THROUGHPUT ANALYSIS OF A TRANSPORT PROTOCOL OVER AN X.25 NETWORK (*)

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ABSTRACT

After the identification of the more relevant factors of the X.25 network service we develop a throughput analysis of the transport protocol in the customary case of bulk traffic. The key parameters to tune the protocol performance are the transport window and the network window. An expression for the transport throughput is obtained in terms of several parameters. Quantitative results show the high degree of influence of the selected windows on the transport throughput.

1. INTRODUCTION

The OSI transport service has the responsibility to optimize the use of the network resources. In order to have guidelines to achieve this goal a performance analysis is required. The U.S. NBS, the ETSIT and Telefonica (the Spanish PTT) are engaged in cooperative research concerning data communication protocols. One part of the research program is intended to investigate the performance of the ISO class 4 transport protocol for operation over X.25 virtual circuits. The ETSIT is now developing an X.25 network simulator module to be used in a transport simulator implemented by NBS [Mil-86]. In order to have a reference that will allow the validation of the simulator, we have obtained some analytical results in the case of a single transport connection over a unique network connection.

The purpose of this paper is: a) to propose a model of the X.25 network service and b) to show some analytical results of throughput of the transport protocol operating over X.25 network service.

2. X.25 MODELLING

The X.25 virtual circuit service can be represented by a set of parameters and performance measures seen by the user. That set shows the network behaviour with no need of knowledge about the internal structure of the network. Consequently we propose a model based on this representation of the X.25 behaviour as seen by the user. Figure 1 outlines the model, using X.25 connections between two hosts, A and B.

Among the more relevant parameters of a virtual circuit service are the following: X.25 window, Kn; packet length, Ln; baud rate of access lines, Cna, Cnb; several virtual circuits between two end users, Ncv. Other features relevant to some applications are the use of expedited data and the availability of the X.25 D bit.

The basic performance measures related to the user are transit delay, Tn; and throughput over the virtual circuit. Other relevant performance indicators are: the establishment and release delays, and the probability of a network shutdown.

A throughput limitation would appear in a X.25 connection as a consequence of the several flow control procedures used in the network (e.g., input control, end-to-end control,

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backpressure). This limitation is seen by the network user by means of only one mechanism, the X.25 window, for any kind of flow control technique used in the network.

The X.25 window can be represented with a static parameter, the width, and a dynamic behaviour, the window advance delay, Tv. That is, the time elapsed between a packet input to the network and the delivery of its network acknowledgement (i.e., with a RR packet).

3. TRANSPORT PROTOCOL MODELLING

The purpose of the Transport Service is to provide, to the upper layers, data transportation at a required quality of service in an optimum manner. It is the requirement of the Transport Layer to provide a service in a transparent and reliable way, without regard to the underlying communications medium. To achieve this goal several mechanisms are used, that are grouped in five classes of transport protocol, in order to cover the broad scope of the quality of service required by the users and the variety of communications media and networks. [Hun-84], [Sta-84].

There are four key transport protocol mechanisms: Error control, Flow control, Ordered delivery and Sharing of connections (i.e., splitting and multiplexing). The degree of influence of these mechanisms over the performance, depends on the type of network connection used. For instance, if a X.25 virtual circuit is used, the transport protocol retransmission time-out period (the typical error control tuning parameter) has no influence over the throughput owed to the high reliability of that kind of network. (Unless of course the timer is set too low).

Furthermore, if we assume, as a first step, that we use a single X.25 virtual circuit per transport connection, and vice versa, only the flow control mechanism is relevant for performance tuning purposes. As in other layers, the flow control mechanism is implemented using a window, whose width we denote by Kt.

Consequently in this paper we focus on the throughput analysis (in the customary case of bulk traffic) of the transport protocol over an X.25 network connection, using the transport window as the unique tuning parameter of the transport layer.

4. INFINITE X.25 WINDOW ANALYSIS

As a first approach we analyze the case of infinite network window, in order to introduce the method of analysis.

We suppose a transport connection carrying It data bits of upper layers in data "segments" (as we call data Transport Protocol Data Units for short) of length Lt (including overhead from layer four to two). The receiver entity replies to each segment with an acknowledgement, that will arrive to the sending transport entity after a time delay Tak, (Fig. 2-a). The sending entity would be stopped if the following inequality holds:

$$(Kt - 1)\, Lt/Cna < Tak \qquad (1)$$

Cna being the capacity of the network access link at the sending entity side.

As can be seen from figure 2-a the bulk data transfer assumption leads to a cyclic behaviour, when inequality (1) holds. Let us call Toc this cycle time, then the throughput (as seen by the sending transport entity) is given by the number of data bits transmitted per cycle, that is

$$Cef = Kt \;\; It \; / \; Toc \qquad (2)$$

And replacing Toc in terms of other parameters we have:

$$Cef = \frac{Kt\ It}{Tak + (Lt/Cna)} \qquad (3)$$

Or using the throughput efficiency:

$$\frac{Cef}{Cna} = Kt \; \frac{It}{Lt + Tak\ Cna} \qquad (4)$$

In general the link speeds, Cna and Cnb, could have different values. Then, it is more convenient express the throughput efficiency with respect to the smallest link speed. In the following we denote this minimum speed by Cna.

