The OSI 95 Connection-Mode Transport Service - The Enhanced QoS[1]

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Abstract

During the last ten years, tremendous changes have taken place in the communication environments. First, there has been a continuous increase in network performance that has led, for instance, to increasingly high access data rates available in the lower layers. Furthermore, the changes in the offered network services have raised the issue of providing, at the transport level, services already provided at the subnetwork level, such as multicast or synchronous services for example. With the arrival of new applications, such as multimedia or client/server applications, a widening of the application requirements has also been observed. It is this evolving environment that has been at the origin of the ESPRIT II Project OSI 95. An important task in the framework of this project is the definition of an enhanced Transport Service taking account of the aforementioned evolutions. The enhanced Transport Service specified for OSI 95 consists of several types of service. The paper presents the connection-mode Transport Service. We focus mainly on the following original features of our connection-mode service: a new semantics for QoS parameters and the associated negotiation and re-negotiation..

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1. Introduction

In the last ten years, we have seen a tremendous change in the communication environment. The LANs have drastically changed the scene and the high-speed LANs have accelerated the trend. More recently, the MANs have opened new possibilities, not to mention the broadband ISDN which is expected to be deployed starting in the middle of this decade.

The communication environment has not only drastically changed during the eighties, but we have also faced a drastic change in the application requirements of which we will mention only the client/server paradigm and the multimedia-based applications.

It is this changing environment which is at the origin of ESPRIT II Project OSI 95, started in October 1990. The consortium headed by BULL involves Alcatel Bell, Alcatel Austria ELIN, INRIA, Institut National des Télécommunications, Intracom, Olivetti Research, as well as the

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The technical direction of the project is assumed by the University of Liège that is responsible for the design and the formal specification of a new transport service and a new transport protocol called TPX. Two other tasks are done in parallel in order to better assess the new environment. The first one is defining the specific requirements coming from the distributed multimedia applications and ODP systems which may have an impact on the new transport service. The second one is defining the data link layer services provided by ATM networks, in order to identify new underlying network service facilities.

The goal of the project is not only to specify new transport service and protocol. It is also to apply LOTOS [BoB 87], a formal description technique, from the very beginning of the design process. The methodology for the design of the service and the protocol will be based on the constraint-oriented style in order to allow an incremental development of the protocol. This method allows the addition of, the removal of or a modification in a mechanism without jeopardising the other part of the work. It is expected that this basic use of a formal description technique during the process of specification will end up in better results. The new methodology has been tested on TP4 and the results appears very promising [Led 92]. The complete specification of the service and the main parts of the specification of the protocol TPX will be available in December 1992 [BLL 92b].

After a general presentation of the framework of OSI 95 and of the different types of transport service presently under study, the connection-mode Transport Service of OSI 95 and its facilities will be presented in detail.

2. Need for New Transport Service and Protocol

The transport protocols TCP and TP4 were designed in the late seventies at a time when the network environment was essentially based on point-to-point communications and when packet switching was an emerging concept.

In ISO, the Transport Service was seen at the beginning as a unique service based on the connection mode and, in this framework, one protocol class, TP4, was designed for the poor network service environments [Dan 90]. TP4, as well as TCP, were designed to be able to recover from the worst situation in terms of packet losses and packet disorders. It took several additional years to see an addendum to the standard Transport Service able to handle the connectionless mode [ISO 8072 ADD1].

In [Dan 92a], [Dan 92b] and [DBL 92a], we explain in detail why we believe that we need new OSI standards for the Transport Service and for the Transport Protocol. Our opinion is based on the analysis of the consequences of the changes we have been facing in the network performance and network services as well as in the application requirements. Let us review the various influences.

2.1. Changes in Network Performance

The basic contributions of the LANs have been a drastic improvement of the network performance in terms of access data rate as well as in terms of bit error rate and packet error rate.

In-depth studies of mechanisms and implementations regarding the transport performance on top of LANs have been done [CJR 89] [GKW 89] [Mei 91] [JSB 90] [Zit 91] and have ended up in two different schools of thought.

The first school advocated the design of new transport protocols such as NETBLT [CLZ 87], VMTP [ChW 89], SNR [NRS 90] and XTP [Che 89] [Wha 89] [PEI 92].

The second school is putting the burden of the poor transport performance on the bad quality of the implementations and is claiming the capability of existing or slightly modified transport protocols to better handle the performance available at the MAC level [CJR 89]. Furthermore, there exist many choices of implementation from VLSI to pure software, more or less integrated in the operating system, using additional dedicated computing power or not [GKW 89] [JSB 90] [Zit 91].

Even if the processing of the protocol mechanisms is generally not the most time-consuming part of the transport activity, it would not be bad to have mechanisms that are well aligned with the objectives and intended services of the protocol and that will simplify the implementation problems.

We must also keep in mind that in big internet networks (based on IP or on CLNP) congestion is becoming the main source of packet losses. Increasing the resources to avoid packet losses due to congestion may be done by increasing the buffering capacity of the intermediate nodes, but this will drastically increase the round-trip delay and may not be considered as a good solution [Jai 90].

2.2. Changes in Network Services

Today there exist subnetwork services which are neither available at the network level nor at the transport level.

One of these services, the multicast service, is related to the capability of addressing not only a given service access point, but a group of SAPs through multicast or all SAPs through broadcast. Many applications have a direct interest to see this multicast service offered at the network level as well as at the transport level. Such an extension of service will not be possible by just patching what exists in many extant transport protocols.

Another example of service which is or will be available soon at the subnetwork level is the average or peak bandwidth guarantee.

