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OSI95

The OSI95 Transport
Service with
Multimedia support

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The QoS Enhancements in OSI95

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The QoS Enhancements in OSI95

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The new communication environment has brought new requirements on the qualities of service for which the present "best effort" semantics is inadequate. The response to this evolution goes through the definition of a new model of QoS for the lower layers. In the "best effort" model, when a service provider accepts a transmission with a given QoS, it does not commit itself to any duty about the way it will take account of this QoS. The "guaranteed" QoS requires resources reservation mechanisms which are not always available. We present in this paper a new semantics for the QoS. It allows a service user to express more accurately its requirements, and although it does not include yet a concept of guarantee of the result, the fact is that it assures the users that the provider will monitor the selected parameters and return some defined feedback about the way it succeeds in meeting their requirements. New negotiation rules have also been specified, which are consistent with the new semantics. An example illustrates the practical use of the notions we have introduced which are at the origin of the OSI95 transport service.

Key words: Quality of Service (QoS), New Communication Services, Multimedia

1 Introduction

The term Quality of Service (QoS) is the collective name referring to the service performance which determines the degree of satisfaction of the user of a specific service. The CCITT make a clear difference between *user-oriented* QoS which is a service performance measure from the user's point of view and the *network-oriented* QoS which is the quality of the bearer service that is necessary to provide a certain terminal with the requested user-oriented QoS [CCITT I.350]. In this paper we will concentrate on the user-oriented QoS, defined at the Service Access Point (SAP) of a layer of the architecture, and drop from now on the user-oriented qualifier.

The role of the QoS becomes more and more important with the present evolution of the applications. The client/server-based applications demand low-latency request/response-oriented services. The multimedia applications, with their particular needs on throughput and quality of transmission, tend to extent on local, or even wider, networks.

It is believed in this context that 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.

Before introducing the new semantics, let us review the present situation.

2 The QoS Paradigm

The goal of this paper is to study the quality of the service offered by a transport service provider to transport service users, in a peer-to-peer connection mode service.

The figure 2.1 represents the paradigm that will be used in this study. The only observable events are the occurrences of transport service primitives at the two transport service access points (T-SAP).

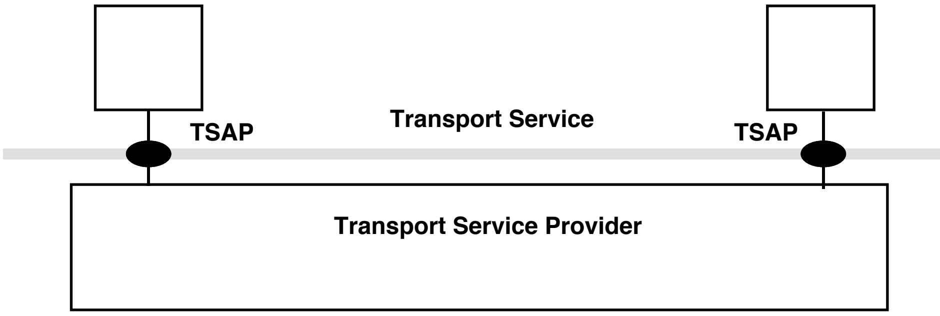

Fig. 2.1 The Transport Service Model

The term Quality of Service (QoS) is the collective name given to certain characteristics associated with the invocations of the service facilities as observed at the SAP. The QoS is specified in terms of a set of parameters. The performance QoS parameters, in particular, are those QoS parameters whose definition is based on a performance criterion to be assessed.

For the service user[1], the quality of service is determined by the values of some end-to-end parameters. The most important performance criteria for a connection are related to the throughput, the transit delay and the reliability.

It is very important to have a clear view about the way to define a performance QoS parameter. Of course the assessment of a performance criterion requires the introduction of timing considerations. Since the only events observable by a service user, when it is using a service facility, are the primitives that occur at its SAP, the only notion of time which can be relied on to introduce timing considerations is the notion of time of occurrence of a service primitive at a SAP. Such a time is an absolute time which is not usable in isolation.

Time has to appear in the definition of the performance QoS parameters in the form of time intervals between occurrences of service primitives. Thus, any performance QoS parameter has to be defined in relation with the occurrences of two or more related service primitives. These primitives may be related in very different ways. They may be related just because they pertain to a same connection, or because they are occurring successively at a same SAP, or because one or several parameters of one of the primitives occurring at a given SAP have been replicated in the other primitive(s) occurring at peer SAP(s), etc.

[1] In the following, we will use "service user" and "service provider" instead of "transport service user" and "transport service provider"

The figure 2.2 gives examples of time intervals usable in relation with the performance parameter definition. More complex relationships resulting from combinations of several basic relationships are also possible.

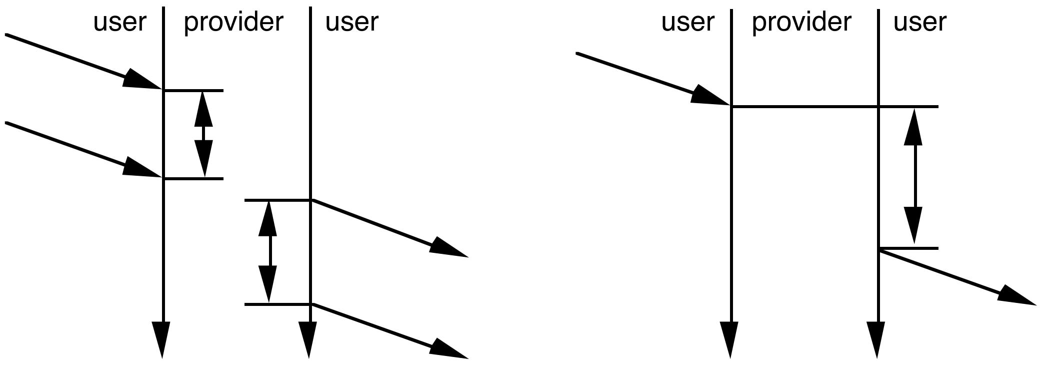

Fig. 2. 2 Time intervals usable in relation with the performance parameter definition

In the connection mode, the values of the QoS parameters are negotiated at the connection establishment time. In the connectionless-mode, the QoS are selected by the calling user and related to a single SDU.

The QoS paradigm of this section is consistent with the view of the user-oriented QoS in [CCITT I.350] which states that "from a user's point of view, quality of service may be expressed by parameters which

- focus on user-perceivable effects, rather than their causes within the network.
- should not depend on the internal design of the network.
- have to take into account all aspects of the service from the user's point of view, which can be objectively measured at the service access point.
- may be granted to the user at the service access point by the service provider.
- are described in network independent terms and create a common language understandable by both the user and the service provider."

This view of the QoS is clearly aligned to our view that QoS parameters must be based on observable events at the SAPs.

2.1 QoS Parameter Definition

A performance QoS parameter, by its definition, must be able to express the requirement of the service users. An instantaneous value of the throughput may be of more interest for a service user than an average value that may be more convenient to use for the service provider.

