Project Number: **IST-1999-20841**
Project Title: **SEQUIN**

Deliverable D2.1
Quality of Service Definition

Deliverable Type: PU-Public
Contractual Date: 31 March 2001
Actual Date: 31 March 2001
Work Package: 2
Nature of Deliverable: RE - Report

Authors:

Mauro Campanella	INFN-GARR,
Pierre Chivalier	Renater
Afrodite Sevasti	GRNet
Nicolas Simar	DANTE

Abstract:

A qualitative and quantitative definition of Quality of Service is needed for implementation in the European networks. This deliverable provides a definition of QoS which is independent of the underlying networking technology. It will sketch the definition of an end-to-end QoS service that can be implemented in a multi-management domain environment across Europe.

Keywords: QoS, GÉANT, IP Premium

Table of Contents

1 EXECUTIVE SUMMARY

Data communication using computer networks and the general Internet, including the National Research & Education Networks (NRENs), is today provided by IP technology and a unique type of service called Best Effort.

With the appearance of time-sensitive applications, and the more and more ubiquitous use of Internet as a work tool, congestion and uncertainties in delay and delay variation have led to a degradation of quality of the response of applications.

QoS (Quality of Service) is a generic term which takes into account several techniques and strategies that could assure application and users a predictable service from the network and other components involved, such as operating systems.

Enabling "QoS" on a network implies the definition of QoS and the deployment of various mechanisms, including scheduling, control admission, shaping, control on routing latency/ performance and resource planning. All these technique are aimed at providing an end to end Quality of Service for selected traffic.

The provision of QoS via international end-to-end guaranteed bandwidth between researchers necessarily involves the concatenation of a variety of independently managed networks. In addition, these networks may be based on differing networking technologies.

This Deliverable provides a QoS definition that reflect users' needs and that can be used to quantify QoS services. After a brief review of research status on QoS international bodies, the result of interviews with various users is analysed and complemented by a technical definition of QoS based on a list of parameters (capacity, delay, delay variation and packet loss). This definition will provide the basis for the implementation of an end-to-end approach to Quality of Service that will operate across multiple management domains and will be independent of the transport technology.

2 QOS - STATE OF THE ART OF RESEARCH

Data communication using computer networks and the general Internet, including the National Research & Education Networks (NRENs), is today provided by IP technology and a unique type of service called Best Effort.

With the appearance of time-sensitive applications and the more and more ubiquitous use of Internet as a work tool, congestion and uncertainties in delay and delay variation have led to a degradation of quality of the response of applications.
The end to end quality of an application is the joint effort of three main components: an application, the operating system and the transport of application data by the network. The focus of the this work is on QoS on networks.

At least three different approaches can be identified to provide QoS:

- bandwidth over provisioning
- the use of Data Link characteristics and traffic engineering
- QoS architectures

2.1 Over provisioning

Intuitively, the term indicates a network in which the amount of bandwidth in the various links is much greater than the peak utilisation value. This definition is quantified in two different ways: the absence of congestion in any part of the network for a finite, even small, amount of time, or the request that the average network load is always less than a finite percentage in each link.
As an example, it can be requested that the monthly or daily usage of a link should not be greater than 10% of the capacity [VR1]

Provided that the network can be built entirely with over dimensioned links and it is equipped with hardware capable of delivering packets at wire speed, this approach offers QoS guarantees for capacity. It offers less stringent guarantees for delay, particularly delay variation, which will be functions of the network load.

2.2 Use of Data Link Characteristics and traffic engineering.

The most significant architecture at the data link layer that can provide various type of QoS is ATM (Asynchronous Transfer Mode) which transports data in fixed size cells on virtual circuits. ATM features built in QoS capabilities. In particular, it can provide the equivalent of a leased line through Constant Bit Rate (CBR) virtual circuits. To ensure the required end to end QoS, ATM should be deployed at every hop of the path. Given its high cost, complexity and scalability issues using switched virtual circuits and its low penetration in the LAN market, it cannot be used as the only QoS architecture in the network.

New technologies such as MPLS (MultiProtocol Label Switching) [RFC 3031] can be seen as a different way of providing QoS guarantees through an accurate use of the available network bandwidth. MPLS is not a QoS architecture, but rather a routing and forwarding technique that aims at integrating the control of IP routing with Layer 2 switching. The use of "labels" allows the creation of logical paths which can be different from one flow to another and that can exploit the available resources at their best. Providing a different path to different flows may provide a better service from the network to selected traffic.

2.3 QoS Architectures

2.3.1 IETF

IETF working groups have defined two different architectural approaches to provide QoS mechanisms in Internet:

- IP IntServ (Integrated Services)
- DiffSERV (Differentiated Services)

2.3.1.1 IP Integrated Services (IntServ)

Integrated Services [RFC1633] is a service model to provide fine-grained assurances to individual flows. At present there are two services defined in the model:

1 Guaranteed Service [RFC 2212] offers quantifiable bounds on latency to flows that conform to a traffic specification.
2 Controlled Load Service [RFC2211] offers delay and packet loss "equivalent to that of a lightly network".

