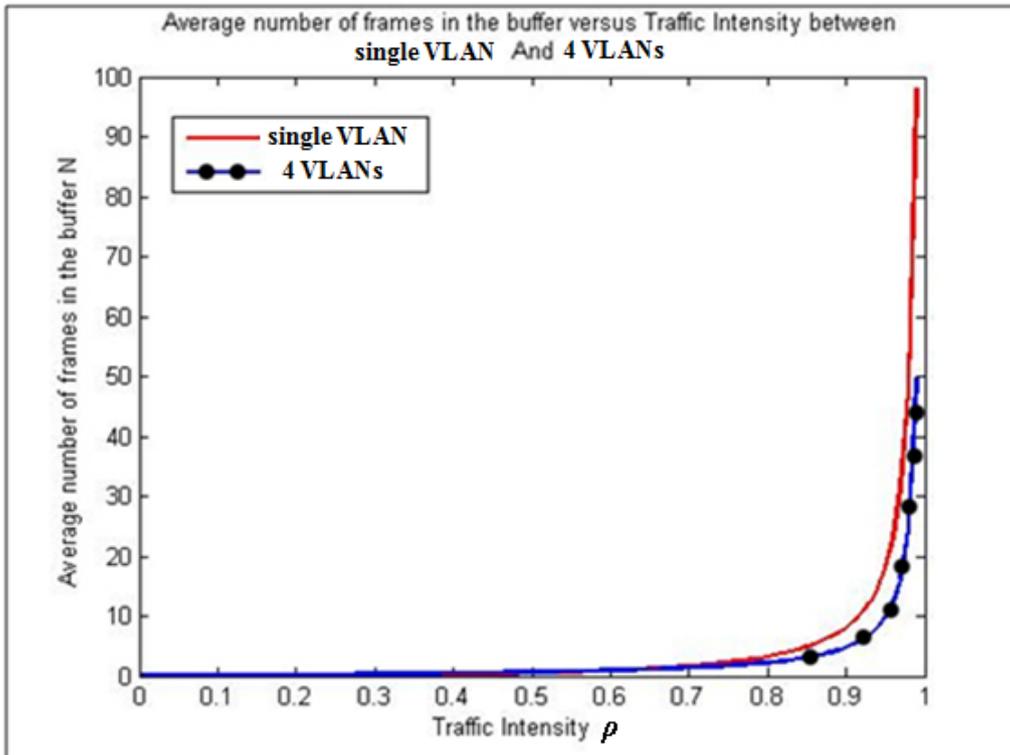


Fig. 6 Average number of frames versus traffic intensity.

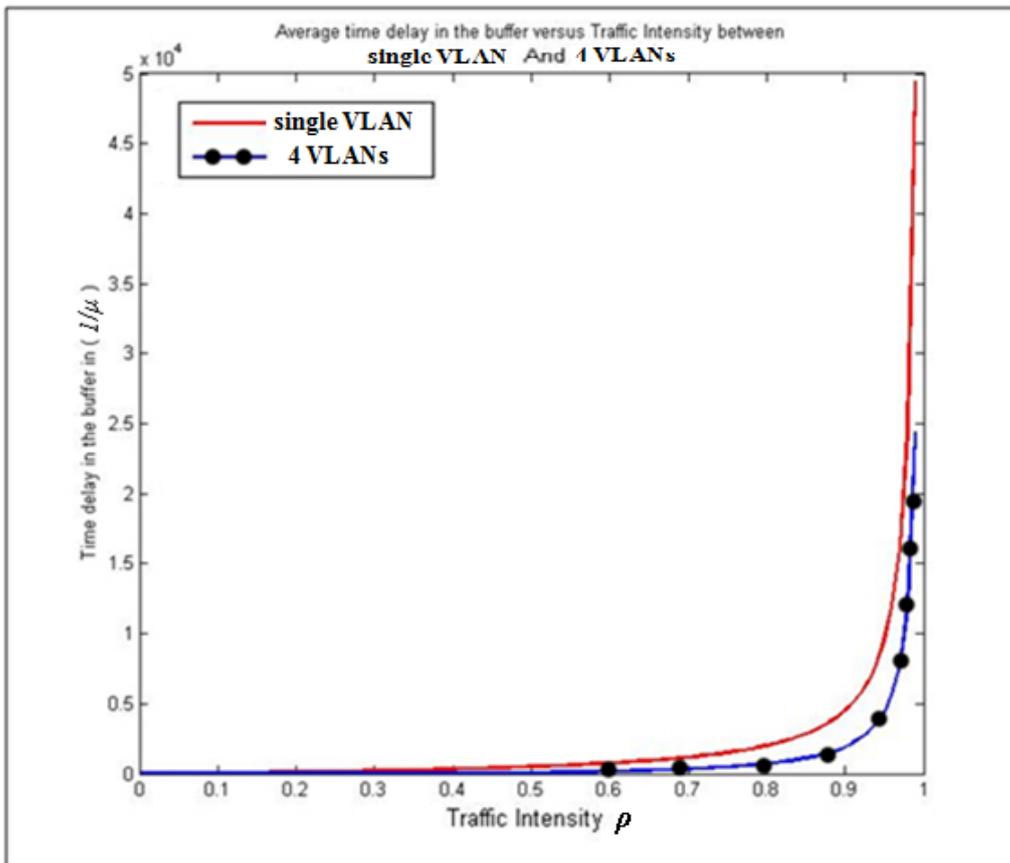


Fig. 7 Average time delay versus traffic intensity.

## **5. Conclusions**

A 4-VLAN switch network model has been proposed with the derivations of the average number of frames and the total time delay. Comparisons with a single VLAN switch model have proved the superiority of the proposed 4-VLAN model from points of view of validity (minimum average number of frames  $N$  in the buffer) and speed characteristics. The four VLANs switches model are of equal processing times. The analyses have proved that it is possible to configure any VLAN switch as many parallel sub-processors according to the number of used VLANs. Such idea can be extended to model VLAN switches dynamically to manage a variable number of VLANs with variable traffics.

It has been shown that traffic intensity can be increased with the minimization of average number of frames in the buffer. The traffic intensity can also be increased with the minimization of time delay in the buffer. That because the offered load is equi-distributed on the four servers in the system.

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