Furthermore, our interest in a service model must not hide the fact that the implementation of the service may require the monitoring of the QoS parameters and their definitions must be done with this characteristic in mind. Examples of possible definitions are given below. Other definitions or slightly different ones may be found in [FRV 93].

2.1.1 Transit Delay

The **transit delay** associated with an invocation of a peer-to-peer SDU transfer facility may be defined *as the time interval between the occurrence, at the SAP of the sending user, of the DATA request primitive that conveys the SDU and the occurrence, at the peer SAP, of the corresponding DATA indication primitive*. Here, the DATA request and indication primitives are related by the fact that the SDU parameter of the DATA indication has been replicated from the SDU parameter of the DATA request. This definition may be used in the connectionless-mode case as well as in the connection-mode case.

2.1.2 Transit Delay Jitter

In connection mode, it is conceivable that a performance parameter calculated at each invocation of a service facility intervenes in the definition of a more complex performance parameter whose calculation is based on a certain number of invocations of this service facility. A **transit delay jitter** may be defined for one direction of data transfer of a connection as *the difference between the longest and the shortest transit delays observed on this direction since the connection establishment*. Here, each pair formed by a DATA request and the corresponding DATA indication primitives is related to the other pairs of primitives by the fact that they pertain to a same direction of data transfer on a connection.

2.1.3 Throughput

An example of a performance parameter whose definition is based on the time of occurrence of service primitives at the same SAP is the throughput of a direction of data transfer on a connection. Unlike the definitions of the previous two performance parameters, the definition of the throughput does not only use time intervals between occurrences of service primitives, but uses an additional quantity, namely the length of the transferred SDUs.

In the specifications of the ISO services [ISO 8072], the throughput for one direction of transfer of a connection is defined in terms of a sequence of n (with $n \geq 2$) successfully transferred SDUs.

When particularised to the case $n = 2$, this definition becomes:

"the throughput for one direction of transfer is defined to be the smaller of:

a) the number of SDU octets contained in the last transferred SDU divided by the time interval between the previous and the last T-DATA requests; and

b) the number of SDU octets contained in the last transferred SDU divided by the time interval between the previous and the last T-DATA indications",

where the throughput measured in a) and b) may be referred to respectively as the sending user's throughput and the receiving user's throughput for the direction of transfer considered. With $n = 2$, this definition corresponds to an instantaneous throughput.

The figure 2.3 represents the ISO sending user's throughput when $n = 2$.

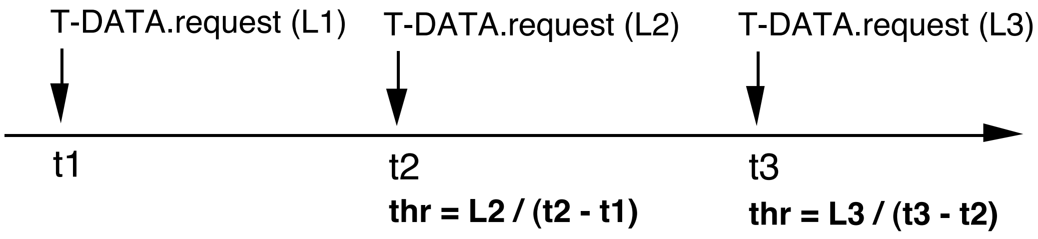

Fig. 2. 3. ISO definition of the sending user's throughput

An alternative way to define the throughput associated with an invocation of the SDU transfer facility on one direction of transfer of a connection is the following: the **global throughput** for one direction of transfer is still defined to be the smaller of the **sending user's throughput** and the **receiving user's throughput** but these two throughputs are now defined differently from the ISO's view:

- the **sending user's throughput** is now defined as the *number of SDU octets contained in the last transferred SDU divided by the time interval between the last and the next T-DATA requests*.
- the **receiving user's throughput** is now defined as the *number of SDU octets contained in the last transferred SDU divided by the time interval between the corresponding last and next T-DATA indications*.

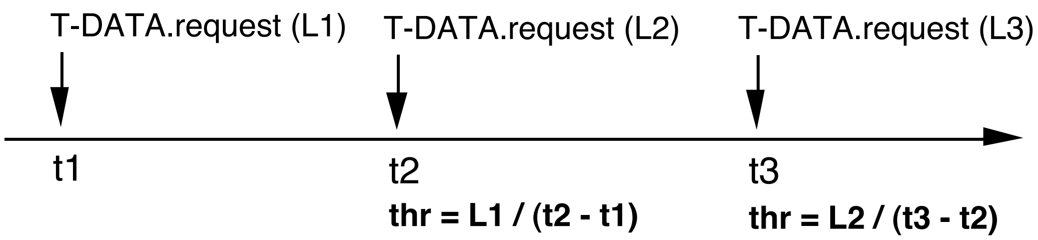

Fig. 2.4. OSI95 definition of the sending user's throughput

This definition corresponds also to an instantaneous throughput. It is this definition of the throughput that has been adopted in the framework of the OSI95 Enhanced Transport Service Definition [DBL 92b], [DBL 92c], [BLL 92b]. The figure 2.4 represent the OSI95 definition of the sending user's throughput [BLL 93]

With the latter definition, the behaviour of the service provider between two occurrences of DATA request primitives on the sending side is influenced only by the time that is elapsing. This is due to the fact that the length of the SDU that is used for the calculation of the current throughput value (i.e. the value associated with the last invocation of the SDU transfer facility) is known. Only the time interval between the last DATA request and the next expected DATA request is unknown until the occurrence of this next primitive. This means that the constraints that the service provider has to obey on the sending side will be expressed only in terms of the time already elapsed since the last DATA request, regardless of the possible lengths of SDU in the next DATA request. Of course a similar conclusion is true on the receiving side.

With the ISO's definition, the behaviour of the service provider between two occurrences of DATA request primitives on the sending side depends not only upon the time that is elapsing but also upon the possible lengths of SDU in the next expected DATA request. This results from the fact that the length of the SDU that is to be used for the calculation of the current throughput value (i.e. the value associated with the next invocation of the SDU transfer facility) is obviously unknown, as well as the time interval between the last DATA request and the next expected DATA request, until the occurrence of this next primitive. This means that the constraints that the service provider has to obey on the sending side will be expressed in terms of the time already elapsed since the last DATA request but also in terms of the possible lengths of SDU in the next DATA request. Of course a similar conclusion is true on the receiving side.

In relation with the introduction of § 2.1, it is clear that the OSI95 definition of the throughput may be easily monitored and may be linked to a protocol mechanism such as the access rate control.

2.2 Types of QoS Negotiations

In the peer-to-peer case, the three actors of the negotiation are the calling (service) user, the called (service) user and the service provider. All negotiations are based on the classical 4-primitive exchange; request, indication, response and confirmation (figure 2.5).