Intserv requires state information in each participating router and, if this state information is not present in every router along the path, QoS guarantees cannot be ensured. Usually, but not necessarily, Integrated Services are associated with Resource ReSerVation Protocol (RSVP) [RFC2205] signalling. Signalling processing times and the need for storing per flow information in each participating node is believed to lead to scalability problems, particularly in the core of the Internet. [RFC2208]

2.3.1.2 Differentiated Services

IP Differentiated Services (DiffSERV) [RFC2475] is a layer 3 framework to provide control to aggregates of flows. It requires state awareness only in the edge of a DiffSERV domain. At the edge, packets are classified into flows and the flows are conditioned (marked, policed or shaped) to a traffic conditioning specification. Then the flows are aggregated. A DiffSERV Codepoint (DSCP) identifies a per-hop behaviour (PHB) and it is set in each packet header.

The DSCP is carried in the DS-field, which is formed from six bits of the former ToS byte of the IP header [RFC2474]. The PHB is the forwarding behaviour which is to be applied to the packet in each node in the DiffSERV domain. Although there is a "recommended" DSCP associated with each PHB, the mappings from DSCPs to PHBs are defined by the DS-domain. In fact, there can be several DSCPs associated with the same PHB. Three important PHB are:

1. The class selector PHB [RFC2474] subsumes the IP precedence semantics of the former ToS byte. It offers relative forwarding priorities.
2. The Expedited Forwarding (EF) PHB [RFC2598] [I-D-RFC2598bis] guarantees that packets will have a well-defined minimum departure rate which, if not exceeded, ensures that the associated queues are short or empty. EF is intended to support services that offer tightly bounded loss, delay and delay variation.
3. The Assured Forwarding (AF) PHB group [RFC2597] offers different levels of forwarding assurances for packets belonging to an aggregated flow. Each AF group is independently allocated forwarding resources. Packets are marked with one of three drop precedence, such that those with the highest drop precedence are dropped with lower probability than those marked with the lowest drop precedence. DSCPs are recommended for four independent AF groups, although a DS domain can have more or fewer AF groups.

2.3.2 IEEE 802.1p

Most local area networks (LAN) are based on the IEEE 802 technology. 802.1p defines a field in the layer-2 header of the 802 packets to carry one of eight priority values. LAN devices, like switches, are expected to handle the traffic according to the 802.1p priority, by means of appropriate queuing mechanisms. The scope of 802.1p is limited to a LAN, once the packet crosses a layer 3 device, the 802.1p tag is removed, but it can be mapped to a layer 3 equivalent information, for example in the ToS byte of the IP header.

2.3.3 ITU-T

The ITU-T Study Group 13 is working on various recommendations, including Y.1541 "Quality of Service (QoS) classes for IP networks" [Y.1541]. ITU-T is proceeding along the same tracks of IETF in the definition of QoS parameters, the major difference is in the definition of the measurement methodology which is more statistical oriented ITU-T and more deterministic IETF. The study group 13 is proceeding rapidly and it is closing the gap with IETF. For a review of the status of development at December 2000,see reference [CIT-ITU]

2.3.4 QoS Signalling and Policy Protocols

In order to provide network QoS, it is necessary to configure the network mechanism outlined above. The configuration can be done from a centralised entity, either manually or via a distribution protocol from a central console. It can also be dynamically requested from the applications. Both admission policies and configuration rules can be enforced in this way.

RSVP (Resource ReSerVation Protocol) [RFC2205] is a signalled QoS configuration mechanism. Using this protocol, applications can request end-to-end, per conversation, QoS from the network. The use of RSVP is not limited to the Intserv model and can be appropriate for signal generic request, as well as for signalling QoS for traffic aggregates in the DiffSERV framework. RSVP is a layer 3 protocol and its messages carry information about classification, quantification of the conversation, service type requested and admission policy.

The complexity of setting up a multi domain, multi vendor dynamic signalling cannot be underestimated. Signalling requires each participating node to maintain state information and exchange state updates and requests with its neighbours. In a multivendor, multidomain environment which spans multiple countries, the interoperability issues and complexity of the state can produce frequent instabilities of the signalling system.

3 QUALITATIVE AND QUANTITATIVE DEFINITION OF QUALITY OF SERVICE

For the definition of Quality of Service in a network, two complementary approaches have been followed. The first understands qualitatively users' perception and requirements of QoS through interviews. The result of the interview is then summarised in a list of desirable QoS services and their characteristics. The second defines the minimum set of QoS parameters, to allow a precise quantification of services.

3.1 Interview Summary

A study was carried out into the need for Quality of Service in networking. A number of Pan-European groups of users were approached in order to gain an understanding of how the networks are used, their requirements for Quality of Service and how these requirements might develop over a period of time. A model questionnaire was sent to 20 groups of users. See Annex 2.

Over a period of 6 weeks, we received 11 answers. Two of these answers were from different organisations within the same group of user and, therefore, their answers were merged. For each question, you will find the number of answers received and their distributions per type of answers. A detailed table with the answer for each institution interviewed can be found in Annex 1.

