RELATIONSHIP BETWEEN PERFORMANCE PARAMETERS FOR TRANSPORT AND NETWORK SERVICES

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Abstract

Various performance parameters are defined which characterize the quality of service offered by a layer of the OSI model. In particular the parameters for the Transport and Network are considered. The set of parameters are classified into:

i) Connection related parameters;
and ii) Access point related parameter;

We further make an analysis of the relation between the parameters of the service provided by the Transport layer and the parameters of the Network service used by the Transport protocol, depending on the class of Transport protocol used. This is an example of a hierarchical approach to the evaluation of performance measures for the N-layer service in terms of performance measures of the (N-1)-layer service in conjunction with the performance measures of the N-layer protocol entity.

Keywords:
Protocols,
OSI reference model,
Performance parameters,
Performance analysis,
Transport protocol,
Transport service,
Quality of service.

1.0 Introduction

With the rapid development of distributed systems, considerable work has been carried out in both the theoretical and experimental fields of computer networks in order to provide means for establishing communication between end users with a selected quality of service for the duration of a connection.An important aspect of computer networks (with heterogeneous host computers) is the standardization of the so-called higher level protocols which realises meaningful communication between application programs. In this context ISO has proposed a layered model, called OSI Reference Model, comprising 7 layers [ISO RM].In this model the service provided by a "N-layer" is achieved by using the "N-1 layer" service in conjunction with the N-layer protocol.The approach of standardising each of the layers separately provides the advantages of modularity and flexibility. The user of a service accesses the service through a Service Access Point which supports a set of connections.

In the context of this model we define in the following sections various parameters characterizing the performance of the service provided by a particular layer. These parameters have been classified into: i)Connection related parameters , and ii)Access point related parameters. This work is an extension of the one reported in [BARC80,BARC81,MUEH82]. The formal definition of the performance parameters for the Transport layer is given and the relation of these parameters to the corresponding Network parameters is evaluated.

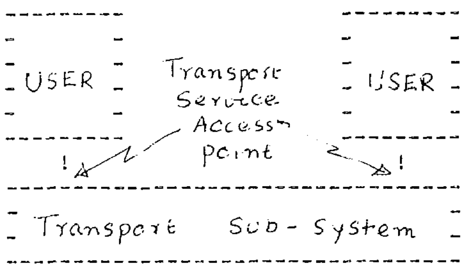

FIG. 1: "Black-box" view of the Transport Sub-system

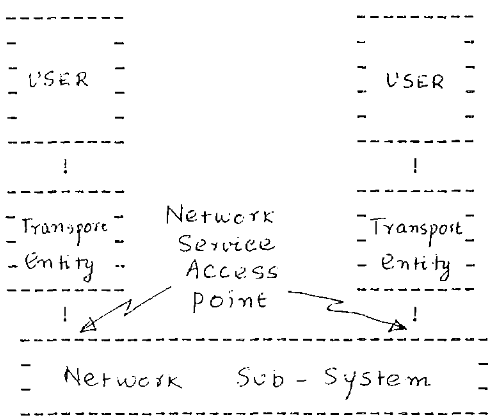

FIG. 2: Entities involved in providing the Transport Service to the user

2.0 Performance parameters of the Transport Layer

We define in this section the different sets of parameters relating to the Transport layer [ISO TS]. FIG 1 shows the user view of the Transport sub-system. The performance parameters are defined by referring to the execution of the service primitives at the access points. The definition of many performance parameters (but not all) involve service primitive executions at the two end points of a connection, since they define end-to-end service properties. It is assumed that exact time instants can be defined for the execution of each service primitive. In the case of an interface implementation where queues are used to transfer the service primitives between the user and the protocol entity, the performance parameters may be defined in terms of the time instants when the primitives are entered into the queue. Certain difficulties in measuring the performance parameters are discussed [BARC81].