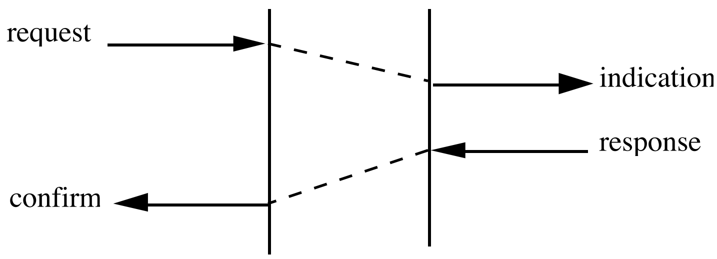

Fig 2.5 The classical 4-primitive exchange

For some performance parameters such as the throughput, the higher the better. For some other performance parameters such as the transit delay jitter, the smaller the better. Throughout this text, we will use the terms "weakening" and "strengthening" a performance parameter to indicate the trend of the modification. Weakening a throughput means reducing its value but weakening a transit delay jitter means increasing its value.

2.2.1 Triangular Negotiation for Information Exchange

In this type of negotiation, the calling service user introduces in the request primitive the value of a QoS parameter. This value may be considered as a suggested value because the service provider is free to weaken it as much as it wants before presenting the new value to the called user through an indication primitive. The called user may also weaken the value of the parameter before introducing it in the response primitive. This final value will be included without change by the service provider in the confirm primitive. At the end of the negotiation, the three actors have the same value of this QoS parameter (figure 2.6).

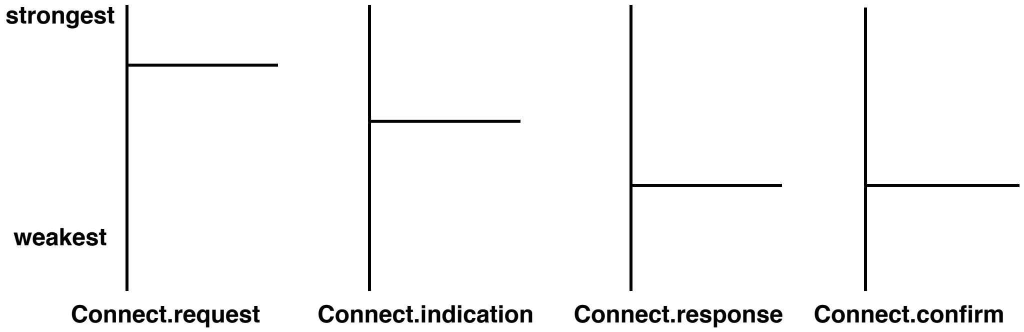

Fig 2.6 Triangular Negotiation for Information Exchange

Taking account of the freedom for the service provider to weaken the value suggested by the calling user, the service provider will reject directly the request only if it is unable to offer the service whatever the value of the QoS.

The calling user has always the possibility to request a disconnection if it is unsatisfied by the value resulting from the negotiation.

The goal of such triangular negotiation is essentially to exchange information among the three actors and to fix the weakest value agreeable to the three actors.

The ISO Transport Service uses this type of negotiation for the performance-oriented QoS [ISO 8072]. The classes 1 and 3 of the ISO Network Service [ISO 8348] are also based on the same scheme.

2.2.2 Triangular Negotiation for a Contractual Value

With the previous negotiation, it is clear that, in such a scheme, it is not possible for the service user to request a well-defined value for a QoS parameter. Coming back to our service oriented view and to the liaison between the QoS value and the service user requirements, it is necessary to introduce a negotiation scheme which allows the service users to express clearly their requirements.

In this type of negotiation, the goal is to obtain a contractual value of a QoS parameter which will bind both the service provider and the service users. Here the calling user introduces, in the request primitive, two values of a QoS parameter, the minimal requested value and the bound for strengthening it. If it accepts the request, the service provider is not allowed to change the value of the minimal requested value. However the service provider is free, as long as it does not weaken it below the minimal requested value, to weaken the bound for strengthening before presenting the new value of the bound for strengthening and the unchanged value of the minimal requested value to the called user, through an indication primitive (fig 2.7). It will be the privilege of the called user to take the final decision concerning the selected value. This selected value of the QoS will be returned by the called user in the response primitive and is acceptable for the service provider. This selected value will be included without change by the service provider in the confirm primitive. At the end of the negotiation, the three actors have agreed on the value of this QoS parameter (fig 2.7).

The service provider may have to reject the request if it does not agree to provide a QoS in the requested range.

The called user may also reject the connection attempt if it is not satisfied with the range of values proposed in the indication primitive.

With respect to the minimal requested value introduced by the calling user, the only possible modification introduced by the negotiation is the strengthening of the minimal requested value but limited by the bound for strengthening value. The service provider may weaken the bound for strengthening and the called user may strengthen the minimal requested value but up to the limit accepted by the service provider.

It is this scheme of negotiation that is used in OSI95 for two types of requested values.

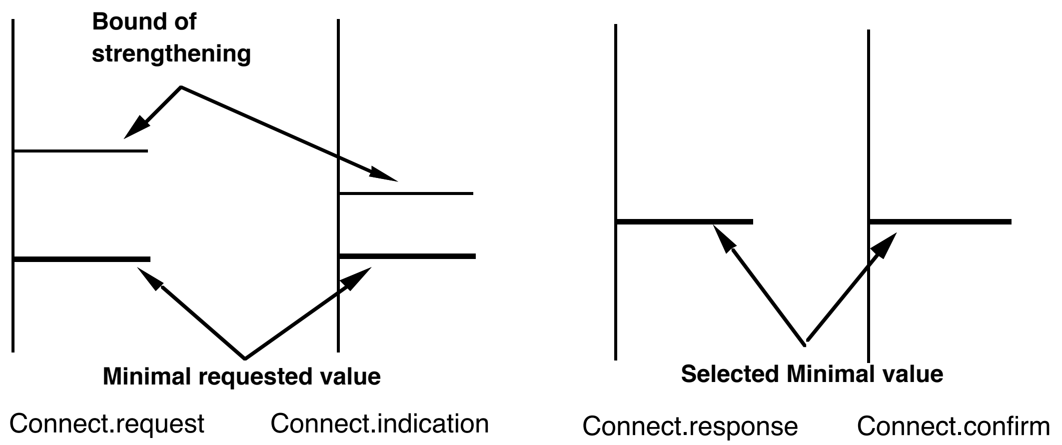

Fig. 2.7 Triangular Negotiation for a Contractual value

3 Best Effort QoS

3.1 The Semantics of the QoS in the ISO Transport Service

Coming back to the result of the negotiation for information exchange of § 2.2.1, it is clear that it is difficult to attach a strong semantics to the resulting value of the QoS parameter. It is only a value on which all three actors agreed.

The semantics of the QoS in the ISO Transport Service is that of the Best Effort, and "*users of the Transport Service should be aware that there is no guarantee that the originally negotiated QoS will be maintained throughout the Transport Connection lifetime, and that changes in QoS are not explicitly signalled by the Transport Service provider.*" [ISO 8072]

Even when the calling TS user prohibits the negotiation of a particular QoS parameter and therefore, expresses its QoS as an "absolute" requirement in the CONNECT.request, the service provider will still be allowed to violate the QoS value without notice during the lifetime of the connection.

The QoS parameter does not require a permanent monitoring by the service provider because it is not possible to specify a particular behaviour of the service provider if the real value of the QoS parameter is weaker than the agreed value. The service users do not expect any particular behaviour in such case. They are just expecting the *"best effort"* from the service provider.

