

# A Stall Rate Analysis of Heavy and Transient Traffic LAN by Simulation on Multi-Layer Protocols

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## Abstract

In this paper we propose a new criterion for analyzing and evaluation the behavior of Ethernet LAN, *Stall Rate*. It is computed as a ratio of the waiting time for transmission of frame to total transmission time. It explicitly represents the reason of low throughput of network under high load. We measured *Stall Rate* by detailed simulation of Ethernet and higher protocol layer. We developed an detailed event driven simulation model for multi-layer protocols, which includes application model and user-behavior model. Using this model, the characteristics of a high-loaded network under a practical situation are analyzed in wide domain from data link layer to application layer.

## 1 Introduction

Performance evaluation of computer network has been a significant subject of research in the last decade. High accurate traffic estimation and analysis of behaviors are very important for construction of Local Area Network (LAN) at a large scale workstation system. Especially, a LAN for educational computer systems have potential high load and high transient traffic because of the behavior of users who attend to lecture using the same system on a network. However, reports about the performance of high-load and high-transient-load LAN have not been published to date.

The reasons of low network throughput under high load are collisions on Ethernet, the performance of retransmission control mechanism in transport layer, dependencies between a server and clients in application layer and so on. However, the interactions between them are not clear. Network simulation is a useful method to analyze these behaviors. However, most network simulation reports [1][2][3] focus a particular

layer protocol or protocols under transport layer, or simplifies protocols.

In this paper we propose a new criterion called *Stall Rate* for analyzing the behavior of Ethernet LAN. It is computed as a ratio of the waiting time for transmission of frame to total transmission time by simulation model proposed by the authors [4] [5]. It explicitly represents the reason of low throughput under high load. The relationship between the behaviors of data link layer protocol and upper layer protocols (i.e. TCP/IP, FTP and NFS) can be analyzed by this measure criterion.

We found availability of the evaluation method by applying it to a large scale distributed system at a computer education institution.

## 2 Simulation Model

### 2.1 Overview of The Modeling

In this study, the network protocols are modeled in detail to simulate network behaviors under high-load and transient-load. The proposed network model consists of three models, (1) Network Model, (2) Application Model and (3) User Model, to represent multi-layer protocols and user behavior. The details of these models and method of its simulation are initiated in [4] and well-discussed in [5] by the authors.

### 2.2 User Model

A user model defines timings of user operation. We selected a LAN in a class room of computer education as a sample of high-load and high-transience LAN. In such environment, most of students begin to operate workstations all together directly after an instruction for students to operate a file on the file server. As a result of this, network requests from client workstations used by students concentrate on the file server,

Table 1: Parameters of User Models

Model	$\mu$ [sec]	$\sigma$ [sec]
M (Mouse Input)	2.2	1.6
K (Keyboard Input)	6.3	10.6
O (At the same time)	1.0	0.0

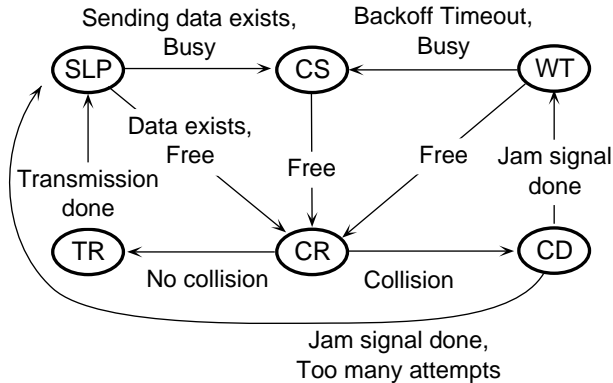


Figure 1: State Diagram of Ethernet Sub-Model

and a high load and transience are instantly made on the LAN. We modeled the timings of user operation on such situation.

As a user model, we assumed that the time when a client workstation sends a request message,  $t_b^{(i)}$ , is distributed according to the time required for students to respond to the instruction. The probability density function of  $t_b^{(i)}$ ,  $f(t_b^{(i)})$  is determined as a distribution such that the probability of random value  $t_b^{(i)}$  is negative, is zero at the normal distribution  $N(\mu, \sigma^2)$ .