It is important to note that the parameters defined below may be considered in different senses, such as : a)service parameters required by the user; b)service parameters desired, where, the user may accomodate less "good" values; c) service parameters promised by the service provider; d)service parameters measured over a certain period for a certain collection of connections:

(i)average values,
(ii)maximum values (or minimum) values,
(iii)90 % case values
etc.

2.1 Connection related parameters

We define in this section performance parameters related to a single connection, which is referred to in the following, by the index i.

2.1.1 Delay parameters

a) Connection establishment delay:

This parameter refers to the time it takes to establish the connection.

$$\tau_{Ei} = t_{CC_i} - t_{CR_i}$$

where

- t_{CC_i}: the time at which T_CON_Conf was received by the user for the connection i;
- t_{CR_i}: the time at which T_CON_Req was sent by the user for the connection i (at the same access point).
  (Note :We assume that the peer user responds to the T_CON_Ind immediately.)

b) Normal data transit delay:

This parameter defines the average end-to-end delay suffered by the data over connection i:

$$\bar{\tau}_{DA_i} = \frac{1}{n}\sum_{j=1}^{n}\left[t_{DTI_i}(j) - t_{DTR_i}(j)\right]$$

where

- $t_{DTR_i}(j)$: the time at which the T_DATA_Req was sent by the user including the beginning of the j-th Service Data Unit (SDU).
- $t_{DTI_i}(j)$: the time at which the T_DATA_Ind including the beginning of the j-th SDU was received by the peer user.
- n : number of SDU's transmitted during an appropriate observation period.

c) Expedited data transit delay:

This parameter defines the average end-to-end delay suffered by the expedited data during the data transfer phase.

$$\bar{\tau}_{ED_i} = \frac{1}{n}\sum_{j=1}^{n}\left[t_{EDI_i}(j) - t_{EDR_i}(j)\right]$$

where

- t_{EDR_i} : the time at which the j-th T_EX_DATA_Req was sent by the user.

t_{EDI_i} : the time at which the j-th T_EX_DATA_Ind was given to the peer user by the peer entity.

n : number of SDU's transmitted in an appropriate observation period.

d) Connection termination delay:

This parameter refers to delay between a disconnect request and the reception of the corresponding indication by the peer user:

$$\tau_{T_i} = t_{DI_i} - t_{DR_i}$$

where

t_{DR_i} : the time at which the T_DISC_Req for the connection i was received from user.

t_{DI_i} : the time at which the T_DISC_Ind was given to the peer user.

2.1.2 Error parameter

The error parameter is defined as the ratio of number of TPDU's in error, lost or duplicated to the total number of TPDU's transmitted.

$$UE = \frac{n_e}{n} \; ; \begin{bmatrix} n_e : n_e \text{ of TPDU's in error, lost, duplicated} \\ n : \text{Total number of TPDU's transmitted.} \end{bmatrix}$$

We note that a more useful measure would probably be the probability that a received Network service data unit (NSDU) contains an error (one or more). However, this probability would usually depend on the average length of the data unit. For small error rates and large service data units, fragmented within the Network layer into Network PDU's, this probability would be proportional to the length of the NSDU, which justifies the above assumption.

2.1.3 Throughput

This parameter defines the information rate over the connection.

$$TC_i = B_i / t$$

where

B_i : the number of information bits of SDU's that connection i transfers during a given observation period.

t : length of the observation period.

2.1.4 Considering several connections

Clearly, the parameters defined above for a single connection can be considered for a large number of connections. It is straightforward to define mean values, standard deviations, or in general probability distributions, for the parameters defined above. (Note that in the case of the connection establishment delay parameter only the cases of successful establishments are considered. The unsuccessful cases are considered for the connectability parameter discussed in section 2.2). Such mean values or distributions may be defined for different collections of connections; for example all connections established from a particular access point (see also section 2.2), all parallel connections between two particular users during some particular observation period, or subsequent connections over a large period of time.

