High-speed Transmission Evaluation of Gigabit Local Area Networks by Limiting Performance Model

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Abstract

Recently the internet traffic increases rapidly year by year. We have already proposed a limiting performance evaluation method for 10 and 100Base client/server LANs. We extended the method so as to express different types of LANs, including gigabit LAN. We classified LANs into 8 types, according to the hub types, and derived each formula which express the file transfer time. The measured file transfer time was compared with the calculated values. As a result, high-speed transmission evaluation of gigabit LAN by limiting performance model is given excellently by the formulae.

Keywords: *Transfer Time, Limiting Performance Model, Gigabit Ethernet, Flow Control Method*

1. Introduction

Recently the internet traffic increases rapidly year by year. To avoid traffic congestion, many technologies are investigated for public networks and for local area networks (LANs). Gigabit Ethernet is expected to satisfy the high- speed transmission demands in LANs economically. When the gigabit technologies are introduced into LANs, the high- speed performance should be evaluated quantitatively. The performance improvement should also be evaluated when existing hardware by 10 or 100Base technologies is replaced with the gigabit hardware. The LAN performance evaluation was investigated for many years[1], and analysis was reported for various situations[2]. However, the evaluation is generally complicated. This is mainly because the analysis includes the communication occurrence probability. We have already proposed [3] a limiting performance evaluation method for client/server LANs. Formulae to give a file transfer time have been derived and the calculated values were in good agreement with measured ones in 10 and 100Base LANs. This approach is effective, because the calculation is simple and the results are easy to understand to evaluate the performance improvement. In this paper, high- speed transmission evaluation of gigabit LAN is described. The limiting performance evaluation method for the 10 and 100Base LANs was extended to the gigabit LAN evaluation.

Firstly, the formulae to express the file transfer time on the limiting performance base were extended so as to include different types of LAN. The LAN is a client/server type, where client machines are connected to servers via a hub. The LANs were classified, according to the hub types specified by the possible combination of the speeds of 10, 100 and 1000MBase, including a 100/1000Base hub, which denotes a hub with some number of 100Base ports to clients and 1000Base uploading ports to servers. The LANs were constructed and the limiting performance was evaluated by measuring the file transfer time. The measured and calculated results were compared, and it was found that the high- speed transmission could be evaluated reasonably for the hub with the gigabit port. The theoretical and experimental results are described.

2. Performance Evaluation for 8 Types of LANs by Extending Limiting Performance Model

2.1. LAN Classification

Fig. 1 shows the client/server LAN configuration to be evaluated in this paper. We have a server and some clients (CLs) connected to the server via a hub. When a client is going to use data stored in the server, a request is sent to the server. If the requests by some clients take place simultaneously, a congestion occurs, because the path between the server and the hub is just one. This is controlled by

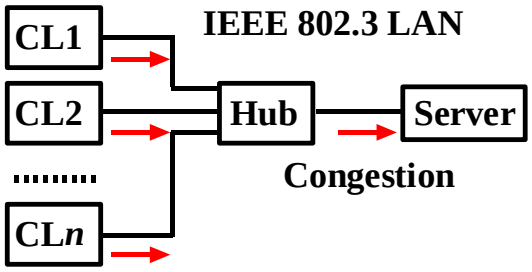

Fig. 1 LAN Configuration to be Evaluated

a media access control protocol. Historically, the carrier- sense multiple- access with collision detection (CSMA/CD) protocol was developed for the bus configuration, such as 10Base-5 LAN. Afterward, such a star- wired configuration as Fig. 1 was developed, and now it is used widely. In the configuration, the media between the hub and each client are dedicated to each client, but the media between the hub and the server are shared with the clients. A switching hub was also developed, providing a microsegmented LAN configuration. Additional functions of the media access control were developed for the star- wired LAN with a hub. This was mainly made by the flow control: backpressure and pause function[4]. To evaluate transmission speed improvement by upgrading network, suitable formulae are necessary for the different types of the star- wired LAN.