Random values  $t_b^{(i)}$  generated from  $f(t_b^{(i)})$  determine behaviors of client workstations, and are used as simulation parameters.  $\mu$  and  $\sigma$  give the degree of concentration of network accesses. Three access concentration models M, K, and O are developed for representation of various command input methods as shown in Tbl. 1. The ideal model O is for a comparison. These parameters are obtained by measurement of a real educational workstation system.

### 3 Stall Rate for Traffic Analysis

We introduce a new measure of Ethernet status called *Stall Rate* here. This measure is obtained by the Ethernet state transition model (Fig. 1). Now we assume the total of time that the state of node defined in Ethernet sub-model  $S^{(i)} \in \{CS, CR, TR, CD, WT\}$  as  $T_{XMT}$ , the total of time that  $S^{(i)} = CS$  as  $T_{CS}$ , the total of time that  $S^{(i)} = WT$  as  $T_{WT}$ . Therefore,  $T_{XMT}$ ,  $T_{CS}$  and  $T_{WT}$  represent the total transmission time and total carrier sensing time and total waiting time

because of collisions, respectively. Averaged CS-stall rate  $R_{CS}$ , WT-stall rate  $R_{WT}$ , and a total stall rate  $R_T$  under  $N$  stations are defined as follows.

$$R_{CS} = \frac{1}{N} \sum_{i=1}^N \frac{T_{CS}^{(i)}}{T_{XMT}^{(i)}} \quad (1)$$

$$R_{WT} = \frac{1}{N} \sum_{i=1}^N \frac{T_{WT}^{(i)}}{T_{XMT}^{(i)}} \quad (2)$$

$$R_T = R_{CS} + R_{WT} \quad (3)$$

Total stall rate  $R_T$  is the ratio of the time that a station does not send signal to medium to the time that the station is processing to transmit frames. CS-stall rate  $R_{CS}$  and WT-stall rate  $R_{WT}$  mean the ratio of the time of carrier sensing and the time of waiting for retry because of collision, to the time that the station is processing transmission.

From the value of  $R_T$ ,  $R_{CS}$  and  $R_{WT}$ , status of Ethernet can be evaluated as follows.

- When  $R_T$  is large, the network is congested.
- When  $R_{WT}$  is large, many collisions are occurred in the network.
- When collisions continuously occur,  $R_{WT}$  grows larger.
- When  $R_{CS}$  and  $R_T$  are large, the network is very congested and stations can not start transmission because of continuous busy state of medium.

These characteristics are evaluated by popular measures like collision rate or network utilization. However, these measures does not represent explicitly why a node can not transmit frames. For example, collision rate is large when a network is congested. However, when the network is very congested, the reason of long transmission delay is the continuous busy periods of medium than collisions. This is not represented clearly only from collision rate. On the other hand, by evaluation with stall rates, the reason of this is graphically represented that  $R_{CS}$  is large and  $R_T$  is nearly 100 % (e.g. Fig. 3). This is very useful for designing new networks.

### 4 Simulation Results

We adapted this simulation method to evaluate educational workstation system as a sample of high-load and high-transient network system. Simulation is performed under the following assumptions.

- Ethernet LAN (10BASE-T and 100BASE-TX), consists of a single collision domain.
- $N$  workstations and a server station are connected to a HUB by 10 meter cables.
- File transferring from server to clients by NFS or FTP.
- All client stations start to send a request message to the server following to the timings described in three user models (model M, K and O).
- TCP sending buffer size and receiving buffer size are 4096 bytes each. Initial value of TCP retransmission timeout is 6.0 [sec]. The maximum and minimum value of the timeout are 64.0 [sec] and 1.0 [sec] respectively.
- NFS timeout parameter  $timeo = 0.7$  [sec],  $retrans = 3$ . These values are same as the defaults of Sun OS 4.1.
- CPU time and latency of HUB are neglected.