2.3. Changes in Application Requirements

The client/server paradigm is one of the important changes which took place during the last decade. From a communication point of view, it requires a low latency and an extended addressing capability. This low latency is difficult to achieve when using the complete current OSI stack. Some systems [Her 88] have chosen a collapsed OSI architecture based on a convergence sublayer located in the lower part of the layer 7, acting as a transport layer and giving access to the SAP of the subnetwork at the layer 2 interface. Others systems have developed better focused transport service and protocol [ChW 89] [MaB 91]. Today most of the client/server-based systems are implemented on a local basis, but the clear trend to use this new paradigm at the corporate network level will require a re-evaluation of the architecture presently used. In order to integrate the distributed computing systems in the OSI architecture, it is mandatory for the transport service to offer the needed addressing capabilities as well as a request/response-oriented service with low response time.

The multimedia workstation is another source of new application requirements. The video part of such an equipment will be seen as a sequence of data structures which have to be submitted to the presentation device at a rate compatible with the type of presentation we are looking for. Such a video may be transmitted as a sequence of video frames, each frame being divided into TSDUs at the transport level and reconstructed at the remote end. The correct reconstruction requires from the transport service a sufficient throughput and a jitter on TSDUs which is below some fixed value. Unfortunately, nothing today allows a user of the transport service offered by TP4 or by TCP to request a quantitative value for the throughput on its connection, nor to express a limit to the jitter associated with the TSDU transit delay. With video, the error recovery by retransmission does not work properly as it conflicts with the low jitter requirement. Such a data stream is not flow-controllable and if the transport service is not able to provide the required minimum throughput, it will be reasonable to cancel the connection.

Most of today's multimedia applications are implemented on a stand-alone workstation. The trend to expand on networks in the local area is already there. If some existing systems are working properly, it is very often because the transport service is able, through the best effort, to offer to the application a sufficient throughput. This is true for an application implemented on a lightly loaded LAN, but may become problematic when the LAN is more heavily loaded or built with bridges and routers or, last but not least, when this application is running across worldwide networks. In these environments we will face an increase of the latency and a possible reduction of the throughput.

The conclusion of this section is that the improvement of the transport service and protocol does not lie only on the performance, and that it will be necessary to extend the characteristics of the offered services. All applications mentioned above require the possibility to associate, with a transport connection, a quantitative guaranteed Quality of Service (QoS) with regard to the throughput, transit delay and transit delay jitter.

3. The OSI 95 Transport Service

3.1. The Types of Transport Service

Two types of TS[4] exist today: the Connection-mode TS [ISO 8072] and the Connectionless-mode TS [ISO 8072 ADD1]. They correspond to two basic communication needs: reliable in-sequence transfers of several messages and unreliable transfers of a single message.

In OSI 95, we have been envisaging five types of TS:

- an enhanced connection-mode service [DBL 92a] [BLL 92a] [DBL 92b],
- a new fast connection-mode service [DBL 92a] [Dan 92a] [BLL 92a],
- an enhanced unacknowledged (or basic) connectionless-mode service [DBL 92a] [BLL 92a],
- a new acknowledged connectionless-mode service [DBL 92a] [BLL 92a],
- a new request/response connectionless-mode service [DBL 92a] [BLL 92a].

Four of them have already been completely defined and specified in LOTOS [BLL 92b]. Only the fast connection-mode service requires further studies before its definition and its specification in LOTOS can be completed.

Let us note that an enhancement that we strongly favour for all five types of TS but that has not been tackled in OSI 95 is the extension of the addressing capability. In a future specification of our enhanced TS, we intend to take account of the ISO work done on MultiPeer Data Transmission (MPDT) in the project JTC 1.21.09.01 [ISO 7498-1 PDAD 2] which has been suspended in 1989 but is now continued as part of the question Q1/54.

3.2. The Connection-mode Transport Service

In comparison with the standard [ISO 8072], the OSI 95 enhanced Connection-mode TS has been influenced by the search of performance and by various requirements coming from the the new environment which was at the origin of the project.This has led to the following main innovations:

1) A modification of the set of the QoS parameters used in connection mode:
   In particular, an additional transit delay jitter performance QoS parameter is introduced whereas other performance QoS parameters (such as the residual error rate, the transfer failure probalility, …) are discarded because they are deemed unmanageable.
2) The definition of a new semantics for the performance QoS parameters, with the introduction of the concepts of compulsory QoS and threshold QoS:
   This point will be addressed in depth below.
3) More flexibility in the error management (i.e. the error detection and recovery) on a TC[5] :
   If, for many applications, and for bulk data transfers in particular, the connection mode must offer a complete error recovery capability, such a capability may be totally unadapted to the characteristics of the expected TS in case of multimedia applications for example. Indeed, in several multimedia applications, the receiving end is able to manage some losses

[4] TS will be used as an abbreviation of Transport Service

[5] TC will be used as an abbreviation of Transport Connection

but has stringent transit delay and transit delay jitter requirements, so that a complete error recovery capability at the TS level based on retransmissions at the protocol level is not viable. Our approach in OSI 95 has been to permit a tuning (that may lead ultimately to a suppression) of the error recovery.

In case of error detection without error recovery, the TS provider delivers an indication primitive with no data, with the corrupted data or with dummy data replacing the corrupted or missing data, depending upon the requester's or the acceptor's choice at the time of the TC establishment.

4) The widening of the TC release facility to allow the (graceful or abrupt) release of a single direction of transfer at one time on a TC:

   The only TC release facility provided by the current ISO Connection-oriented TS is an abrupt (and thereby possibly destructive) one. Both directions of transfer of a TC are always closed together and abruptly. At present, the concept of orderly (or graceful) release is introduced at the session service level. So it is up to the peer session entities to make sure that there are no more in-transit data on the TC to which is assigned the session connection that is to be gracefully released before requesting the abrupt termination of the TC.