Answers described as a "clear answer" are where the interviewee gave a precise and exact answer to the question.

Answers described as an "interpreted answer" are a partial answer to a given question which needed to be completed by reference to other answers within this interview.

3.2 Interview Results Summary

3.2.1 *Introduction questions*

- What applications, apart from e-mail, do you use as part of your collaboration.

  Ten answers were received.

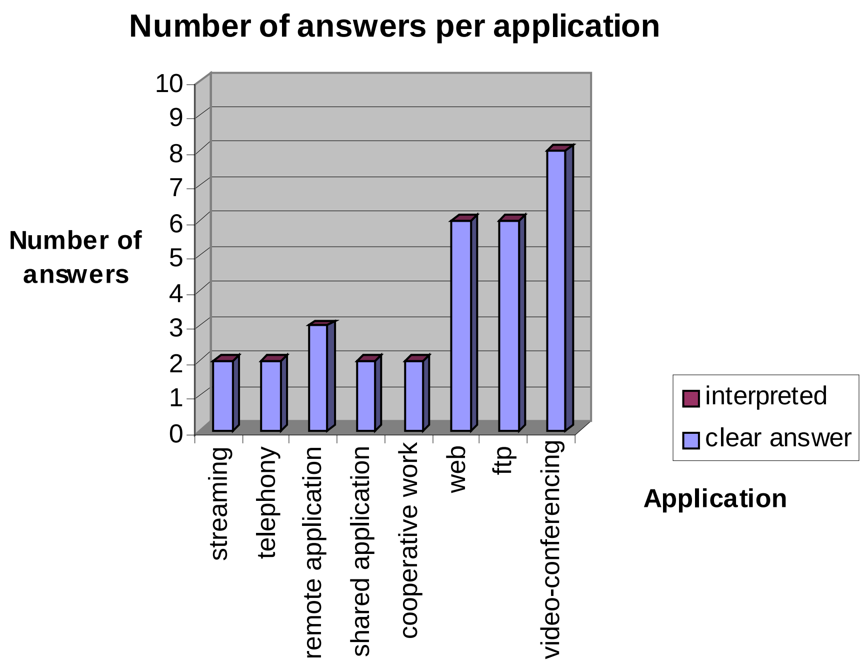

Figure 1. Number of answers received per applications

Other applications have been mentioned only once as virtual reality, shared 3-D applications, distributed simulations and database transfer.

Remarks:

There are two different requirements for the use of video-conferencing:- commodity communication service (spontaneous set-up, occasional degradation are tolerated) or pre-scheduled events (pre-planning set-up, no acceptance of busy signal due to overloaded network).

- Do you encounter difficulties with your present network access, what are the main problems encountered and suggested solutions.

  Seven answers were received. The most frequently encountered difficulties, with their occurrence (in parentheses), are listed below:-

  - Reservation response time too long (2)
  - Difficulty in localising a problem (2)
  - Time consuming administrative tasks (2)
  - Lack of throughput (3)

Other difficulties, appearing once only: Mbone access, low quality video-conferencing, upgrade problems. Please note that we have not detailed in which part of the network these difficulties were encountered.

3.2.2 Geography

- Can you tell us what locations you currently connect to.

  Ten answers were received.

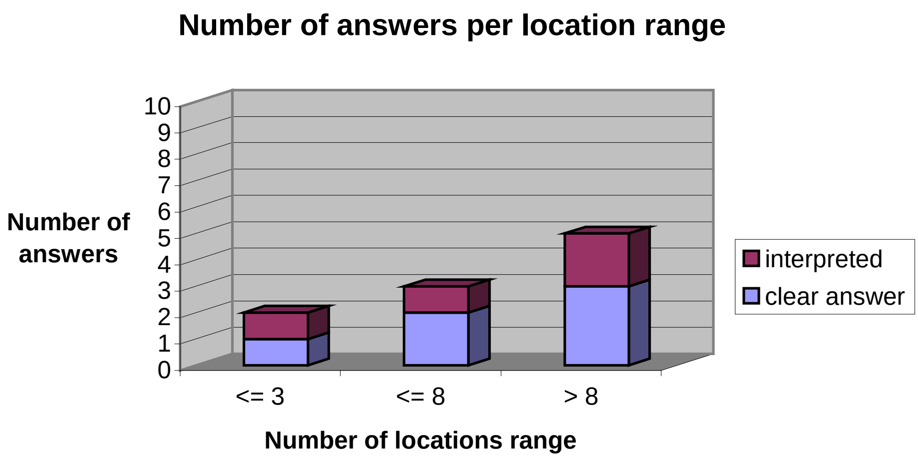

Figure 2. Number of answers received per location range

- Are all of the locations academic sites.

  Ten answers were received.

  Nearly all (9) of the interviewed groups had non-academic partners.

- Are there locations, which are not currently connected that you would like connected.

  Ten answers were received.

  Four of the interviewed groups intended to connect new locations not already connected.