Table 1 shows the classification of hubs to be evaluated in this paper. A hub is a non-switching (NSW) or a switching (SW) type. The media access is controlled with a CSMA/CD protocol in NSW hubs, and the flow is controlled with either back pressure or pause function in SW hubs. The hubs can be classified into 8 types, according to possible combination of the speeds of 10, 100 and 1000Base, as listed in Table 1. Here, 10/100 means a hub with some number of 10Base ports to clients and 100Base uploading ports to servers. The symbol 100/1000 also means a hub with 100Base ports for clients and 1000Base ports for servers.

2.2. Limiting Performance Evaluation for 10/100Base and 100/1000Base LANs

The limiting performance evaluation method for the 10 and 100Base LANs has been reported[3], as described in section 1. In this paper, we extend the formulae which expresses the file transfer time on the limiting performance base so as to include different types of LAN. The limiting performance was measured as a delay in the LAN which we defined as the longest time of the values to transfer all the packets by each client, when all the clients start simultaneously transferring their data to the server.

Fig. 2 shows a simultaneous packet transfer model for the limiting performance evaluation of SW hubs. The hub has media access control (MAC) chip to manage the flow control and the switching, buffer memory to hold packets for MAC, and address table for the switching. In the limiting performance evaluation, we defined the parameters listed in Table 2. The formulae could be derived, in the same way as the previous calculation[3], for all the types of hubs. The results are summarized in Table 3. The details to derive the formulae are described in other paper[5]. The parameter values in the formulae are to be determined by the measured values. The values are described in section 3, together with the experimental results.

3. Result and Discussion

3.1. Comparison between Measured and Calculated Values of Transfer Time

The different types of LANs were constructed by using the 8 types of hubs, and the limiting performance was evaluated. A transfer time measurement tool[3] was used. This tool consists of CL modules and one controller. After the controller detects all the CLs, all the CLs start simultaneously start file transfer to the server with using FTP. When one measurement is completed, the measured transfer time is sent to the controller and the results are saved.

Two servers were prepared. One is called

Table 1 Classification of Hubs

Hub		Speed	
NSW	CSMA/CD	10	
		100	
		100	10/100
SW	Back Pressure	10	
		10	
		100	
	Pause	10	
		100	
		100/1000	

Table 2 Parameter Meanings

Parameter	Meaning
n	Client Number
u	Unit Packet Size
t_u	Transfer Time to Send One Packet u
x	Unit Waiting Time to Establish the Link
y_1	SlotTime for All Ethernet Data Rates
y_2	Unit Waiting Time to Take a Packet into Buffer in the Hub
z	Transfer Time to Send One Packet u inside the Hub

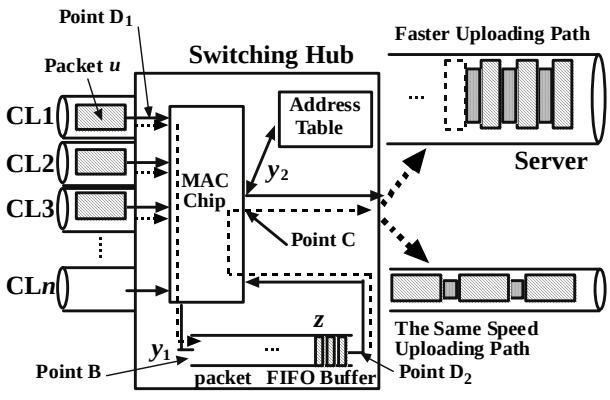

Fig. 2 Simultaneous Packet Transfer Model for the Evaluation of LAN

server 1 (SV1) with a PCI-bus speed of 64bit/33MHz, and the other is called server 2 (SV2) with a PCI-bus speed of 64bit/66MHz. Both the network interface cards of SV1 and SV2 had a speed of 1000Mbps. SV1 was used for all the measurements for LANs with 10, 100 and 10/100 hubs, whereas, SV1 and SV2 were used for the 100/1000 hub, respectively, to evaluate the high-speed transmission of gigabit transmission.