   Our enhanced Connection-mode TS has a graceful TC release facility that permits the graceful closing of each direction of transfer separately [DBL 92b]. Moreover, in order to solve certain problems of interleaving between the graceful and abrupt TC releases, it has been decided to augment the existing abrupt TC release facility with the possibility of closing each direction of transfer abruptly but separately.

5) The introduction of a QoS re-negotiation facility :

   This facility based on the requirements expressed in [LBC 92], allows the re-negotiation of the QoS parameters on a TC without having to close the TC and even without having to interrupt the data transfers on the TC.

6) The introduction of an out-of-band data transfer capability for a TC:

   The out-of-band data transfer capability is to be used in conjunction with the Connection-mode TS. The idea behind this capability is to permit some TSDUs to be transmitted by relying on types of TS other than the Connection-mode TS while still maintaining a relationship between these TSDUs and open TCs.

   The interest of transmitting out-of-band TSDUs over TCs with no acknowledgement procedure at all seemed quite limited. The Acknowledged Connectionless-mode TS has been elected to transmit out-of-band TSDUs.

   Even though it has not the same properties, the out-of-band data transfer capability may be an interesting alternative to the expedited data transfer facility which does not fit anymore the new environment. A recommended use of the out-of-band data transfer capability is in support of the QoS re-negotiation. With the current QoS re-negotiation facility, only the TS user that initiated the TC may start a re-negotiation. When the other TS user wants to re-negotiate the QoS on the TC, it could inform the TS user that has the right to re-negotiate and provide this TS user with the relevant information by way of the out-of-band channel corresponding to the TC.

3.3. The Fast Connection-mode Transport Service

In today's high-speed networks, the 'throughput * round-trip delay' (or T * RTD) product may easily be of the order of several hundred kbit or even several Mbit. Such values of the T * RTD product imply that an opportunity for sending quite a sizable amount of data will be lost if data can be sent only after the exchanges related to the negotiation of the TC have taken place.

The fast connect idea has been introduced in XTP. As XTP has been developped in TCP/IP environment, it is using the usual Listen primitive.The need for standardise XTP, has pushed the XTP group to try to use on top of XTP, a service closed to ISO 8072 and using the classical sequence of four primitives. We have shown in [Dan 92a][DBL 92a] that this in contradiction with the fast connect behaviour. .

We have suggested a different TC set-up scheme for the fast connect, based on the concept of listening, in order to solve the problem [Dan 92a] [BLL 92a]. However, the definitive selection of a sequence of TC set-up primitives for the Fast Connection-mode TS requires additional studies. Hence, unlike the other four types of TS, the Fast Connection-mode TS has not been defined and specified in LOTOS yet.

The main lessons that can already be drawn from our work on the fast connect is that a full QoS negotiation is not compatible with the fast TC establishment philosophy (i.e. the QoS negotiation must be reduced to a "take-it-or-leave-it" approach) and that it is therefore necessary to provide new specific TC set-up primitives for the fast connection mode.

3.4. The Unacknowledged Connectionless-mode Transport Service

It is an enhanced version of [ISO 8072 ADD1]. The improvement regards the semantics of the transit delay performance QoS parameter in the T-UNITDATA primitives which has been enriched with the concept of compulsory QoS.

3.5. The Acknowledged Connectionless-mode Transport Service

This new service is an extension of the previous one [DBL 92a] [BLL 92a]. The T-UNITDATA primitives are renamed T-ACKDATA.request and T-ACKDATA.indication. A third primitive denoted T-ACKDATA.confirm is needed that confirms to the calling TS user the delivery of the T-ACKATA.indication by the TS provider to the called TS user. Additionally, the set of QoS parameters is slightly modified with the introduction of a service completion delay QoS parameter and the semantics of the transit delay performance QoS parameter is still enriched with the concept of threshold QoS.

All information about this new type of TS can be found in [BLL 92b].

3.6. The Request/Response Connectionless-mode Transport Service

This other new service is a further extension of the Acknowledged Connectionless-mode TS [DBL 92a] [BLL 92a]. The three T-ACKDATA primitives are renamed T-REQRES.request, T-REQRES.indication and T-REQRES.confirm. A fourth primitive denoted T-REQRES.response is needed that is invoked by the called TS user. The set of QoS parameters is slightly modified again.

All information about this new type of TS can also be found in [BLL 92b].

4. The QoS enhancement

The QoS is the collective name given to a set of parameters associated with the data transmission between (N)-SAPs. It is believed that to match the requirements of client/server-based applications as well as new applications such as multimedia, it is necessary to define for the lower layers a new model of QoS involving a new semantics of the QoS parameters and the definition of new parameters. It is also essential to investigate how the QoS enhancement may help to provide, at layers 3 and 4, facilities offered by layer 2. The new high speed environment may provide new facilities of interest for the above mentioned applications.

4.1. Best-effort QoS value

If the QoS concept has been introduced in the OSI RM, it is fair to say that we are far from a well defined and widely understood concept.

If a service user introduces, in a request primitive, the value of a QoS parameter, it is not always clear if this wish is related to a boundary or to an average value.

If a service user introduces, in a request primitive, the value of a QoS parameter, it is possible for the service provider to reject the request due to the requested QoS value.

It is also possible that the value of an initial QoS value requested by the service user will be modified by a negotiation process involving the remote user and/or the service provider.

If the *initial* value represents the wish of the service user, what is, for this service user, the semantics associated with the *negotiated* value which may be different from the *initial* one?

Will the negotiated value be considered by the service provider as a boundary value or as an average value and why?

Whatever semantics is selected for the requested value when no negotiation takes place or for the negotiated value when a negotiation takes place, it has to be recognised that the service provider will not react if the value is not met.

If the service provider does not reach the QoS value, nothing will be done, the service user being not even informed about the situation by the service provider as no STATUS.indication primitive has been defined.