- Do you know what the network connections are at the sites which are currently connected.

  A lot of interviewees did not specify network connections but five of them were able to give the capacity of at least one connection.

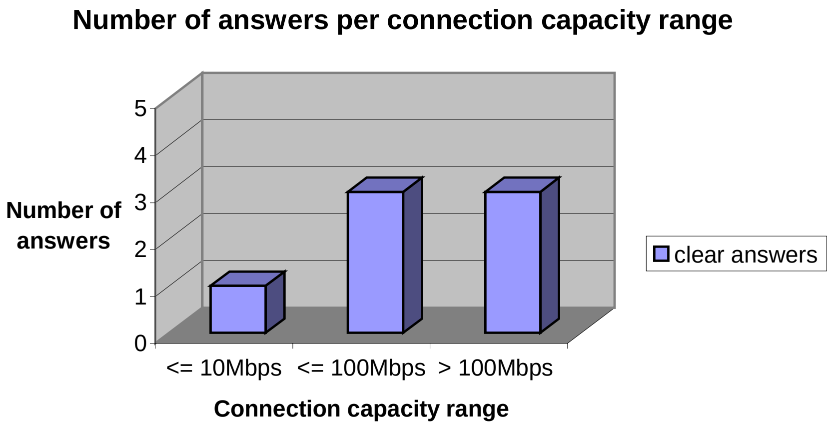

Figure 3. Number of answers received per capacity range

- Do you have any requirements for connectivity outside Europe. If so, to what countries do you wish to connect.

  Eight answers were received.

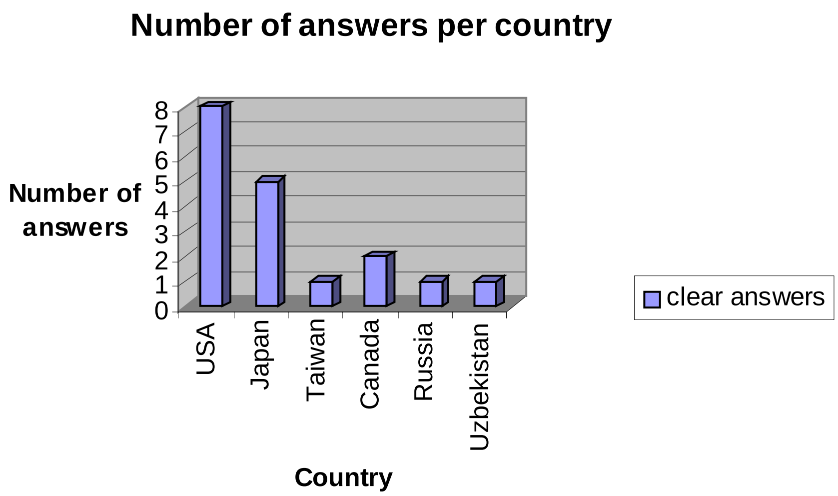

Figure 4. Number of answers received per country

- With respect to connectivity to the USA, can you say whether your principal need is for connection to research networks in the USA or for general Internet connectivity.

  Nine answers were received.

  Six groups needed research and general Internet connectivity and two groups needed research connectivity only.

3.2.3 Qualitative Perception of QoS

- In qualitative terms, what do you understand by QoS.

  Ten answers were received:-

  - Availability:

    Nine interviewees specified what they understood as QoS. For all of them, the availability meant an absence of interruption.

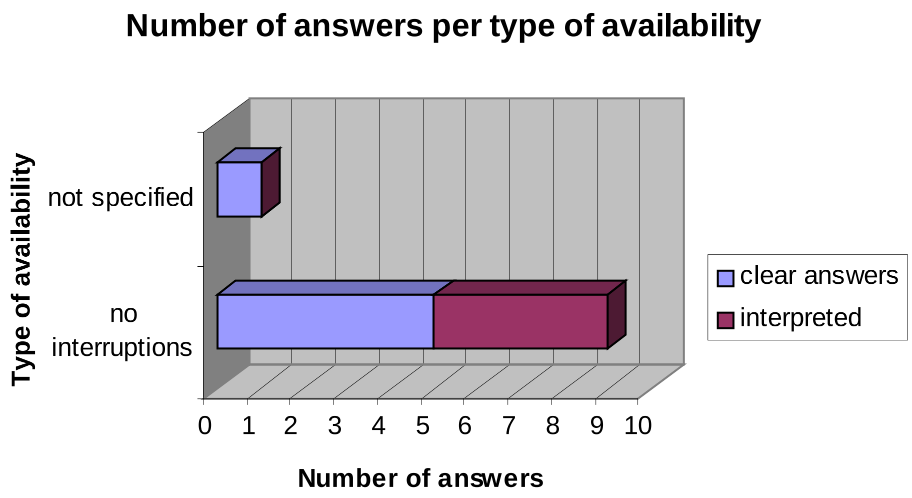

Figure 5. Number of answers per type of availability

- Reliability:

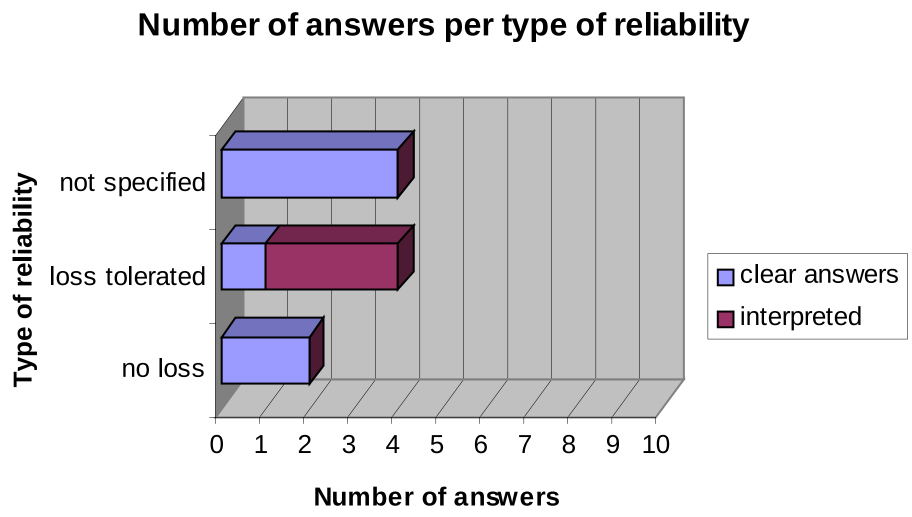

Figure 6. Number of answers per type of reliability

Reliability was specified in five of the interviews. The reliability was mainly defined as a loss parameter: no loss or loss tolerance.

- Response time:

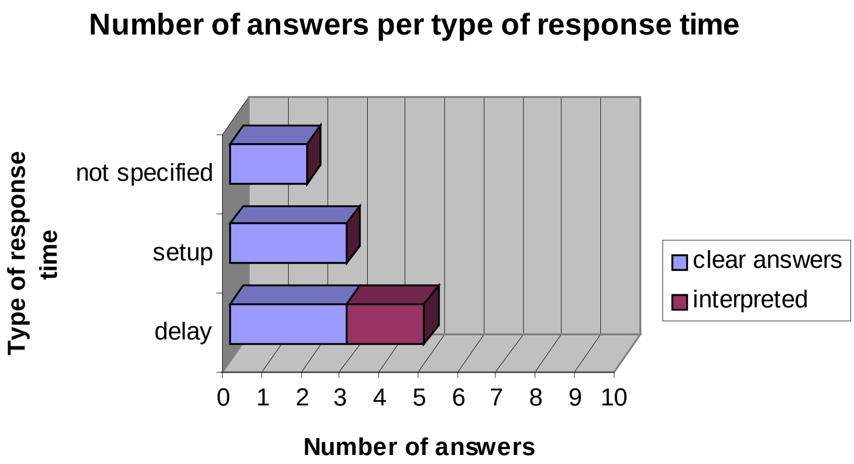

Figure 7. Number of answers per type of response time

Response time was defined in six of the interviews. It was defined as a delay, or as the time for establishing a connection.

Remarks:

The “no interruption of service” is a topological, link redundancy or a routing problem. More information concerning the reliability and response time can be found in the next question.

3.2.4 Quantitative Perception of QoS

- In quantitative terms, what do you understand by QoS. I am thinking in terms of numerical definition of Quality of Service.

  Eight answers were received.

  They nearly all agreed on the dependence on the applications used. We can find the maximum following value:-

  - for loss rate : 0%, 0.5%, 5% and 10%.
  - for delay : 50ms, 100ms, 150ms, and 300ms.
  - for delay variation : 20ms, 100ms.

  They also needed some BW guarantees: 512kbps, 2Mbps, 4Mbps, and 10Mbps. There was also one answer for 100Mbps if the latency is low.

  For more information about the specific values, see the grid summary of the interviews in Annex 1.

- Do you think that QoS should cost more than normal service? If a premium were to be charged for QoS, would you be in a position to pay for it.

  Eight answers were received:

  If reasonable charging was fair, compared to the advantages offered, THEN yes (4). One answer agrees with this sentence and three were interpreted as having this meaning.

  IF application needed THEN yes (2)

  Probably (1)

  No (1). One answer is interpreted as no

- It is planned to organise a pilot activity in respect of QoS as part of this project. Would you be interested in participating as an experimental partner in such a project?

  Ten answers were received.

  Yes (5)
  Maybe (2). Depending of cost, effort and time scale.
  No (3), Two of these answers were due to the fact that the project was finished.

- Are there particular requirements that you have today in respect of QoS.

  Nine answers were received.