2.2 Access point related parameters

In section 2.1 we defined parameters which are related to a given connection. These parameters are of interest to the users of the connection . In this section we define some parameters which relate to a given access point. Their definition involves the execution of service primitives relating to different connections at this access point only. It is noted that some of the parameters defined here may cover aspects which are already covered by the parameters defined in section 2.1. Neverthless, it seems that their separate definition is useful.

a) Maximum Connection Throughput:

This parameter refers to the maximum information transfer capacity of one connection i when all the other connections of the access point are "idle". It is the maximum of TCi defined in section 2.1.2.

b) Access Point Throughput:

This parameter defines the maximum (total) information transfer capacity when N connections are active and transferring data through the access point. It is equal to :

$$\max \sum_{i=1}^{N} TC_i$$

where

N : number of connections active at the access point.

c) Connectability:

This parameter characterises the ability of the service provider to establish the connection requested by the users.

$$C = (n_a - n_b - n_c) / (n_a - n_b)$$

where

n_a : total number of connection establishment requests made at the access point.

n_c : number of unsuccessful requests at the access point due to problems internal to the service provider, such as local congestion within the service providing entity, network congestion, inability to agree on a protocol class to be selected, temporary malfunctions, etc.

n_b : number of unsuccessful requests due to invalid parameters requested by the user, such as non-existing Transport address, etc.

This parameter could be a function of the actual throughput and connection establishment frequency at the access point.

d) Provider Disconnection Rate:

This parameter defines the rate of disconnections which are generated by the provider.

$$d_t = \lim_{\Delta t \to 0} \left[\frac{1}{N_t} \frac{\Delta D_t}{\Delta t} \right]$$

where

N_t : the number of connections active (in the data transfer phase) already for the period of t seconds.

ΔD_t : number of disconnections generated by the provider during the period of t seconds.

Δt : appropriate time period.

This parameter is a measure of the "mean time between failure" [CHUN79].This could be a function of the elapsed lifetime of the connection, the actual throughput and connection establishment frequency at the access point.

i) Average Connection Life Time:

This parameter defines the expectancy of the connection duration before encountering disconnection due to the service provider. It is related to the provider disconnection rate (see above) by:

$$\bar{\tau}_{cL} = \int_0^{\infty} \left[1 - \int_0^{t} d_{\tau} \, d\tau \right] dt$$

3.0 Relation Between Transport And Network Layer Parameters

The logical characteristics of the Network service specification [OSI NS] are very similar to those of the Transport service. Therefore the performance parameters for the Network service may be defined similar to those of the Transport service, as described above. The Network service has, however, certain additional elements, such as resets and data delivery confirmation , which require seperate performance parameters. For the Network generated resets, for example, one may define an average "provider reset rate", similar to the provider disconnect rate defined above.

The purpose of this section is to discuss how the Transport performance parameters of an OSI Transport layer are related to the cooresponding performance parameters of the underlying Network layer. In many cases, as discussed below, the Transport performance parameters can be derived from the Network parameters depending on certain protocol options, such as the selected protocol class, the degree of multiplexing, etc., and other reasonable assumptions. In the following we use a notation where x(T) and x(N) stand for a performance parameter x for the Transport and Network service, respectively.

With reference to FIG 2 ,it can be seen that the Transport service is provided by the Transport entity using the Network service. It is obvious that the performance parameters of the Transport layer must be related to those of Network layer and factors relating to the Transport entity itself.In subsequent sections we derive the relationship for each of the parameters defined in the preceding sections.

The assumption made in the following calculations is that the processing time of an input interaction (user request or TPDU reception) by the transport entity is Tp, and that the output interactions (user indications and/or TPDU sending) are generated at the end of this time interval. In case of queueing interface, the time Tp includes the time spent in the input queue of the protocol entity.

3.1 Connection Related Parameters

3.1.1 Delay Parameters

a) Connection establishment delay:

The delay seen by the Transport user includes the processing delay by the two transport entities involved and the Network delay for exchanging the CR and CC Transport protocol data units (TPDU's). In the case that a suitable network connection is already established (possibly shared with other connections in case of protocol classes 2,3 or 4) we have :

$$\tau_E(T) = 2 * \bar{\tau}_{DA}(N) + 4 * T_p$$

where Tp is the processing time for connection establishment PDU's.