We can not even assume that the service user has a precise knowledge of the real value of the QoS parameter as no monitoring by the service provider is specified. The only way for the service user to assess the value of a QoS is to monitor it.

In many cases, the QoS is expressed in qualitative term without any specification of a given value and this confirms the lack of relationship between the QoS parameter and a real performance parameter.

Using the qualifier ”best effort” in such situation indicates a rather optimistic view of the situation. We will however keep it by respect for the tradition.

If, to operate in a correct way, an application requires a well defined set of performance parameters, the present approach will not be suitable.

4.2. Compulsory QoS value

4.2.1 Non-negotiated compulsory QoS

The idea behind the introduction of a compulsory QoS value is the following one: if a service user introduces a compulsory QoS value for a non-negotiated performance parameter, it expects that the service provider will reject the request if the service provider believes that it is not able to fulfil it. Furthermore if the service provider accepts the request, the service provider will have to monitor the performance parameter and to abort the requested service facility if the requested compulsory value cannot be achieved.

The decision of the service provider to reject the request may be based

- on the rejection by the underlying service provider of the underlying request with related compulsory values
- on the overall knowledge of the capability of the underlying service
- on the past history of other associations of the same type involving the same set of service users.An interesting way to be explored is the feasibility for the service provider to rely on the information collected by the management entities of the service. Today we have a new environment due to the efforts that have been invested in the OSI management.

If the service provider does not have any reason to reject the request, it will accept it and it will try to match the requested compulsory value. However it must be clear that the acceptation of the request does not imply an obligation of results.

By monitoring the execution of the requested service facility, the service provider will

- either execute it without violating the requested compulsory performance parameter.
- or abort it if the performance parameter is not fulfilled.

4.2.2. Compulsory QoS versus guaranteed QoS

The concept of guaranteed QoS has been introduced by several authors very often in relation with resource reservation. The guaranteed QoS has a more stronger semantics. It means that if the service provider accepts the request, it has to fulfil it within the constraints introduced by the guaranteed QoS values.

On the other hand, the compulsory concept reflects the fact that, in some environments (e.g. a lightly loaded LAN), the compulsory QoS value may be achieved without resource reservation. Of course, the same LAN, which does not provide any reservation mechanism or any priority mechanism, may, when heavily loaded, prevent the service provider from reaching the compulsory QoS value and oblige it to abort the execution of the requested service facility.

4.2.3. Statistical QoS

In “ISO/IEC JTC1/SC6 N 7309”, the concept of a statistical QoS has been introduced with the following definition “Statistical QoS defined a rigid requirement that must be met by the provider”. This concept seems to be closer to the guaranteed QoS than to the compulsory QoS. However the qualifier “statistical” may be confusing with respect to the searched semantics.

4.2.4. Negotiated Compulsory QoS value

If a service user introduces a compulsory QoS value for a performance parameter to be negotiated, it must first be clear that the only possible modification of this parameter is the strengthening of its value. In particular, it is absolutely excluded for the service provider to modify this value in order to relax the requirement

However the calling service user may not be interested in an unlimited strengthening of the compulsory QoS value. It will therefore, introduces a second parameter which will fix the bound to what extend the compulsory QoS value may be strengthened.

When the service provider analyses the request of the calling service user, it will have to decide if it rejects or not the request. In the later case, it will have to analyse the bound of strengthening. This bound may be modified (brought closer to the compulsory value) by the service provider, before issuing the indication primitive to the called service user, in such a way that any choice of value between the compulsory QoS and its associated bound will be acceptable for the service provider.

After receiving the indication primitive, the called service user may accept or reject the request. If it accepts it, it may modify (strengthen) the compulsory QoS value up to the value of the bound and return it in its response. In this case the negotiation is closed and the service provider may confirm the acceptance of the request and provide the final compulsory QoS value.

If the negotiation is successful, the bound is of no interest anymore and the the compulsory QoS value reflects now the global request to the service provider from the set of the two service users.

We are now back to the non-negotiated case. (see section 3.1).

4.2.5. QoS parameters and information parameters

The introduction of compulsory QoS values implies that the service provider will have a more difficult task to fulfil. It is therefore not surprising that the service user may have to provide the service provider with more information about the characteristics of the elements associated whit the request?. For instance, requesting a throughput of 2 Mb/s with (N)-SDUs of 10 Kbytes is different from requesting a throughput of 2 Mb/s with (N)-SDUs of 40 bytes. Hence, the introduction of the concept of compulsory QoS requires the introduction, in the primitives associated with a request, of additional parameters. These additional parameters may be designated as information parameters to distinguish them from the QoS parameters proper.

4.3. Threshold QoS value

Some service users may find that the solution of aborting the requested service facility when one of the compulsory QoS value is not reached, is a little too radical. They may prefer to get information about the degradation of the QoS value without abortion or ahead of abortion if this new QoS parameter is used in conjonction with compulsory QoS. To achieve that we propose to introduce the idea of a “threshold QoS value”. We will first assume first that this threshold QoS is used without any associated compulsory value.

4.3.1 Non-negotiated threshold QoS

If a service user introduces a threshold QoS value for a non-negotiated performance parameter, it expects that the service provider will not reject the request. If the service provider accepts the request, the service provider will have to monitor the performance parameter and, if the requested threshold value cannot be achieved, to indicate it to the service user.

If the service provider is able to provide a QoS better than the threshold value, everything is fine.

4.3.2 Threshold QoS versus Best Effort QoS

If the threshold QoS is used without any compulsory QoS, the main difference between the threshold and the best effort is that the former has the obligation of monitoring and the obligation to indication if the threshold value is not reached.