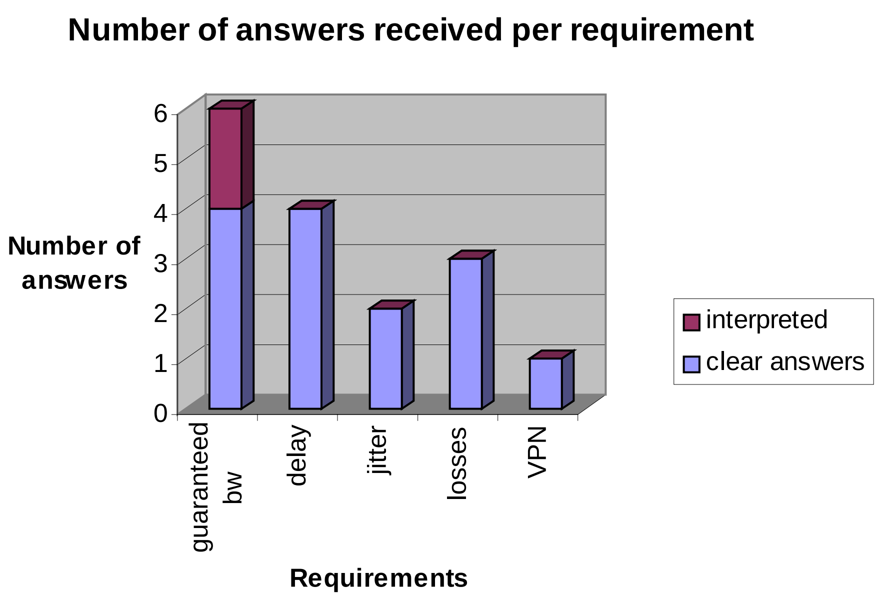

Figure 8. Number of answers received per requirement

They also ask for availability (1) and for an improvement of the network trouble reporting(1).

- Can you provide an indication of why, in your opinion, the present network does not satisfy these requirements.

  Seven answers were received.

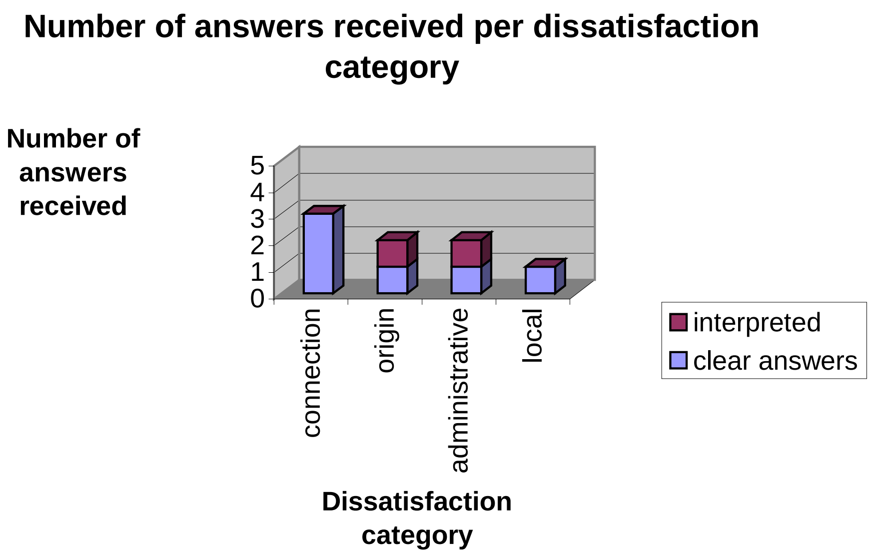

Figure 9. Number of answers per dissatisfaction category

Connection category : length of time taken to obtain a connection was too long.

Origin category : problems were difficult to identify and resolve.

Administrative category : administrative demands too numerous.

Local category : problems with the local environment.

We can also add only best effort (1) , no ipv6 (1) and number of insufficient back up links (1).

3.2.5 Network Options

- Do you have a view of what you would expect from your network in the future.

  Nine answers were received.

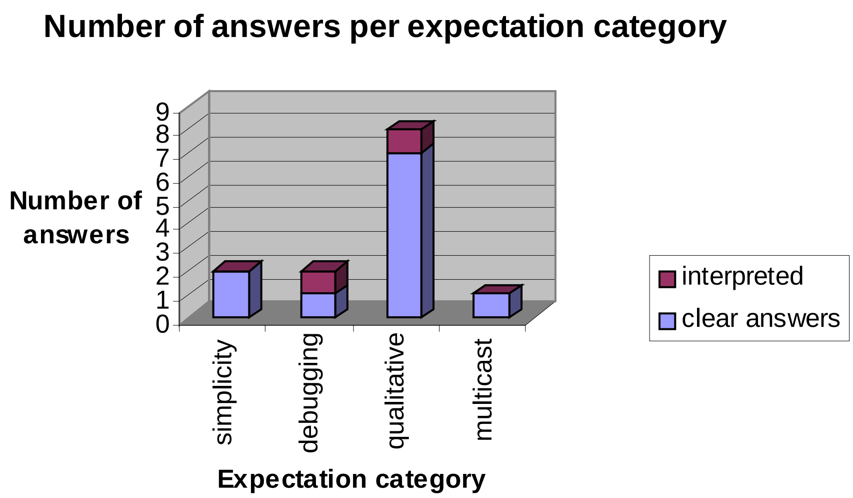

Figure 10. Number of answers per expectation category

- Concerning bandwidth, what is the typical bandwidth that you would like to see delivered end-to-end.