If a new network connection is first established we have:

$$\tau_E(T) = \tau_E(N) + 2 * \bar{\tau}_{DA}(N) + 4 * T_p$$

b) Normal data transit delay:

We have

$$\bar{\tau}_{DA}(T) = \bar{\tau}_{DA}(N) + 2 * Tp$$

assuming no retransmissions (classes 0 and 2); and Tp being the processing time for the data PDU's. For retransmissions (in the case of classes 1,3 or 4), considerations similar to the case of HDLC (see for example [WANG82]) could be applied.

c) Expedited data transit delay:

The delay of the Expedited Data as seen by the Transport user depends on whether the Expedited Data is "mapped" on to an "Expedited

(Interrupt)" packet of the Network (possibly in case of class 1 protocol) or to a normal packet. Thus the relationship in this case will vary with the transport protocol specification.

Thus, we have

$\bar{\tau}_{ED}(T)=\bar{\tau}_{DA}(N)+2*Tp$

assuming "normal data" delay in the Network, or

$\bar{\tau}_{ED}(T)=\bar{\tau}_{ED}(N)+2*Tp$

assuming "expedited data" delay in the Network.

d) Connection termination delay:

Here again we have two cases depending on whether implicit termination (the Network disconnect service is used, no exchange of TPDU's, in case of class 0 only) or explicit termination (exchange of TPDU's) is used.

Hence we have ,

$\tau_T(T)=\bar{\tau}_{DA}(N)+2*Tp$

for explicit termination;

and $\tau_T(T)=\tau_T(N)+2*Tp$

for implicit termination.

3.1.2 Error rate parameter

We analyse in this section the relationship between the undetected error rate of the transport layer to that of the network layer.

UE(T)=UE(N)*[1/DF(T)]+TE(T)

where

- DF(T) : the detection factor of the transport which is a measure of the detection capability of the transport entity when error recovery mechanism is used (classes 1,3,4).
- TE(T) : the error rate introduced by the transport entity itself and which escapes its error checking mechanism.

3.1.3 Relation between average connection throughput parameters

a) Simple case: The throughput as defined in section 2.1.2

$TC(T)= B/t$

If we ignore the influence of possible error recovery actions (retransmissions and/or reassignment of network connections), we have the simple formula ;

TC(T)=TC(N)*(1-k) ,

where k is protocol overhead factor defined below (page 16).

The above formula assumes that a single Network connection is dedicated to each Transport connection. In the case of multiplexing or splitting, this assumption is not true. Since the load distribution in this case is very much implementation dependent, we do not pursue this point any further.

b) Considering Network connection reassignments: From the Network disconnection rate we can find the number of Network disconnection (due to Network provider problems) during the lifetime of a transport connection till it is disconnected by the user. In the case of classes 1,3,4 the transport protocol recovers from these failures through reassignment of the Network connection. We assume that the network failures can be recovered through a single attempt to establish a new network connection.

The time the transport protocol takes to reassign a network connection (RT) is computed for two cases,

- case 1 : for the network disconnection originating at the "CALLING" end of the transport connection; $RT1=T_p+\tau_E(N)$
- case 2 : for the network disconnection originating at the "CALLED" end of the transport connection;

$$RT2 = T_p+\bar{\tau}_T(N)+\tau_E(N)$$

Assuming that the network disconnections occur with equal probability at both ends, we have the average reassignment time :

RT=(RT1+RT2)/2

Though the failure of the network sub-system could be due to failure of the network layer anywhere in the connection, the above assumption seems reasonable from the performance point of view. We also assume that $\tau_E(N)$ is a realistic value for the establishment of a new connection after the failure.