In the following section, we present some experimental results to show the ability of this simulation method that enables evaluation of network performance from the data link layer to the application layer.

#### 4.1 File Transfer Time

As an example of evaluation on the application layer, Fig. 2 presents averaged file transfer time which is defined as the period of time between the time when a client station sends the first request and the time when the clients receive all requested data. The size of transferred file is 1 MB.

**FTP Model:** On 100BASE-TX LAN, file transferring time is under 10 [sec] for user model M and K at  $N < 150$ . These values are sufficient for practical use. On 10 BASE-T LAN, file transfer time of user model O increases linearly. At user model M and K, it keeps low value at low  $N$ , however, it increases  $N > 5$  or  $N > 20$  for user model M and K respectively and it gradually approaches to the result of user model O. These results mean that messages are successfully transmitted in congestion at low  $N$  because of the distribution of operations by users. This condition can be called as ideal good condition.

**NFS Model:** On 100BASE-TX LAN, file transfer time is under 5 [sec] for user model M and K at  $N < 100$  as same as the case of NFS model. On 10BASE-T LAN, it shows same character as same as FTP model at  $N < 120$ , however at  $N > 120$  it increases rapidly. From this results we think that the maximum client

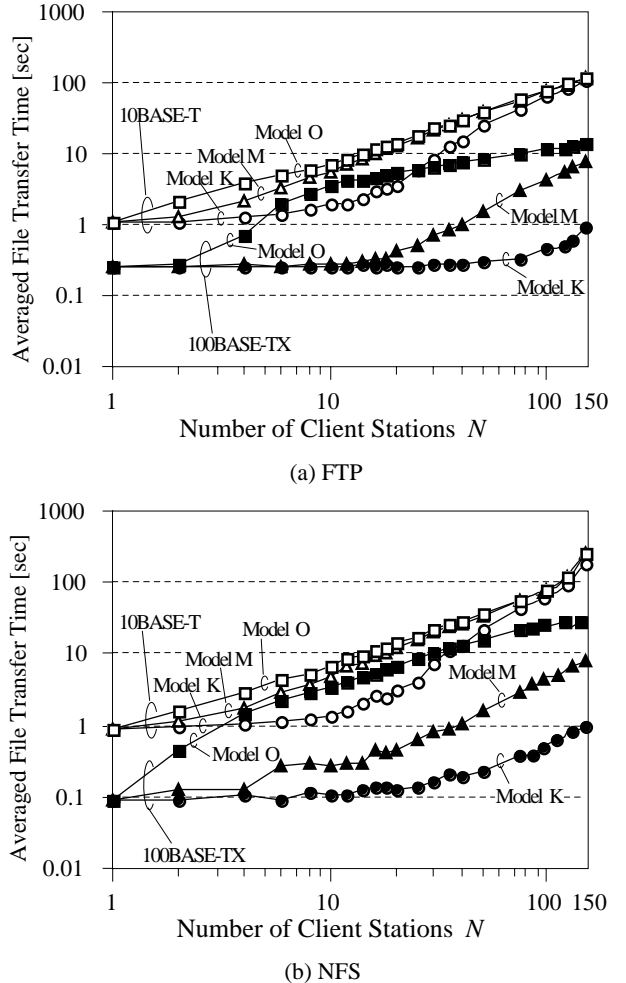


Figure 2: Averaged File Transfer Time

number for practical use in such network is about 120, and more clients cause system failure.

These results lead us to the conclusion that guidelines for the number of workstations at educational LAN which keeps low file transfer time and low collision rate is 20 nodes for 10 Mbps Ethernet LAN, 100 nodes and more for 100 Mbps Ethernet LAN.

#### 4.2 Analysis with Stall Rate

Fig. 3 represents averaged stall rate of client stations  $R_T = R_{CS} + R_{WT}$  of FTP model and NFS model on 10BASE-T. In the figure  $R_{WT}$  is drawn from the top of the graph,  $R_{CS}$  is drawn from bottom. The rest white space of the graph means time that the stations are sending signals.