  Ten answers were received.

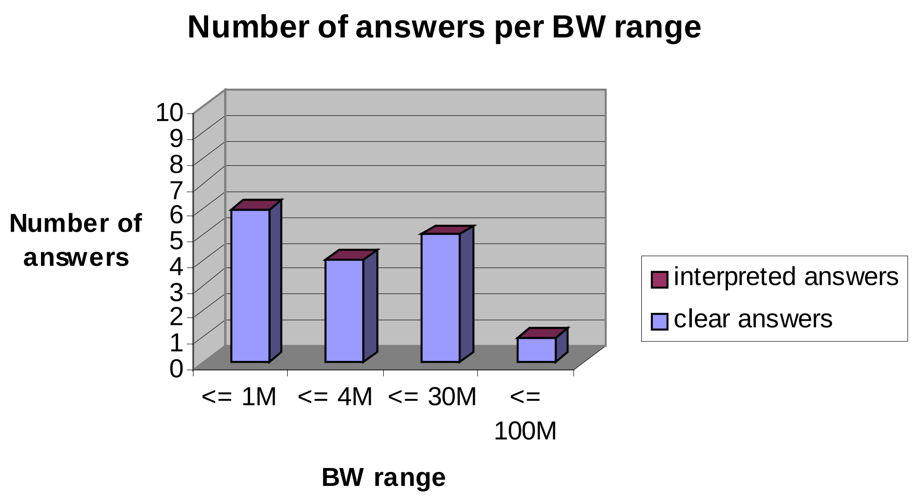

Figure 11. Number of answers per BW range

The capacity range depends on the capacity of the core backbone and the classes of service chosen. It's traffic engineering.

- Would an occasional use service for QoS be of interest to you.

  Seven answers were received.

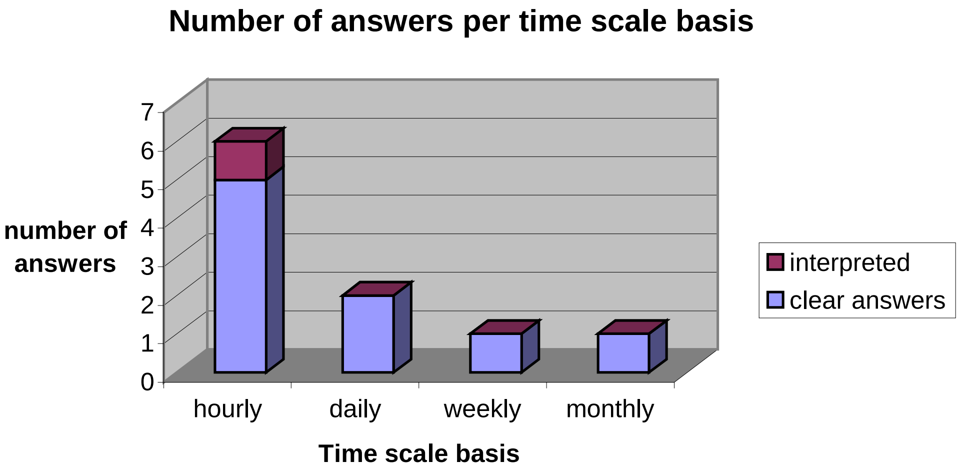

Figure 12. Number of answers per time scale basis

- Is security an important element for you.

  Ten answers were received.

  The security was important for all of them (nine clear answers and one interpreted).

- What elements of security do you regard as important.

  Nine answers were received.

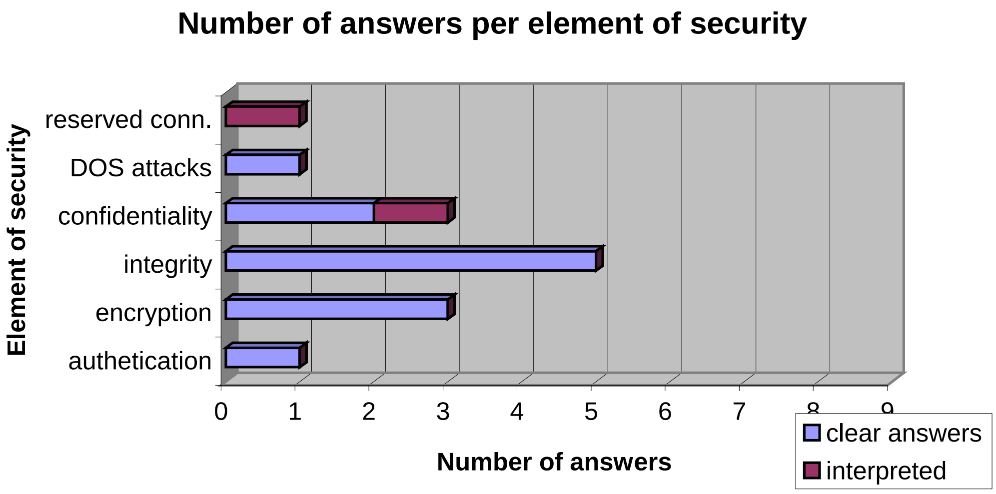

Figure 13. Number of answers per element of security

- Do you wish to limit your network access to other members of your group.