The transfer time was measured by changing the file size F and client number n with the measurement tool. The measured and calculated results are shown in Fig. 3. The calculated values were obtained by the equations in Table 3. The parameters tu, x, y and z in the formulae were obtained by solving simultaneous equations which were derived by substituting measured values into t(F, n). The parameter values are listed in Table 4. It is found that the parameter values listed in Table 4 are in good agreement with the physical expectation. The transfer time values of the unit packet are expected to be 1.2 ms (=1460x8bits/10Mbps) and 0.12 ms (=1460x8bits/100Mbps) in 10Base (NSW and SW) and 100Base (NSW and SW) LANs, respectively.

It is found from Fig. 3 that the measured and calculated values are in good agreement. This result verifies that the formulae in Table 3 and the parameter values in Table 4 are suitable to evaluate the limiting performance. The transfer time keeps almost constant for the 10/100 hub, when the client number is less than 8. This is due to the higher transmission speed of the uploading path to the server[3]. The same result was obtained for the 100/1000 hub. However, the threshold client number is less than 3 and 4 for SV1 and SV2, respectively. This is due to the limitation of the PCI-bus speed of the servers. From the result, it can be estimated that the effective speeds of uploading for SV1 and SV2 are at most 300Mbps (=100Mbps x 3) and 400Mbps (=100Mbps x 4), respectively.

The speed was less than 1000Mbps. The similar results were reported[6], showing that peer-to-peer throughput was 719.2 Mbps between a server and a client with 64bit/66MHz speed PCI-bus. This is because the bus is used for other tasks in the server, leading to the lower speed of the file transfer.

3.2. Throughput Improvement Evaluation by Introducing a 100/1000Base Hub

According to the formulae, we can estimate quantitatively the performance improvement by upgrading

Table 3 Obtained Formulae According to Each Hub

Hub		Formula
NSW		$t(F,n)=\frac{F}{u}\left[nt_u+n\frac{n-1}{2}x\right]$
SW	BP	$t(F,n)=\frac{F}{u}\left[t_u+B(n)y_1\right]$
	Pause	$t(F,n)=\frac{F}{u}\left[nt_u+(n-1)y_2\right]$
10/100	$1 \leqq n \leqq 8$	$t(F,n)=\frac{F}{u}\left[nt_u+nz\right]$
	$9 \leqq n$	$t(F,n)=\frac{F}{u}\left[nt_u+n\frac{n-1}{2}x\right]$
100/1000	$1 \leqq n \leqq n_{th}$	$t(F,n)=\frac{F}{u}\left[nt_u+nz\right]$
	$n_{th} \leqq n$	$t(F,n)=\frac{F}{u}\left[nt_u+(n-1)y_2\right]$

Table 4 Obtained Parameter Values

LAN			t_u (msec)	Z	(msec)
NSW		10	1.200	x	0.080
		100	0.130		0.010
SW	BP	10	1.273	y_1	0.051
		100	0.131		0.005
	Pause	10	1.226	y_2	0.028
		100	0.123		0.002
10/100Base		$1 \leqq n \leqq 8$	1.264	z	0.010
		$9 \leqq n$	0.142	x	0.010
100/1000Base SV1		$1 \leqq n \leqq 3$	0.115	z	0.007
		$4 \leqq n$	0.026	y_2	0.033
100/1000Base SV2		$1 \leqq n \leqq 4$	0.115	z	0.006
		$5 \leqq n$	0.014	y_2	0.030