4.3.3. Negotiated Compulsory QoS value

If a service user introduces a threshold QoS value for a performance parameter to be negotiated, it must first be clear that the only possible modification of this parameter is the strengthening of its value. In particular, it is absolutely excluded for the service provider to modify this value in order to relax the requirement

However the calling service user may not be interested in an unlimited strengthening of the threshold QoS value. It will therefore, introduces a second parameter which will fix the bound to what extend the threshold QoS value may be strengthened.

When the service provider analyses the request of the calling service user, it will have to analyse the bound of strengthening. This bound may be modified (brought closer to the threshold value) by the service provider, before issuing the indication primitive to the called service user, in such a way that any choice of value between the threshold QoS and its associated bound will be acceptable for the service provider.

After receiving the indication primitive, the called service user may accept or reject the request. If it accepts it, it may modify (strengthen) the threshold QoS value up to the value of the bound and return it in its response. In this case the negotiation is closed and the service provider may confirm the acceptance of the request and provide the final threshold QoS value.

If the negotiation is successful, the bound is of no interest anymore and the threshold QoS value reflects now the global request to the service provider from the set of the two service users.

We are now back to the non-negotiated case.

4.4. Threshold and compulsory QoS values

It is when both, the compulsory and the threshold QoS values are associated that the usefulness of this enhancement of the QoS is the most evident. We will see a detailed example with the TS.

4.5. A last enhancement to the QoS values

In most cases, if the service provider is able to offer a better value of the QoS than the threshold, the service user will not complained about it. In some case, the service user want to indicate a limit not to be overflowed. We will see an example in the TS case

5. The connection-mode Transport Service

The connection-mode TS will be offered through the classical sequence of four service primitives to open a TC, allowing a full negotiation of the characteristics of the TC before the beginning of the data transfer.

5.1. Best effort and compulsory QoS

The term Quality of Service (QoS) refers to certain characteristics of a TC as observed between the endpoints at the TSAPs. The QoS is described by means of QoS parameters.

The current ISO connection-oriented TS only supports the concept of a "best effort" QoS. This means that the TS provider will do its best effort to reach the QoS requested by the TS users. If we add that, very often, the QoS parameters will be expressed in qualitative terms, without any actual commitment to given values, we understand easily why such an approach will not suit, for instance, a video application requiring a sustained throughput as well as a bounded delay jitter for the duration of the TC.

Our approach in the framework of OSI 95 has been to augment today's concept of best effort QoS with a concept of compulsory QoS. A QoS parameter with a compulsory value implies that the TS provider, if it accepts this compulsory value during the QoS negotiation performed at the time of TC set-up, will have to monitor the TC and to disconnect the TC as soon as it notices that the requested compulsory value cannot be maintained for the whole data transfer phase.

From the current ISO standard, we have kept, without any change in their semantics up to now, the TC protection and the TC priority.

Among the performance QoS parameters of the current ISO standard, we have kept the throughput and the transit delay, but their semantics has been enlarged with the possibility of specifying compulsory values. All other performance QoS parameters of the current ISO standard have been discarded.

Additionally, we have introduced a new performance QoS parameter, namely the transit delay jitter, with here also the possibility of specifying a compulsory value.

The introduction of compulsory QoS values in the QoS negotiation implies that the TS provider will have a more difficult task to fulfil. It is therefore not surprising that the TS user may have to provide the TS provider with more information about the characteristics of the sequence of TSDUs it intends to submit. Requesting a throughput of 2 Mb/s with TSDUs of 10 Kbytes is different from requesting a throughput of 2 Mb/s with TSDUs of 40 bytes. Hence, the introduction of the concept of compulsory QoS requires the introduction, in the primitives associated with the opening of a TC, of additional parameters such as the maximum and the minimun size of TSDU. These additional parameters will be designated here as information parameters to distinguish them from the QoS parameters proper.

Let us first define accurately the performance parameters.

Throughput

We define the **throughput** as *the ratio of the size of the submitted TSDU to the time elapsed until the occurrence of the next T-DATA.request on the same TC.*

We see that our definition of the throughput corresponds to a form of "instantaneous" throughput which is measured at each invocation of the data transfer facility, and not to an average throughput which would be calculated over a given fixed period.

After the negotiation phase, the meaningful values regarding the throughput are the minimum compulsory value and the maximum value. Before explaining in detail how the negotiation of these values takes place, let us try to clarify their role.

The minimum compulsory value for the throughput is the value that the TS provider must be able to maintain during the whole TC lifetime. Otherwise it must immediately shut down the TC. So, if a T-DATA.request interaction occurs at time T_0, with a TSDU of size L, the TS provider must be ready to offer another T-DATA.request interaction at the latest at time $T_0 + \Delta t_{max}$, where Δt_{max} is given by the ratio of L to the minimum compulsory value for the throughput. Besides, the TS provider must be able to offer the first T-DATA.request interaction immediately after the receipt of the T-CONNECT.response on the called side and the issuance of the T-CONNECT.confirm on the calling side.

The maximum value for the throughput is a value that may never be exceeded for the duration of the TC. So, if a T-DATA.request interaction occurs at time T_0, with a TSDU of size L, the TS provider shall offer another T-DATA.request interaction at the earliest at time $T_0 + \Delta t_{min}$, where Δt_{min} is given by the ratio of L to the maximum value for the throughput. The maximum value for the throughput can thus be used for rate control purposes.

Figure 1 shows the relation between the TSDU size L and the Δt_{min} and Δt_{max}.