In the figure 2-b the behaviour of the throughput efficiency is outlined (for several Cna's), it increases linearly with the transport window, Kt, following (4) while inequality (1) holds. When the window is large enough, (1) does not hold and then the source does not stop, and the throughput remains constant (Cef/Cna = It/Lt) even if the window width increases.

5. FINITE X.25 WINDOW ANALYSIS

When we consider in the analysis the influence of the finite width of the network window, we have new potential events leading to a source stop. We will introduce these events with the aid of figure 3, where we show: a) the sequence of packets (we suppose that each transport segment is carried in a single packet) sent by the transport entity of a host A to the X.25 virtual circuit; b) the sequence of packets (from A) delivered by the network to a Host B, after a network transit delay, Tn; c) the sequence of packets (with total length Lat) carrying transport layer acknowledgements issued by the B host entity; d) the sequence of these acknowledgements delivered to the A host entity after a network transit delay, Tna, (generally different from Tn because the data segments are larger than an ACK).

If we observe figure 3, we can identify two main reasons leading to a source stop.

The first reason is a transport network closure due to an eventual large delay between the transmission of a segment by the transport entity A and the reception of its acknowledgement issued by the entity B.

A second reason is a network window closure because the A entity issues Kn packets in a time shorter than the sum of the window advance delay, Tv, plus the transmission time of a X.25 acknowledgement over the link to the host A (that is, Lan/Can, Lan is the length of a X.25 ACK, i.e., a RR packet).

Taking into account these two reasons we have obtained the following expression for the cycle time:

$$Toc = \frac{Lt}{Cna} + \max[a,b] \qquad (5)$$

Where Lt/Cna is the transmission time of the first segment of a cycle; a and b are terms mainly related to the transmission through the network and to the transmission through the network access link, respectively, that are given by:

$$a = Tn + \frac{Lt}{Cnb} + \frac{Lat}{Cnb} + Tna + \frac{Lat}{Cna}$$

$$b = (Kt-1)\frac{Lt}{Cna} + \max[0,c]$$

$$c = \left\lceil \frac{Kt}{Kn} + 1 \right\rceil \left(Tv + \frac{Lan}{Cna} - (Kn-1)\frac{Lt}{Cna}\right)$$

(Note that the ceil function is denoted by ^()^)

The throughput for the finite window case is obtained substituting in (2) the cycle time, Toc, by (5). Figure 4 shows the throughput behaviour in terms of the transport window, Kt, using as parameters the network window, Kn, and the transit network delays, Tn and Tna, and network window advance delay, Tv (Table 1 summarizes the set of delays used). The results are carried out for three values of access link capacities (2.4 and 9.6 and 48 Kbps), being the same in both sides of the network. The lengths (in octets) of packets used are Lt = 137, Lat = 14, Lan = 9, following the recommendations X.224 and X.25.

6. CONCLUSIONS

From figure 4 we observe the high degree of influence of the selected windows on the transport protocol throughput, for a wide range of cases. Then we can use the expressions (5) and (2) as a first approach to tune adequately the transport protocol over a particular connection.

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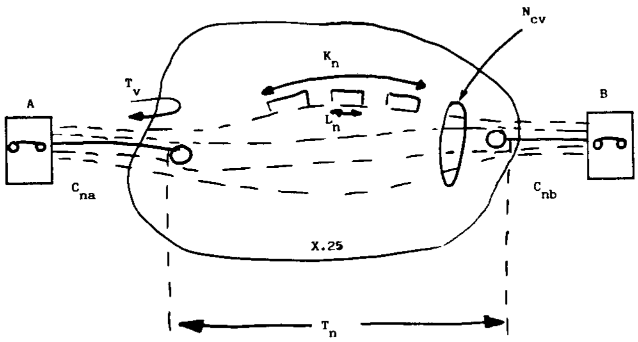

Figure 1. Model of X.25 connections.