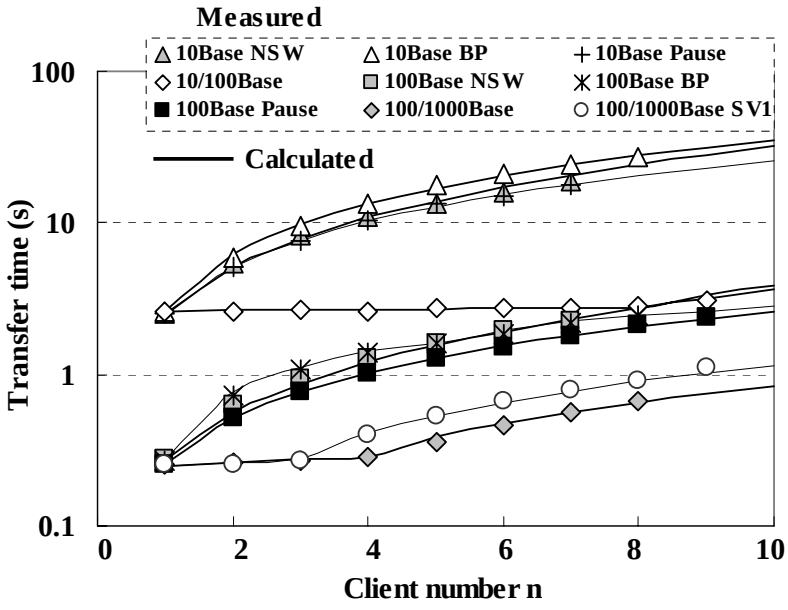

Fig. 3 Measured and Calculated Transfer Time (8 Types of LANs)

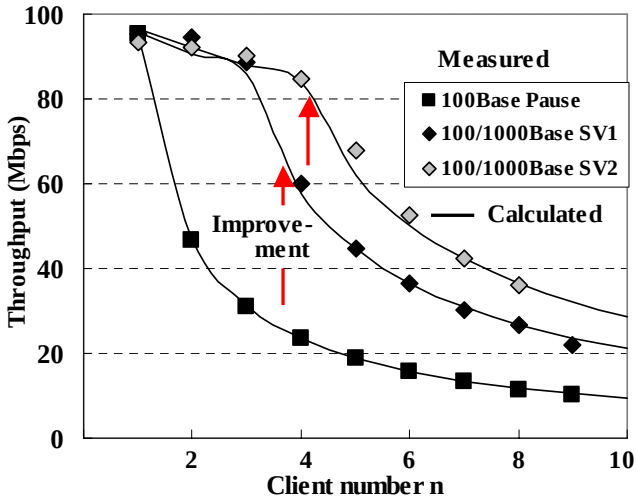

Fig. 4 Measured and Calculated Throughput

a hub. A throughput improvement was evaluated by replacing a 100Base SW hub with a 100/1000Base hub. A throughput tp(F,n) of LAN is given by

$$tp(F,n) = \frac{n \cdot F}{t(F,n)} \qquad (1)$$

when n clients send a file (size=F) simultaneously. The transfer time was measured for the LANs with a 100Base hub and 100/1000Base hub, respectively, with changing client number n. Each client sent a 3MB file simultaneously to the server, and the transfer time was measured. The results are shown in Fig. 4. The throughput was calculated by Eq.(1) and the curves are also shown in Fig. 4. It is found that the measured and calculated values are in good agreement with each other.

The results show that the throughput in the 100Base LAN decreases rapidly with increasing client number n, whereas the improvement by replacing the 100Base hub with the 100/1000Base hub was attained fully. This is due to the high-capacity of the 1000Base path to the server. However, the throughput in 100/1000Base LAN decreases for more clients than 4 and 5 for SV1 and SV2, respectively. This is because the effective speeds of 300Mbps and 400Mbps are exhausted by the packet streams of 100Mbps and the average waiting time y_1, as in the same way as for 10/100Base hub[3].

4. Conclusion

A high-speed transmission of gigabit LAN has been evaluated theoretically and experimentally, based on a limiting performance model. Formulae were derived to give the limiting performance for the LANs with 10, 100, 10/100, 100/1000Base hubs. The formulae were given so as to include the hub types of switching, non-switching and flow controls of back pressure and pause function.

Eight types of LAN with different hubs were constructed and the limiting performance was measured. It is clarified that the measured and calculated results are in good agreement. This verifies that this limiting performance approach is effective, even for the high-speed evaluation of gigabit LAN. The performance improvement by replacing 100Base hub with 100/1000Base hub was actually evaluated and demonstrated.

Acknowledgement

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