In such a loosely defined environment, if a service user introduces, in a request primitive, the value of a QoS parameter, it is not always clear whether this suggested value is related to a boundary or to an average value. In the latter case, the measurement sample or the number of SDUs to be considered is often far from obvious. However, this is not a great problem if no monitoring has to be done.

For a negotiation in which the service provider is not allowed to weaken the value suggested by the calling user, it is possible for the service provider to reject the request due to the requested QoS value but, as already mentioned, in case of acceptance, nothing will be done if the service provider does not reach the QoS value. In this case, the service user is not even informed about the situation by the service provider as no REPORT indication primitive has been defined.

It is therefore not surprising that in many cases, the QoS is expressed in qualitative terms without any specification of a given value. This confirms the lack of relationship between the QoS parameter and a real performance parameter. The only way for the service users to assess the value of a QoS is to monitor it.

The situation we just described is the today situation of transport service and transport protocols in ISO.

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

3.2 The Monitoring and the Protocol Functions

With such a poor semantics of the performance QoS parameters of the ISO TS, it may be surprising that the situation has been accepted for more than 10 years.

This results from the fact that some performance QoS values result directly from the protocol functions which are implemented by the service provider. The best example of this situation is the error control scheme in protocols such as TP4 [ISO 8073]. The goal of this protocol is to deliver the data in order and without corruption to the receiving user. To achieve this, TP4 uses two protocol functions : the detection of errors and the retransmission of the lost or corrupted data. The errors are detected with a checksum that covers each DATA TPDU. This checksum can only detect errors with a known probability which depends on the length of the DATA TPDUs covered by the checksum. When a DATA TPDU has been lost or corrupted, it will have to be retransmitted. With these protocol functions with known (i.e. mathematically provable) properties, TP4 achieves its goal with a very low value of the residual error rate. When the protocol detects (usually after a certain amount of retransmissions without acknowledgement) that it is no more able to transmit the data reliably, it releases the connection.

In such a situation, the monitoring of the residual error rate by the service provider is impossible and the associated QoS negotiation is without interest because requiring a residual error rate weaker than the value provided by the error control function is without interest and requiring a residual error rate stronger than the value provided by the error control functions may not even force the service provider to reject the connection request.

For the data communication, the ISO transport service has been considered as adequate because it was offering a reliable service which was the basic requirement. The throughput, the transit delay and the transit delay jitter were not considered as critical factors of performance and the "best effort" situation we just described was acceptable for most of the past applications.

3.3 The Semantics of the QoS in TCP/IP[2]

Due to the lack of service definition for TCP and for IP, it is difficult to speak of QoS parameters, which are parameters of the service primitives of the OSI Reference Model. To understand the QoS provided by TCP we have to analyse the protocol and the protocol data units and to evaluate the service provided by the protocol entities.

During the connection set-up in TCP, there is no selection or negotiation of any QoS parameter and so we cannot speak of the QoS of a TCP connection. Therefore, when the calling TCP user asks for a connection, it does not have to select the values of the QoS parameters which will apply during the connection.

IP does not allow a negotiation of the QoS parameters, but this is not surprising, as IP offers a connectionless service.

Instead of relying on QoS parameters associated with the connection, the calling TCP user is allowed to select dynamically the QoS of each TPDU sent through the IP layer. However this possibility, for the TCP user to select the QoS for each data sent on the connection, is not required by all implementations [Bra 89].

Assuming no influence of the transport layer entities, the QoS, associated with a TPDU and provided by TCP to its user, will be the QoS provided by the IP layer.

3.4 ToS and QoS

Each IP datagram contains a field named *Type of Service* (ToS) which can be considered as carrying the QoS parameters of IP. The ToS is expressing the wishes related to the priority, the delay, the throughput and the reliability of the datagram.

The ToS in IP can only be used as a qualitative indication of the quality of service required for the datagram. Only a few implementations effectively support the ToS field that should be used as an aid in routing. Therefore the semantics of the QoS in both TCP and IP can also be classified as Best Effort.

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[2] We chose to analyse both IP [Pos 81a] and TCP [Pos 81b] in the same section because TCP is rarely used without IP and because of the link between the QoS offered at TCP and IP level.

Some attempt to define a more global goal, through the ToS values, has been recently introduced [Alm 92] but the ToS field is still only an advice given to the network. This limited support for the ToS parameters is inherent to the connectionless-mode operation of IP.

4 The Need for an Enhancement

In [Dan 93], the need for new standards or at least for an enhancement of existing ones, has been analysed, based on the consequences of the changes we are facing in network performance, in network services and in the application environment.

At the service level, the need for an enhancement means the need for a new semantics for the QoS. If, in the past, the basic requirement, at the transport service level, was a reliable transfer of data associated with a best effort for the other performance QoS parameters, the situation has to be improved.

A new application based on a client-server paradigm may have a specific requirement for the transit delay and the round-trip time.

Some multimedia-based applications will not be able to operate properly if the throughput offered by the transport service falls below some specific value.

The time dependence between successive video frames may not be preserved if the delay jitter goes above a given value.

Those three examples are mentioned to show that the best effort approach for the throughput, the transit delay and the transit delay jitter may not be an acceptable mode of operation for the service provider.

To enhance the present situation, it is possible to associate with the QoS the concept of a guarantee. By so doing we will associate a very strong semantics with the QoS. This has of course some implications which will be analysed in the next section.

5 The Guaranteed QoS

It would be nice to be able to have the concept of a guaranteed QoS, especially when the guaranteed values result from a negotiation for a contractual value presented in section 2.2.2.

The possibility for the service provider to give such a guarantee is related to the existence of enough resources associated with some protocol function for allocating the resources and managing them during the connection.

As already discussed, a residual error rate on a connection may be guaranteed by the service provider if enough storage resources can be allocated to the connection and if it operates an error control function with known properties.

A minimum throughput on a connection may be guaranteed by a transport service provider if each transport protocol entity can be allocated enough processing and storage resources and if the underlying network service provides the guarantee of a throughput compatible with the requested one, taking into account the layer overhead (figure 5.1).