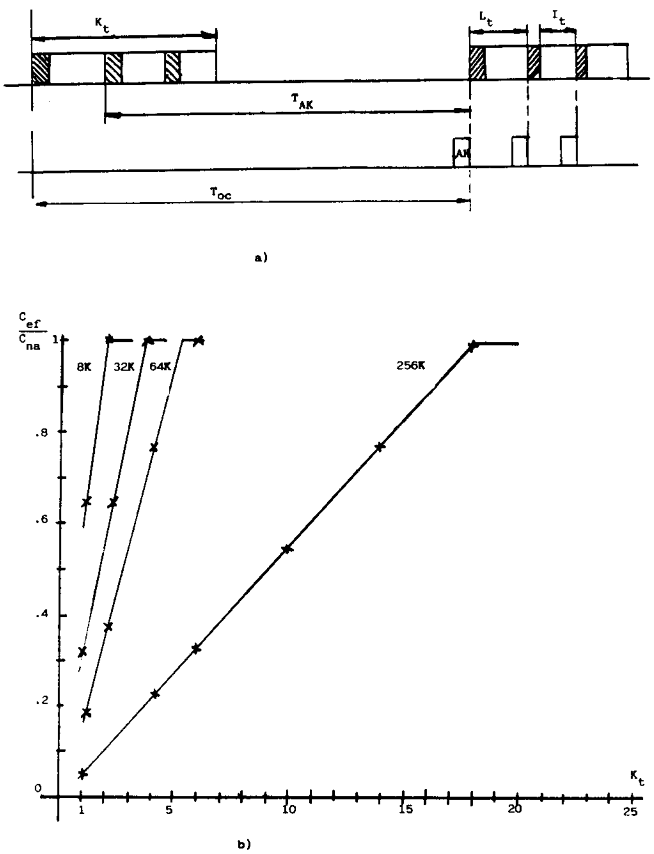

Figure 2. a) Frames with infinite network window. b) Througput efficiency.

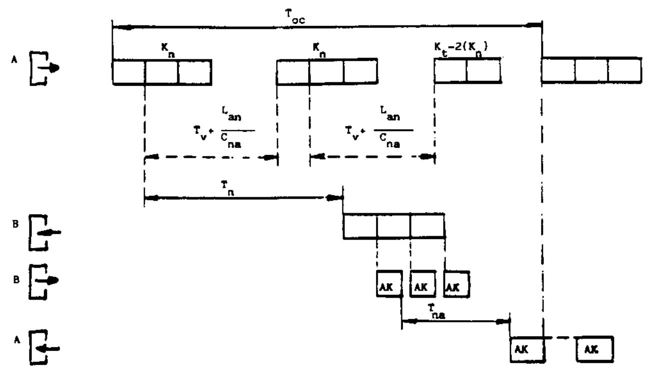

Figure 3. Frames with finite network window.

Figure 4.a Throughput efficiency. (Cna=Cnb= 2.400 bps).

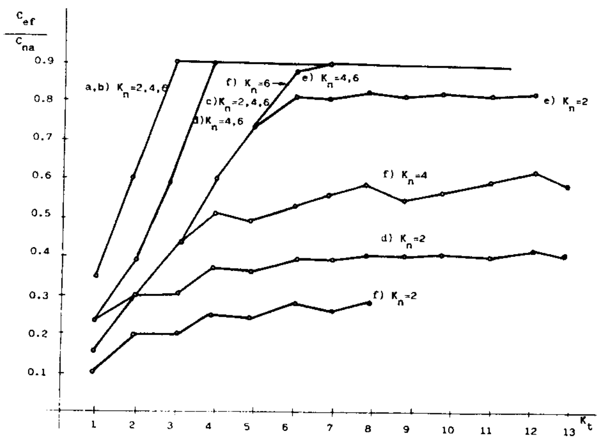

Figure 4.c Throughput efficiency. (Cna=Cnb= 48.000 bps).

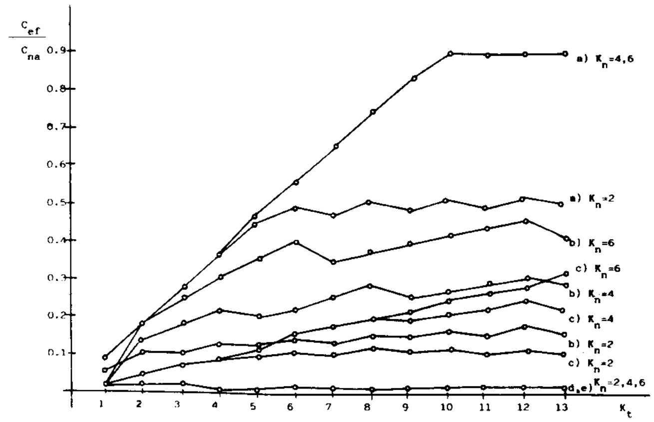

Figure 4.b Throughput efficiency. (Cna=Cnb= 9.600 bps).

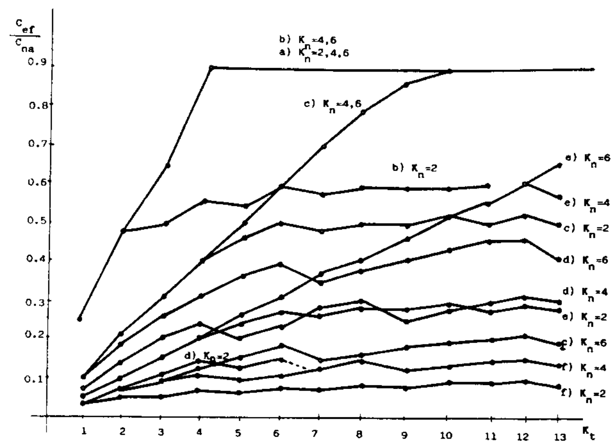

Table 1. Network delays (in sec.) used to obtain figure 4.

Line	Tn	Tna	Tv
a	0.1	.07	.05
b	0.1	.07	.2
c	0.5	.3	.25
d	0.5	.3	1
e	1	.8	.5
f	1	.8	2