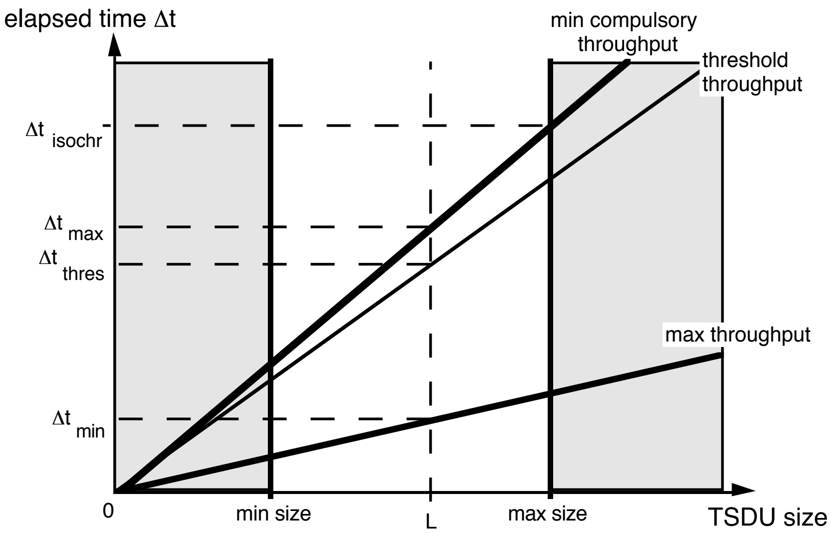

Fig. 1 *Relation between the TSDU size and the Δt_{min} and Δt_{max}*

If the TS provider is not able to offer another T-DATA.request interaction at the latest at time $T_0 + \Delta t_{max}$, the minimum compulsory throughput cannot be achieved and the TS provider must shut down the TC. This does not mean that the throughput associated with a particular invocation of the data transfer facility may never go under the minimum compulsory value. This may happen if the offer of the TS provider for another T-DATA.request interaction is not matched in time by the sending TS user. In such a case however, the inability of maintaining the throughput at or above the minimum compulsory value is entirely the responsibility of the sending TS user. Our choice of an “instantaneous” throughput measured at each invocation of the data transfer facility has the advantage of putting a clear separation between the responsibilities of the TS user and those of the TS provider. The TS provider does not have to disconnect in case of a late submission of TSDU from the part of the TS user.

If a sending TS user generates an isochronous traffic, that is if it produces TSDUs (possibly of variable length) at a fixed rate, this sending TS user may want the TS provider to be ready to accept the submission of TSDUs at the same rate characterised by the constant time interval Δt_{isochr} between the submission of successive TSDUs whatever their length. For this purpose, the TS user may negotiate with the TS provider a minimum compulsory throughput given by the ratio of the maximum size authorised for the TSDUs to the constant time interval Δt_{isochr}.

With such a minimum compulsory throughput, if T_0 is the time at which the last T-DATA.request occurred, the sending TS user is assured that the TS provider will be able to offer another T-DATA.request interaction at the latest at time $T_0 + \Delta t_{isochr}$ in case the TSDU submitted in the interaction at time T_0 is of maximum size or even earlier in case the TSDU is of smaller size, and will disconnect otherwise.

However, by forcing the TS provider to be able to accept a new T-DATA.request before $T_0 + \Delta t_{isochr}$ when the last TSDU is not of maximum size, we impose an unnecessary constraint on it. In fact, for a really isochronous traffic, forcing the TS provider to be able to offer a T-DATA.request interaction every Δt_{isochr} units of time, whatever the size of the TSDU submitted in the previous interaction, is a sufficient constraint. That is why we have decided to add a traffic type indicator to the QoS components pertaining to the throughput parameter. If this traffic type indicator is "non-isochronous", then the Δt_{max} is calculated as explained above, i.e. by taking the size L of the previous submitted TSDU into account. By contrast, if the traffic type indicator is "isochronous", then the Δt_{max} is simply taken equal to Δt_{isochr} as if all the TSDUs were of maximum size (Figure 1).

Obviously, if the negotiated minimum compulsory throughput is equal to zero, Δt_{max} is becoming infinite and we come back to the concept of best effort QoS.

To respond to certain requirements, it is also envisaged to introduce, in our list of QoS components pertaining to the throughput parameter, the idea of a threshold value for the throughput that would be slightly above the minimum compulsory value (Figure 1). If the TS provider was not able to maintain the threshold throughput, i.e. if it was not ready to offer another T-DATA.request interaction at time $T_0 + \Delta t_{thres}$, then it would have to indicate its inability to the TS users but the TC would remain open.

In summary, the behaviour of the TS provider will be time-dependent according to the following table where T_0 is the time at which the last T-DATA.request occurred:

In $]T_0, T_0 + \Delta t_{min}[$,	the provider will not accept a T-DATA.request.
In $[T_0 + \Delta t_{min}, T_0 + \Delta t_{thres}[$,	the provider may accept or not a T-DATA.request.
In $[T_0 + \Delta t_{thres}, T_0 + \Delta t_{max}[$,	the provider must accept a T-DATA.request, or otherwise must indicate it to the TS user.
In $[T_0 + \Delta t_{max}, \infty[$,	the provider must accept a T-DATA.request or otherwise must start the release of the TC.

In this table, Δt_{max} = L / minimum throughput,

where L is either the size of the last TSDU (in the non-isochronous case) or the maximum TSDU size (in the isochronous case).

Transit delay and transit delay jitter

We define the **transit delay** as *the time interval between the occurrence of a T-DATA.request at a TSAP and the occurrence of the corresponding T-DATA.indication at the peer TSAP*. A measure of the transit delay is thus associated with each invocation of the data transfer facility.