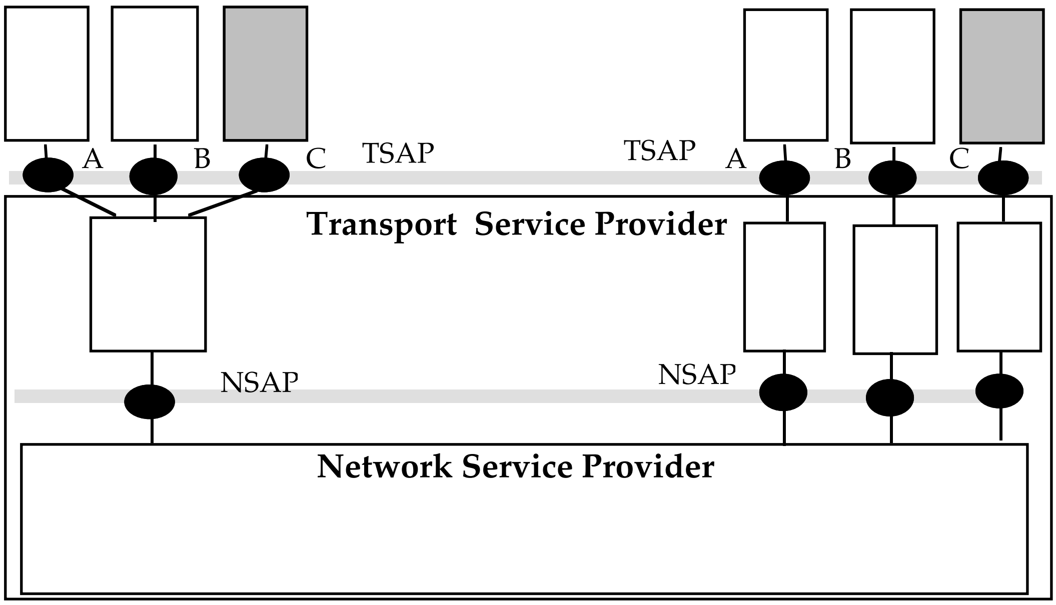

Fig. 5.1 The Transport Service and the Network Service

With the best effort, a request to establish the transport connection CC (figure 5.1), will usually be handled without taking account of the resources already used by the AA and BB connections and of the limited throughput of the network service provider. The result will be that the three connections will share the processing resources of the transport entities and will also share the throughput capacity of the network service provider. Any opening of a new connection will increase the level of multiplexing at the transport level and may affect the performance QoS parameters of the already established connections.

With a guaranteed QoS semantics, the situation will be different. Any attempt to establish a new connection with a guaranteed throughput (such as CC in figure 5.1) will imply the evaluation of the remaining processing and storage capacities of the transport entities and of the possibility for the network service provider to guarantee the needed throughput taking account of the layer overhead.

The basic point here is the permanent availability of resources allocated to the connection. It is only in this case that the service provider will be able to "guarantee" the QoS value requested by the service users. In this case, the monitoring of the QoS values is not necessary as the requested value will be achieved by the service provider, except in exceptional pathological situations.

With a guaranteed QoS semantics, the transport service, if not able to allocate the necessary resources, may be obliged to reject a request to establish the transport connection CC in order to protect the QoS of the already established connections. The same non pre-emptive approach has also been proposed in [FRV 93].

In practice, it is not obvious to obtain a guaranteed throughput from the network service even when the network service is provided by a single subnet. This is however possible with the synchronous service of FDDI and the ATM may also offer an equivalent service.

When the network service is provided by an internet, it is almost impossible to get today any guarantee on a throughput. This is the case with IP and with the ISO internet.

5.1 The Internet Stream Protocol, ST-II

As IP offers a pure connectionless service, it cannot provide any guarantee on the achieved QoS nor allow resources to be reserved. TCP only adds reliability above the IP layer, but it does not support other QoS parameters.

Proposals for an extended IP protocol [Dee 92, 93], [Tsu 93], [Fra 93] recognise the need to include Quality of Service parameters in an extended IP, but they do not completely support it now because there is no common understanding yet of what kind of QoS is needed in such an extended IP. If this extended IP remains entirely connectionless, there is little hope that it will offer any guarantee on the QoS. [Dee 93] states that a new reservation protocol is being developed for SIP. This protocol will be used to set-up a route and reserve resources on each node along the route.

This was already the philosophy of [AHS 90] and of the Internet Stream Protocol, Version 2 (ST-II) which is "*an IP-layer protocol that provides end-to-end guaranteed service across an internet*." [Top 90]. One of the main goals of ST-II was to provide a point-to-point simplex and a point-to-multipoint simplex data transfer for the applications with real-time requirements. In the ST-II specification, these simplex data paths are called "stream".

"*An ST stream is :*

- *the set of paths that data generated by an application entity traverses on its way to its peer application entity(s) that receive it,*
- *the resources allocated to support that transmission of data, and*
- *the state information that is maintained describing that transmission of data*."

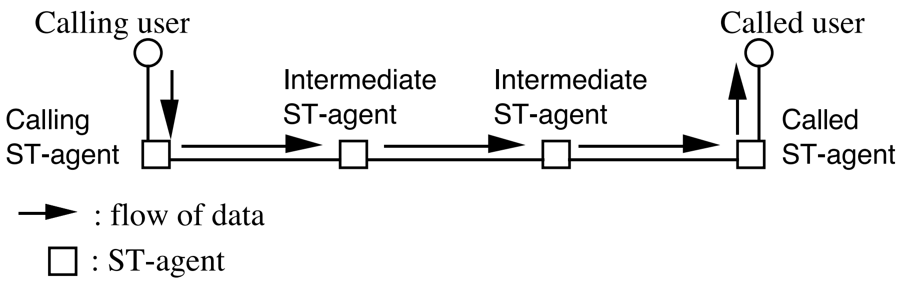

Fig 5.2 :Point-to-Point Simplex ST-II stream

In ST-II, the first step is to set a route along which resources are allocated and to activate ST-agents (figure 5.2).

5.1.1 Triangular Negotiation for a Bounded Target

In this type of negotiation, slightly different from the negotiation for a contractual value of § 2.2.2, the calling user introduces, in the request primitive, two values of a QoS parameter, the target and the lowest quality acceptable. The service provider is not allowed to change the value of the lowest quality acceptable. Here, the service provider is free, as long as it does not weaken it below the lowest quality acceptable, to weaken the target value before presenting the new value of the target and the unchanged value of the lowest quality acceptable to the called user, through an indication primitive. It will be the privilege of the called user to take the final decision concerning the selected value. This selected value of the QoS will be returned by the called user in the response primitive. This selected value will be included without change by the service provider in the confirm primitive. At the end of the negotiation, the three actors have agreed on the value of this QoS parameter (figure 5.3).

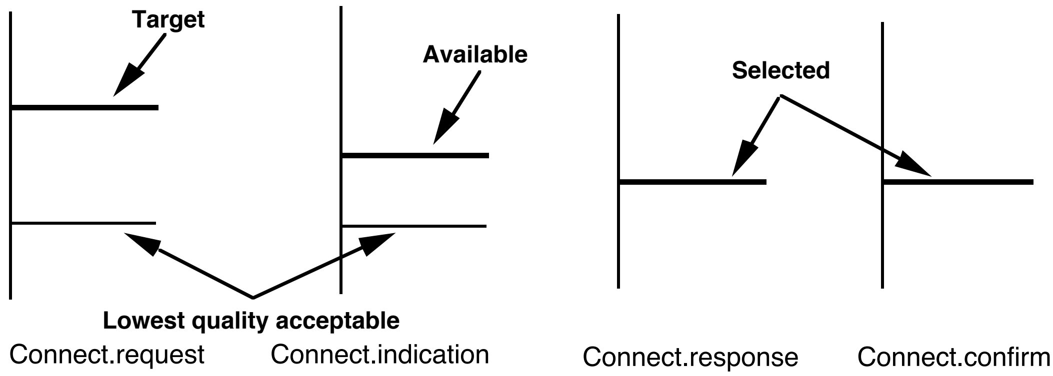

Fig. 5.3 Triangular Negotiation for a Bounded Target

The service provider may have to reject the request if it does not agree to provide a QoS in the requested range. The called user may also reject the connection attempt if it is not satisfied with the range of values proposed in the indication primitive.