Therefore the Transport throughput is given by

i.e $TC(T)=TC(N)*\left[1-\frac{RT}{\left(\frac{1}{d_t}+RT\right)}\right]*[1-k]$

where

k is the ratio of the TPDU header length to the total TPDU length. The header length is 1 or 3 octets for the protocol classes 0 and 1,2,3,4 respectively. In the case of long Trasport service data units (TSDU's), the length of the TPDU's is determined by the protocol parameter "maximum TPDU length". In the case of short TSDU's, the length is equal to the length of the TSDU plus the header.

c) Considering retransmissions:

In addition to the Network rassignment, conidered above, the retransmission due to error recovery of the transport protocol (classes 1,3,4 only) degrade the throughput of the transport user. The various factors determining the retransmission rate (Pr) are undetected error rate of network (UE(N)) , error detection probability ($P_D(T)$) of the transport protocol, network throughput TC(N), and the network reset rate ($R_\gamma(N)$). This parameter (Pr) can be deduced to be equal to :

$$Pr = R_\gamma(N) + (UE(N)*P_D(T)*TC(N) / \text{TPDU Length})$$

The retransmission factor (r), which is the number of bits retransmitted to the total number of bits transmitted, depends on Pr , the effective window used in the transport protocol (W(T)) and the TPDU length (L(T)).The retransmission factor can then be deduced to be equal to:

$$r = [Pr*W(T)*L(T)]/TC(N)$$

Taking into account this factor, the relation of the throughput (of network and transport layers) becomes:

$$TC(T) = TC(N)*\left[1 - \frac{RT}{(\frac{1}{d_t} + RT)}\right]*[1-K]*[1-Y]$$

3.2 Access Point Related Parameters

a) Maximum Connection Throughput:

The analysis of this parameter may be carried out in the same fashion as for the average connection throughput, except that the disconnection rate of the network used in the computation should refer to the value when only one network connection is active. The value so obtained places an upper bound on the throughput. It may also be limited by the efficiency of the Transport entity serving the access point.

b) Connectability:

From the definition (given before) we have:

$$C(T) = [n_a - n_b - (n_{c1} + n_{c2})] / (n_a - n_b)$$

Where

- n_a : Total number of connection connection establishment requests.
- n_b : number of unsuccessful requests due to invalid parameters requested by the user.
- n_{c1} : Number of unsuccessful attempts due to transport protocol problems,
- n_{c2} : Number of unsuccessful attempts due to Network service provider problems,

Thus the connectability of the Network becomes:

$$C(N) = (n_a - n_b - n_{c1} - n_{c2}) / (n_a - n_b - n_{c1})$$

Therefore,

$$C(T) = C(N) * [(n_a - n_b - n_{c1}) / (n_a - n_b)]$$

It is assumed that no multiplexing or splitting does occur. It is further assumed that the transport entity makes only one trial for the establishment of a network connection.

c) Average provider disconnection rate:

This parameter for the Transport and Network are related by a factor which represents the improvement in the reliability of the transport connection due to the transport protocol.

$$d(T) = q*d(N)$$

In the case of protocol classes 0 and 2, this factor is 1 (no improvement). In the case of the classes 1,3 and 4, we may assume that a Transport entity does only a single attempt to reassign a network connection, and that a new network connection must first be established. Then q is equal to the connectability of the Network service.

CONCLUSION

The performance parameters of the OSI Transport service may be defined in terms of instants in time when the service primitives are executed at different access points. A set of relevant parameters are defined in section 2. They may be classified into parameters related to a given connection (or a collection of connections, in which case averages and deviations can be determined) and parameters related to a given access point. Similar parameters apply to the OSI Network service.

In the second part of the paper we discuss how the Transport performance parameters are related to the Network parameters, the selected protocol class and other options such as the multiplexing. Under certain reasonable assumptions, simple formulas, as given in section 3 define the relation between these parameters.

We use in this paper a very simple performance model for the Transport entities executing the protocol. Further refinements could be considered in relation with performance measurements on protocol implementations.We believe that the approach applied here to the Transport layer can also be used for performance considerations of the higher layers of the OSI Reference Model.

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