Finally, we define the **transit delay jitter** as *the difference between the longest and the shortest transit delays observed on a direction of transmission since the TC establishment.*

The general principle explained for the throughput can be applied for the transit delay and the delay jitter QoS parameters, except that the roles of the minimum and maximum values are reversed: the compulsory values are the maximal ones and, of course, the threshold value has to be below the maximum compulsory value. However, we do not see, for the moment, a real interest in minimum values and we will therefore remove them. The maximum compulsory values for the transit delay and for the delay jitter are values that the TS provider may not exceed at any invocation of the data transfer facility (let us note however that the delay jitter has no significance prior to the second invocation). If either of these two maximum compulsory values is exceeded during a particular invocation, the TS provider must immediately shut down the TC. If the transit delay or the delay jitter associated with a particular invocation of the data transfer facility is below the maximum compulsory value but above the threshold value, the TS provider must report this fact to the TS users but leaves the TC open. If both the transit delay and the delay jitter are below their respective threshold values, nothing special happens.

As the time reference when measuring the transit delay is the instant at which the T-DATA.request occurs, the behaviour of the sending TS user cannot have any influence on the transit delay, unlike what happens with the throughput. By contrast, when the TS provider is ready to deliver a T-DATA.indication whereas the receiving TS user is not willing to accept this primitive, the transit delay is getting longer because of the receiving TS user. In this case, TS provider will report or disconnect ultimately, even if it is not responsible for a too long transit delay or delay jitter.

Again, when the negotiated maximum compulsory transit delay and delay jitter are chosen infinite (or, in practice, sufficiently high), we come back to the concept of best effort QoS.

5.2. QoS negotiation

The three performance QoS parameters, viz. the throughput, the transit delay and the delay jitter parameters, are negotiated separately for both directions of transmission on a TC. Let us stress that the information parameter (that give information about the authorised TSDU sizes for each direction of transmission) as well as the traffic type component (isochronous traffic or not) of the throughput parameter are not negotiated; they are fixed once and for all by the calling TS user.

The scheme of negotiation we have envisaged for the negotiable components of the performance QoS parameters is as follows. We only examine the negotiation of the throughput and of the transit delay since the negotiation of the delay jitter is performed quite in the same way as that of the transit delay.

As regards the throughput, the calling TS user supplies in the T-CONNECT.request a proposed minimum compulsory value and an upper bound up to which this value may be raised, as well as a proposed maximum value. The proposed maximum value must be greater than or equal to the upper bound which, in turn, must be greater than or equal to the proposed minimum compulsory value. As regards the transit delay, the calling TS user supplies a proposed maximum compulsory value and an lower bound down to which this value may be reduced. The lower bound must be less than or equal to the proposed maximum compulsory value.

Only the called TS user will be allowed to modify the proposed minimum and maximum compulsory values that have been supplied by the calling TS user. Allowing the TS provider to change these proposed minimum and maximum compulsory values would be a nonsense since compulsory values for the QoS parameters are there solely to reflect the application requirements at the TS interface. If the TS provider deems that it will be unable to maintain the throughput above the proposed minimum compulsory value or the transit delay under the proposed maximum compulsory value, as requested by the calling TS user, it simply refuses the TC set-up. Otherwise, as regards the throughput, the TS provider may just decrease the upper bound (but not lower than the proposed minimum compulsory value) and then decrease the proposed maximum value (but not lower than the new upper bound). As regards the transit delay, the TS provider may just increase the lower bound (but not higher than the proposed maximum compulsory value). By doing so, the TS provider indicates to what extent it can accept a strengthening of the compulsory character of the QoS.

When it receives the T-CONNECT.indication with the QoS parameters proposed by the calling TS user and possibly modified by the TS provider, the called TS user selects the final QoS that will be returned in the T-CONNECT.response and T-CONNECT.confirm. As regards the throughput, the called TS user may increase the minimum compulsory value (but not higher than the upper bound) and then decrease the maximum value (but not lower than the minimum compulsory value). As regards the transit delay, the called TS user may decrease the maximum compulsory value (but not lower than the lower bound). By restricting the allowed modifications as above, the compulsory character of the QoS proposed by the calling TS user may only be strengthened by the called TS user.

5.3. QoS re-negotiation

In the current ISO connection-oriented TS, the QoS is negotiated once and for all at the TC establishment. This means that the negotiated QoS always applies for the whole TC lifetime. To respond to certain requirements formulated in [LBC 92], it is envisaged to introduce a QoS re-negotiation facility in our enhanced connection-mode TS definition.

The introduction of such a facility poses a first problem: who will be allowed to initiate a re-negotiation ? If both users of a given TC are permitted to start a re-negotiation, we will face a major difficulty when they invoke the facility at the same time. Let us remind that, as regards the TC establishment, colliding TC set-up requests lead to the establishment of distinct TCs. Bypassing the difficulty in a similar way is of course impossible in case of re-negotiation.

An obvious solution to the problem is to suppress it by precluding one of the two TS users to initiate a re-negotiation on the TC. Therefrom comes another question: which TS user should have the right to start a re-negotiation whereas the other one would not have this right ? This could be decided during the TC set-up phase, through a form of negotiation by way of the T-CONNECT primitives. The sole TS user authorised to initiate a re-negotiation could also be always the same one, either the calling or the called one. At first glance, it would be preferable to elect the calling TS user, i.e. the initiator of the TC establishment, as the only possible initiator of a QoS re-negotiation on the TC. Whichever the TS user authorised to start the re-negotiation, the other one could anyway use the envisaged out-of-band data transfer facility to indicate to its peer its wish to have a re-negotiation.

Another solution to the aforementioned problem is to allow both TS users to initiate the re-negotiation, and thus to accept the possibility of colliding re-negotiation requests, while giving the precedence to one of them. In case of collision, the re-negotiation request from the TS user that has not the precedence is simply discarded and the other request is processed normally. The different alternatives, proposed in the context of the previous solution to choose the only TS user that should be authorised to start the re-negotiation, remain conceivable to choose the TS user that should have the precedence.