With respect to the target value introduced by the calling user, the only possible modification introduced by the negotiation is the weakening of the target but limited by the lowest quality acceptable value.

The class 2 of the ISO Network Service [ISO 8348] is based on this scheme which is also used in ST-II [Top 90] and [FRV 93]. In this last paper, is also introduced the idea of a time-specified negotiation to ease the reservation problem.

5.1.2 The Flow Specification

ST-II uses a data structure named flow specification (abbreviated as flowspec). This flowspec is used to carry the target and the minimal values of the QoS parameters requested by the calling user. It is also used to carry values introduced by the service provider. The flowspec is passed from ST-agent to ST-agent as the path is defined (fig 5.2). Every ST-agent along the path has to reserve enough resources based on the requested values, to adjust the target values of the negotiation scheme of §5.1.1 and to estimate its contribution to cumulative QoS parameters such as minimum, mean and maximum transit delay. The global information about the path contained in the flowspec is presented to the called user in the CONNECT.indication. The called user will then have to decide whether the performance values are sufficient before accepting the connection.

From a service point of view, a ST-II stream is nothing else than a connection (which can be point-to-point or point-to-multipoint). The fact that ST-II uses a fixed route to send its data is hidden from the service user and is only a protocol matter. The state information is maintained by all the ST agents on the path from the calling to the called user. This information is necessary in all these agents to co-ordinate their activities, and allows users to join or leave the ST-II stream dynamically or when the stream must be reconfigured (i.e. routed over other ST-agents). This reconfiguration might cause the selection of a new route and the allocation of new resources. If some users of the stream are no longer reachable after the reconfiguration, the calling user will be indicated.

The meaning of "resource reservation" from a service user point of view is more subtle. In an ideal world, when all necessary resources are firmly reserved for a connection, that means that the connection is assured that the requested QoS will be fulfilled. In the real world, a pathological situation may always arise, in which case the QoS will not be achieved. This means that a guaranteed QoS will always be provided *but the case of pathological behaviour*.

5.1.3 Firm or Pre-emptive Reservation

In the case of firm reservation, all the resources allocated to a path will be used only for the data transfer on that path. From the calling user view point, it is the best solution but such a solution may prevent a later CONNECT.request to be accepted. The usual solution to this problem is to introduce a priority or a cost concept. The calling user has to specify, in its CONNECT.request, the precedence of its connection. The precedence parameter is used as a measure of the relative importance of the connection. During the connection set-up, a stream being established can steal resources to a stream of a lower precedence. If a new stream steals only a fraction of the resources of a lower precedence stream, the service provider will have to indicate the new values of the QoS parameters to the calling user of the "victim" stream.

When pre-emptive reservation is possible, it is difficult to attach a semantics of *guarantee* to the QoS of a path which is not of the highest precedence. In a more recent flow specification [Par 92], the pre-emptive reservation is not allowed.

5.1.4 Statistical Reservation

Up to now, we always discussed the QoS from the service user perspective and attached to one connection or to one stream. There is also a service provider perspective which takes a more global view. In the present case, the service provider may be tempted to try to satisfy the highest possible number of CONNECT.request. To do so, the service provider may allocate the resources on a statistical basis or using an overbooking scheme.

In this case, it is not only in pathological situations, associated with a very low probability of occurrence, that the QoS may not be achieved. In this case, the probability of not achieving the QoS may be high, reflecting the fact that the requirement is very likely not to be met. To distinguish both cases, we may qualify differently the QoS value when it has to be associated with a probability of achievement that is far from 1. It is what has been done in [CSZ 92] and [Par 92] where a distinction is made between a guaranteed service and a predicted service.

5.1.5 Incomplete Reservation

Up to now, we have assumed the possibility for an ST-agent to allocate resources on a firm basis in the best case, or on a statistical basis or following an over allocating scheme otherwise.

An internet service provider is based on the concatenation of relay functions and one of these relays may be completely unable to allocate resources and to guarantee any throughput on a segment between two ST-agents. Therefore, with incomplete reservation, it is impossible to speak of guaranteed QoS and even a predicted service will be difficult to quantify.

Incomplete reservation along a fixed path may however provide a better service than IP but we are back to a best effort semantics.

5.2 What if?

If the semantics of best effort is associated with the QoS value resulting from a negotiation for information exchange, the service provider has no obligation and nothing will be done if the agreed value is not achieved. The service provider may not even be aware of the situation as it is not obliged to monitor the achieved QoS values.

If the semantics of guaranteed QoS is requested by the service user, the service provider has to reject the request if it does not agree to provide a QoS in the requested range.

Once the request has been accepted, as the result of a negotiation for a bounded target or of a negotiation for a contractual value, the service provider will guarantee the negotiated QoS value and, unless (unavoidable and unpredictable) pathological cases, will provide the requested service. Here, **the service provider has an obligation of results.** This should be the only meaning of a guaranteed QoS and with this strong semantics, there is no need for monitoring, the service provider being certain, at the end of the negotiation, of its ability to provide the requested value[3].

6 The QoS enhancements in OSI95

If a guaranteed QoS is not possible to achieve, it does not mean that the only choice left is the best effort. There is a room for an enhanced QoS semantics. If the service

[3]Without the obligation of results and without the monitoring, we are back to the best effort.

provider is not able, for any reason, to guarantee the requested QoS, it may try to provide the requested QoS value but will have **an obligation of behaviour** if it does not succeed. In this case, the service provider will have to monitor the achieved QoS value.

When the service provider notices that the achieved QoS value is weaker than the negotiated one, it will have to take some action, such as aborting the connection if it has been instructed to do so by the service user.

The service provider may have been instructed not to abort, but to indicate to the service user(s) that it cannot maintain the selected value, and leave to the service user(s) the responsibility of aborting.

It is on this basis that, in OSI95, a new semantics for the performance QoS parameters has been introduced. In this semantics, a parameter is seen as a structure of three values, respectively called "compulsory", "threshold" and "maximal quality", all these values being optional. Each one has its own well-defined meaning, and expresses a contract between the service users and the service provider [DBL 93].

This means, and this is the most fundamental difference with the best effort, that the service provider is now subject to some well-defined duties, known by each side. In other words, the rules of the game are clear.

The existence of a contract between the service users and the service provider implies that, in some cases, the service users are also subject to well-defined duties also derived from the application environment.

Depending upon the type of facilities, these QoS parameters will be subject to a negotiation or not. In case of a negotiation, some rules related to the rights of strengthening or lowering (weakening) the QoS values are defined for each type of value and for each participant in the negotiation. This has to be done to keep the final result consistent with the meaning of the parameter value and is part of the needed admission control of a new connection, admission control which will be based on the QoS on one side and on the source characterisation on the other side. This connection admission control will have to be completed by an admission control on a connection to enforce the contract.