$R_{WT}$  represents directly the frequency of collision on transmission. Hence, as  $N$  increases  $R_{WT}$  increases when  $N$  is small. However, at  $N > 50$   $R_{CS}$  increases and  $R_{WT}$  decreases. The reason of this fact is that

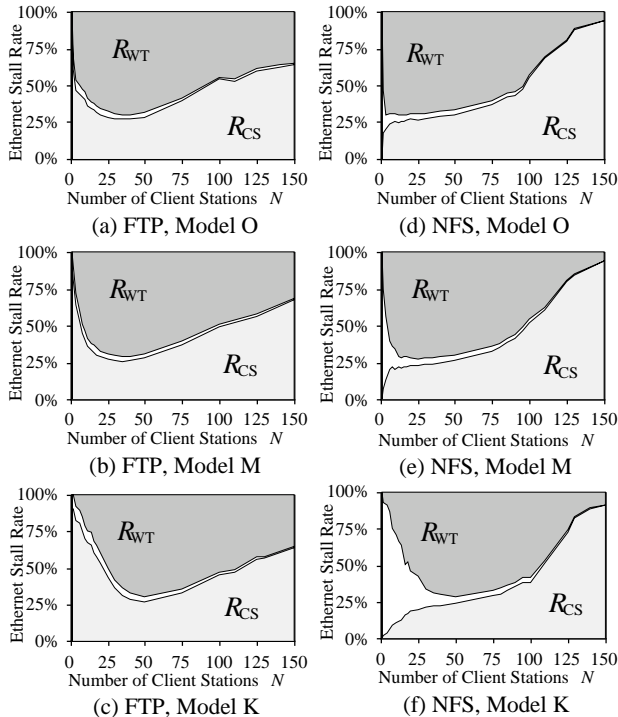


Figure 3: Averaged Stall Rate of Client Stations

client station can not find a chance to send a packet to medium because of continuous carrier from other nodes. Thus, the frequency of carrier decreases and stations have to wait for the free state of medium for a long time. This tendency is remarkable on NFS model. In addition to this,  $N$  when  $R_{CS}$  beginning to increase is the same value when the file transfer time is increasing rapidly. We think this is because retransmission of request message from NFS clients. Retransmissions of request message from clients increase the network traffic rapidly as  $N$  increases. On the other hand, FTP which utilizes TCP as transport layer protocol, only the server station retransmits data. Therefore the effect of  $N$  to the amount of traffic is not larger than NFS.

We evaluated stall rates within whole of simulation time (from the first transmission of all nodes to the last transmission) on this study. However, we think that this method is not appropriate on analyzing situations that the network load is concentrated in a part of the simulation time. If stall rates are evaluated within whole of simulation time on such situation, the characteristics under concentrated load represented by stall rates are hidden by averaging. Stall rates under such situation should be evaluated per appropriate short terms. In addition to this, the dynamic characteristics of networks under transient load can be analyzed by the evaluation method.

## 5 Conclusions

A new evaluation criterion for network traffic named *Stall Rate* is proposed. It consists of three kinds of value; CS-stall rate, WT-stall rate and Total stall rate. These are useful for studying reasons of performance down of Ethernet LAN, and shows the characteristics of the network graphically and directly.

The simulation method was applied for a case of heavy and transient traffic LAN at educational distributed workstation system. Some behaviors and properties of such a LAN that it is very hard to observe them by other methods, are obtained by this modeling and simulation method with proposed stall rate. From the result of this, we presented suitable number of client workstations in educational distributed workstation system.

Although we gave the example of evaluation with stall rate only within total simulation time, we think that the evaluation of stall rates within each short terms in simulation is useful for analyzing dynamic characteristics of high transient LAN.

In this paper, we described an application of our simulation method only on LAN which has only single collision domain. However, fundamental idea of this method can be used for multi-segment LAN. Modeling for complicated networks including switching-HUBs or routers, applications to variety of protocols are topics for future study.

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