If we assume that the data transfers over the TC are not stopped during the re-negotiation phase, the problem of the moment at which the TS users must switch from the old QoS to the new QoS is interesting too. For instance, let us suppose that the old QoS for one of the directions of transmission on the TC had specified a stringent maximum compulsory delay jitter ∂ whereas the new QoS for this direction specifies a maximum compulsory transit delay T. What happens if the time interval between the last T-DATA.request corresponding to the old QoS and the first T-DATA. request corresponding to the new QoS is short enough to make it impossible to meet the old QoS requirements for a T-DATA.request and the new QoS requirements for the next T-DATA.request while maintaining the TSDUs in sequence ?

5.4. T-CONNECT and T-DATA primitives

In comparison with the current ISO standard, two parameters will be added to the T-CONNECT primitives used in our enhanced TS definition, viz. a parameter indicating which direction(s) of transmission is (are) opened on the TC and an information parameter (giving information about the authorised TSDU sizes).The parameters for selecting a whole strategy for error control are included in the QoS parameters. Moreover, the expedited data option parameter will be removed. Therefore, the parameters of the T-CONNECT primitives will be the following ones, where (U) means that the use of the parameter is a TS user option, A is the calling TS user, B is the called TS user, a single * indicates a possible modification by the TS provider and a double * indicates a possible modification by the called TS user:

T-CONNECT.request {calling_address,
called_address,
directions_to_open,
QoS $_{A<->B}$ [protection, priority],
QoS $_{A->B}$ [min compulsory throughput, upper bound for the min compulsory throughput, threshold throughput, upper bound for the threshold throughput, max throughput, traffic type indicator, max compulsory transit delay, lower bound for the max compulsory transit delay, threshold transit delay, lower bound for the threshold transit delay, max compulsory transit delay jitter, lower bound for the max compulsory transit delay jitter, threshold transit delay jitter, lower bound for the threshold transit delay jitter + error control selection parameters],
QoS $_{B->A}$ [same as for A->B except that there is no traffic type indicator],
TSDU_size_range $_{A->B}$ [min TSDU size, upper bound for the min TSDU size, max TSDU size, lower bound for the max TSDU size],
TSDU_size_range $_{B->A}$ [same as for A->B],
TS user-data $_{A->B}$ (U)};

T-CONNECT.indication {calling_address,
called_address,
directions_to_open,
QoS $_{A<->B}$ [protection, priority*],
QoS $_{A->B}$ [min compulsory throughput, upper bound for the min compulsory throughput*, threshold throughput, upper bound for the threshold throughput*, max throughput*, traffic type indicator, max compulsory transit delay, lower bound for the max compulsory transit delay*, threshold transit delay, lower bound for the threshold transit delay*, max compulsory transit delay jitter, lower bound for the max compulsory transit delay jitter*, threshold transit delay jitter, lower bound for the threshold transit delay jitter* + error control selection parameters*],
QoS $_{B->A}$ [same as for A->B except that there is no traffic type indicator],
TSDU_size_range $_{A->B}$ [min TSDU size*, upper bound for the min TSDU size, max TSDU size*, lower bound for the max TSDU size],
TSDU_size_range $_{B->A}$ [same as for A->B],
TS user-data $_{A->B}$ (U)};

T-CONNECT.response
and
T-CONNECT.confirm {responding_address,
opened_directions,
QoS $_{A<->B}$ [protection**, priority**],
QoS $_{A->B}$ [min compulsory throughput**, threshold throughput**, max throughput**, max compulsory transit delay**, threshold transit delay**, max compulsory delay jitter**, threshold transit delay jitter** + error control selection parameters**],
QoS $_{B->A}$ [same as for A->B plus traffic type indicator],
TSDU_size_range $_{A->B}$ [min TSDU size**, max TSDU size**],

TSDU_size_range $_{B->A}$ [same as for A->B],
TS user-data $_{B->A}$ (U)};

The use of the T-DATA primitives in our enhanced TS specification will be exactly the same as in the current ISO standard, except that the T-DATA.indication primitive will have an additional parameter to deal with the selectable error control. So the parameters of the T-DATA primitives will be the following ones:
T-DATA.request {TSDU};
T-DATA.indication {TSDU,
error_control_information}.

The expedited data transfer facility of the current standard has been suppressed.

6. Conclusion

At the ISO/IEC JTC1/SC6 plenary meeting in Berlin, on July 1991, it was agreed to propose two New Work Items (NWIs) to JTC1 for a three month ballot. These two NWIs have been accepted but a few comments have been made.

The ISO/IEC JTC1/SC6 interim meeting in Paris, on February 1992 proceeded with the disposition of comments on the NWI Ballots, agreed to rename the adopted NWIs as "Enhanced Communication Functions and Facilities for OSI Lower Layers" and "Group NSAP Addressing for Multicast Operation", discussed some technical contributions (e.g. [DBL 92a]), and decided that the next meeting in San Diego, on July 1992, will be an opportunity for discussion about various proposals.

Our proposal ([BLL 92b]) contains a LOTOS formal description of the Enhanced Transport Service. This work, where the design and the writing of the LOTOS specification have been carried out hand in hand, helped us discover at an early stage several incompletenesses and inconsistencies that are difficult to detect without a formal model.

The design of an enhanced transport service with its new facilities is a complex task. It is essential to introduce new important facilities to match the requirements of the new applications but we must also avoid to introduce too specific facilities of limited interest. The discussion in the standardisation bodies is likely to introduce modifications to any proposal. The structure of our LOTOS specification is such that it can be modified in a flexible way. If LOTOS does not allow today to fully verify a real-size specification, the existence of new tools is nevertheless increasing the feasibility to validate partially a specification before its standardisation. Up to now, the syntax and static semantics of this LOTOS specification have been checked by the ESPRIT II / Lotosphere Toolset (LITE). The SMILE tool from this toolset also allows the simulation of the specification, but this validation is just starting.

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