7 The Compulsory QoS Value

The idea behind the introduction of a “compulsory” QoS value is the following one: *when a compulsory value has been selected for a QoS parameter of a service facility, the service provider will monitor this parameter and abort the service facility when it notices that it cannot achieve the requested service.*

It must be clear that no obligation of results is linked to the idea of compulsory value. The service provider **tries** to respond to the requested service facility and, by monitoring its execution, it will

- either execute it completely without violating the selected compulsory value of the performance parameter;
- or abort it if the selected compulsory value of the performance parameter is not fulfilled.

This is, by the way, the semantics associated with the error control in TP4 [ISO 8073]. The connection is released after a number of unsuccessful transmission attempts.

7.1 Compulsory QoS versus Guaranteed QoS

The guaranteed QoS has a stronger semantics. When a guaranteed QoS value has been selected for a parameter of a service facility, the service provider will execute completely the service facility without violating the selected guaranteed value of the performance parameter.

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.

7.2 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 with the request in order to facilitate the decision of rejection or acceptance of the request. Requesting a throughput of 2 Mb/s with SDUs of 10 Kbytes is different from requesting a throughput of 2 Mb/s with 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. Information parameters will be used for instance for source characterisation.

Values of QoS information parameters may also have to be introduced to control the negotiation process to preserve the semantics associated with the negotiated value.

7.3 Negotiation of a Compulsory QoS value

The negotiation for a compulsory QoS value will follow the negotiation scheme for a contractual value introduced in § 2.2.2. When a service user introduces a compulsory QoS value for a performance parameter to be negotiated, the only possible modification is the strengthening of this compulsory value. In particular, it is absolutely excluded for the service provider to modify this value in order to relax the requirement

As the calling service user may not be interested in an unlimited strengthening of the proposed compulsory QoS value. It introduces therefore in the request primitive, a second value which fixes a bound indicating to what extent the proposed compulsory QoS value may be strengthened (fig 2.7).

When the service provider analyses the request of the calling service user, it has to decide whether it rejects it or not (it can already do so as it knows that the request could only be strengthened). In the latter case, it has to examine the bound of strengthening. This bound may be made poorer (brought closer to the compulsory value) by the service provider, before issuing the indication primitive to the called service user, in such a way to give, to the called service user, the range of compulsory values acceptable by both the calling service user **and** the service provider.

The service provider does not have to strengthen the compulsory QoS value which must be seen as the expression of the requirements of the service users.

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 completed and the service provider may confirm the acceptance of the request and provide the final selected compulsory QoS value to the calling service user.

If the negotiation is successful, the bound is of no interest anymore (the bound is an example of information values mentioned earlier) and the selected compulsory QoS value reflects now the final and global request to the service provider from both service users.

8 The Threshold QoS Value

Some service users may find that the solution of aborting the requested service facility, when one of the compulsory QoS values is not reached, is a little too radical. They may prefer to get information about the degradation of the QoS value.

To achieve that we introduced a “threshold” QoS value with the following semantics: *when a threshold value has been selected for a QoS parameter of a service facility, the service provider will monitor this parameter and indicate to the service user(s) when it notices that it cannot achieve the selected value*.

This threshold QoS value may be used without an associated compulsory value. In this case, the behaviour of the service provider is very similar to the one it has to adopt with a compulsory value. The main difference is that, instead of aborting the service facility when it notices it is unable to provide the specified value, it warns either or both users depending of the service definition. If the service provider is able to provide a QoS value better than the threshold value, everything is fine.

8.1 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 in the former case, the service provider has the obligation to monitor the parameter and to indicate if the threshold value is not reached.

8.2 Threshold and Compulsory QoS values

It is possible to associate, with the same QoS parameter, a threshold and a compulsory QoS values with, of course, the threshold value "stronger" than the compulsory one.

If the performance parameter degrades slowly and continuously, an indication will be delivered to the service users before the abortion of the service facility. Until such a threshold indication occurs, the service user knows that the service facility is not endangered by the current parameter value.

8.3 QoS Parameters and Information Parameters

Here also, as in the case of compulsory QoS values, information QoS parameters may also have to be introduced to facilitate the decision of rejection or acceptance of the request and to preserve the semantics associated with the negotiated value.

8.4 Negotiation of a Threshold QoS value

The negotiation procedure of a threshold value is similar to the negotiation procedure of a compulsory value. Here also the only possible modification is the strengthening of the threshold value. Here also the calling service user introduces, in the request primitive, an information parameter which fixes a bound indicating to what extent the proposed threshold QoS value may be strengthened.

If a compulsory and a threshold value are associated with the same QoS parameter, there exists a set of order relationship between the compulsory, the threshold and their bounds values which must be verified in the request primitive and maintained during the negotiation.

9 The Maximal Quality QoS Value

In most cases, if the service provider is able to offer a “stronger” value of the QoS parameter than the threshold, the service user will not complain about it. But it could happen that the service user wants to put a limit to a “richer” service facility.

A called entity, for instance, may want to put a limit to the data arrival rate or a calling entity may want, for cost reasons, to prevent the use of too many resources by the service provider.

Such a parameter may be useful to smooth the behaviour of the service provider. Introducing a maximal quality QoS value on a transit delay, i.e. fixing a lower bound to the transit delay values will reduce the transit delay jitter and facilitate the resynchronization at the receiving side.

To achieve that we introduced a “maximal quality” QoS value with the following semantics: *when a maximal quality value has been selected for a QoS parameter of a service facility, the service provider will monitor this parameter and avoid occurrence* *of interactions with the service users that would give rise to a violation of the selected value.*

It is possible to associate, with the same QoS parameter, a maximal quality, a threshold and a compulsory QoS values with, of course, the maximal quality “stronger” than the threshold value, itself “stronger” than the compulsory value.

9.1 Negotiation of a Maximal Quality QoS value

If a service user introduces a maximal quality QoS value for a performance parameter, the only possible modification is the weakening of this maximal quality QoS value. This value can be weakened during the negotiation by the service provider that indicates by this way the limit of the service it may provide and by the called service user.

If the maximal quality is the only value associated with a given QoS parameter, no bound will be introduced in the request primitive and the negotiation will result in the selection of the weakest of the maximal quality values of the service users and the service provider following the negotiation scheme of § 2.2.1.

If the maximal quality value and a compulsory or/and a threshold values are associated with the same QoS parameter, there exists an order relationship between the maximal quality value and the bound value on the threshold (or the bound value on the compulsory value if no threshold value is specified) which must be verified in the request primitive and preserved during the negotiation.

10 About an Example of Negotiated QoS Parameter

As an example of a negotiated QoS parameter, let us consider the throughput on a direction of transfer of a connection with the associated compulsory, threshold and maximal quality values and the throughput definition of the figure 2.4.

The compulsory is the smallest value and represents the throughput that the service provider must be able to offer to the sending and to the receiving users. If at anytime during the whole lifetime of the connection, the service provider happens to be unable to maintain this throughput a DISCONNECT.indication will occur. If the traffic on the connection is dedicated to a video channel, the compulsory value may represent the throughput necessary to maintain the synchronisation between the sending and the receiving users.

However, in the most general case, two particular situations have to be considered. Both are dealing with the responsibilities of the users and of the service provider when the selected values are not matched.

At the sending SAP, the compulsory value may be violated because no DATA request occurred in due time owing to the behaviour of the sending user only (i.e. the service provider was ready to accept a DATA request in due time). This does not imply a failure of the service provider but only results from the behaviour of the sending user. In this case, it may be reasonable to believe that the service provider does not have to issue a DISCONNECT indication.

If at the receiving SAP, no DATA indication occurs due to the receiving user, the compulsory QoS value will also be violated. Here however it seems reasonable to recognise that the compulsory value does not only constrain the service provider but also constrains the receiving user. Its acceptance of the compulsory value implies that it believes to be able to support the compulsory value. Therefore a DISCONNECT indication seems appropriate[4]. Notice that the constraints on the service provider on the input side and on the service user on the receiving side allow the use of a rate control at both ends of the connection.

It is possible, for the threshold value to apply the same rules as for the compulsory value, issuing, of course, a REPORT indication instead of a DISCONNECT indication. However, taking account of the warning characteristic associated with the threshold value, the service provider may issue a REPORT indication to the service users as soon as the threshold value is violated and without a different attitude depending of the responsible entity.

The maximal quality QoS value is the highest value of the three. The service provider, by controlling the occurrence of the interactions with the service users, prevents the sending user's throughput and the receiving user's throughput from crossing the limiting value.

An interesting point to mention is that the combination of the compulsory and maximal quality values helps to make more precise the model of the service provider. The internal queues may build up at a maximum pace linked to the difference between the maximal quality and the compulsory values of the throughput.

11 Related Work

Very few related work exist on user-oriented QoS and have been mentioned already. In this section, we mainly focus on related work on network-oriented QoS.

If a layered architecture may be based on a recursive definition as expressed in figure 5.1 and if the QoS service model of figure 2.1 may be applied to the network layer and even to the subnetwork layer, the model reaches its limits when the service provider is a bearer service. Such a bearer service may not be able to negotiate all the QoS performance parameters but is associated with "network-oriented" QoS allowing the bearer service user to evaluate the user-oriented QoS. An interesting discussion about BER, Cell Loss Ratio, Cell Insertion Ratio, Cell Delay Variation and End-to-end Transfer Delay in an ATM based B-ISDN may be found [ATV 91] where the relation between these parameters and the application requirements are discussed.

The idea of compensating the delay jitter, in packet networks, by an additional storage in the end node in order to restore a synchronous behaviour has been proposed and used for the voice packet in PARC in the early eighties. This idea has been extended to video in [DRB 87] and implemented in the BWN[5] project [DHH 88]. This idea of reducing or eliminating the transit delay jitter by an additional storage at the

[4] This asymmetrical behaviour may not be acceptable in every application environment

[5] BWN is an ESPRIT I project on a Broad Site Wideband Communication Network

end of the service provider may be achieved by a maximal quality QoS on the transit delay (section 9).

This idea of trying to provide a constant delay is also integrated in a proposed solution for a particular class of multimedia applications called *play-back* applications [CSZ 92]. By providing additional storage at the end node, it is possible to fix a play-back time for each packet and, if none arrives after the play-back time, to provide a synchronous service. In [CSZ 92], the play-back time is integrated in the scheduling of the node of an internet, packets which are not in danger to miss their play-back point being delayed in favour of packets which are.

The idea of play-back applications may be linked to a guaranteed service for intolerant and rigid clients or to a predictive service for tolerant and adaptive ones. In the former case, we will have an *a priori* bound for the play-back time and this will lead to a limited utilisation of the nodes. In the later case, it is possible to use a *post facto* bound and achieve a better utilisation of the nodes. However, this requires adaptive clients which may endure reduction and even temporary disruption of service as the result of admission of new clients or of modification of traffic charges of existing ones. The approach of [CSZ 92] favoured the predictive service in contrast to the Tenet approach [Fer 93] which favoured the guaranteed service. It is once again the conflict between the service provider view and the service user view.

The workshop on "Quality of Service Issues in High Speed Networks" held at Murray Hill on April 23-24, 1992 [Kes 92] demonstrated the increase of interest in the issue as well as the diversity of the notion of QoS even if the workshop put an emphasis on the QoS related to the network service. The basic question of the workshop was: how to provide different QoS to the diversity of the applications ? It appears however that the ability of providing bounds for the throughput is necessary, bounds on delay are desirable and bounds on delay jitter debatable. The scheduling discipline is perceived as the key policy [Kes 92]. This workshop confirmed that the performance characteristics of the ATM layer are not easily mapped in the QoS perceived by the user of the service. This workshop was also an opportunity to compare the approach of several projects such as Xunet II, TeraNet [LaP 91] and plaNET/Orbit.

In a recent paper [Kur 93], the author, after reviewing the present situation, discusses the challenges and the open issues involved in providing QoS guarantees to sessions in a high-speed wide area network. If the goal of providing end-to-end QoS guarantees on a session is clear, it is less obvious how a service provider can take advantage of the resource gains offered by the statistical multiplexing of sessions. For every new request, the call admission control must be able not only to provide the guaranteed end-to-end QoS for the new session but also to determine the performance impact of admitting this session on the already-accepted sessions of the network. The performance of the service provider, which previously was linked to the design and the dimensioning of the network is now becoming a real-time problem to be treated by the call admission control. The characterisation of the source is an essential part of the decision process and it is not surprising that the policing of the source is an absolute necessity. What is more surprising is the fact that each element of the network may contribute to deeply modify the characteristics of the source not always in the direction of reducing the difficulty of providing the QoS. The paper discusses the problem of bounds on delay comparing the solutions of queue scheduling which achieve absolute bounds and therefore are able to offer guaranteed QoS and approximate methods which are providing what has been defined earlier as predictive service.

12 Conclusion

After having introduced the QoS paradigm, the principle of the QoS parameter definition and a new taxonomy to distinguish different types of negotiation of the QoS, we discussed the limitation of the best effort QoS and the resources reservation constraints associated with the guaranteed QoS.

We presented in this paper an enhancement of the QoS semantics able to match the communication requirements of the new application environment. This enhanced semantics is based on compulsory, threshold and maximum values and involves a new negotiation scheme aiming at the definition of the contract between the service user and the service provider. This work is at the origin of the OSI95 Transport Service [Dan 92a, 92b], [DBL 92a, 92b], [BLL 92a, 92b, 93]. The table below summarises the behaviour of the service provider within the various semantics discussed.

Table 1 : Behaviour of the service provider within the different QoS semantics

	Best Effort	Maximum Quality	Threshold	Compulsory	Guaranteed
Obligation of Results	NO	YES	NO	NO	YES
Monitoring	NO	YES	YES	YES	NO
Disconnect if achieved value is weaker	NO	N/A	NO	YES	N/A
Indicate if achieved value is weaker	NO	N/A	YES	NO	N/A

N/A : Not applicable

This work has been also presented to the standardisation committees [DBL 93], [ISO 8010] and we hope that it will contribute to the specification of new communication services.

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