  Ten answers were received. Five positive and five negative.

3.2.6 Interview Conclusions

The aim of these interviews is to determine whether the pan-European groups of user requirements in terms of Quality of Service can be met by one or more "QoS services". Table 14 assigns indicative names.

These classes of service are characterised by the width of the value range for each QoS parameter (one-way-delay, IPDV, packet loss and bandwidth).

QoS service	One-way-delay	ipdv	packet loss	bandwidth
Best effort	wide	wide	medium	wide
IP Premium	medium	short	short	according to SLA
Prioritised Bandwidth	medium	medium	medium	according to SLA
Guaranteed bandwidth	medium	medium	short	single value

Figure 14. First distribution proposal of the characteristics range per class of service

The results of the interviews show that we can reduce the number of QoS services to three, by merging Prioritised Bandwidth and Guaranteed bandwidth services into a new IP+ service.
The interviews also provide indicative values ranges for the QoS parameters. See Annex 1, specifically Q3 and Q13 for further information.

(1)	One-way-delay	IPDV	Packet loss	bandwidth
Best effort	Unspecified	Unspecified	< 5%	Unspecified
IP Premium	distance delay + 50 ms	< 25 ms	negligible	according to SLA
IP+	distance delay +100 ms	<25-50 ms	< 2%	according to SLA

(1) These values are indicative and application specific.

Figure 15. Range of value per class of service and QoS parameters

A tentative mapping of the application mentioned in the interview to the different QoS services yields:

- Streaming, telephony, video-conferencing and general real-time applications can be mapped into IP Premium service.
- Web and FTP can be mainly mapped into IP best effort.
- Remote applications, shared applications and co-operative work dependent on the type of use: IP Premium, IP+ or best effort.

3.3 Quantitative definition of QoS

A complementary approach to the top-down interview with users about their QoS needs is a bottom-up approach to define a minimum and sufficient set of QoS parameters.

As briefly described in chapter 2, IETF ant ITU-T organisations have already defined a list of QoS parameters that can be chosen to quantify QoS services.

The naming and meaning of these QoS parameters will follow IETF IP Performance Metric (IPPM) guidelines and framework [RFC 2330]. The working group is near the end of its mandate. It has produced a set of documents, some of which are now at the RFC stage, some are still in the I-D stage. Although some minor modification are expected, and have to be followed, the global framework which will be used in this deliverable is final.

The IETF approach to the definition and measurements of IP Performance parameters differs from the ITU-T proposal. The two organisations agree on the list of parameters that can be used to gauge the performance of an IP link and, hence, its quality, but they use similar or identical acronyms with slightly different meanings. The two bodies are closing the gaps between them. The more significant difference is that the ITU-T proposal adopts a statistical definition of QoS parameters, while IETF allows for more than one measurements procedure for each parameter. See [CHAED] for more info at the date of December 2000.

For a recent overview of ITU-T status see the slides of a presentation held at last IETF [CIT-ITU] and the revised draft of Y.1541 [Y-1541].

We propose the following list of parameters as the basic set used to quantify any QoS service:

- one-way delay
- one-way packet delay variation,
- capacity
- packet loss

An important parameter that should also be taken into account is the minimum MTU size along the path. The assurance of a large enough MTU value will prevent the occurrence of fragmentation.

In addition to this list, there are some basic requirements to a network behaviour that greatly influence the overall quality of any service. A non exhaustive list is:

- Bit Error Rate;
- Physical and data link layer stability;
- Routing stability;
- Overall network hardware performance;
- Monitoring and time required to solve a problem

All these requirements are supposed to be met in a well-behaved network and in the discussion of QoS implementation at layer three we take this assumption for granted.

3.3.1 One-way delay

Intuitively defined as the time needed by a packet to be transmitted and fully received by the destination. [RFC 2679]. It is the sum of two parts :-

- the time needed by the first bit of the packet to travel from the source to the destination. It is a function of the physical distance, of the number of active and passive equipment crossed along the path and the instantaneous network load.

- the time needed to transmit all the bits of the frame, which is a function of the transmission speed of the line

The first part is defined in RFC 2330 as "propagation time of a link" i.e. "The time, in seconds, required by a single bit to travel from the output port on one Internet host across a single link to another Internet host." RFC 2330 also introduces the concept of "wire-time", to differentiate from host-time. This software can only directly measure the time between when the source host grabs a time stamp just prior to sending the test packet and when the destination host grabs a time stamp just after having received the test packet. We refer to these two points as "host times".

For a given packet P:

- the 'wire arrival time' of packet P at host H on line L is the first time T at which any bit of P has appeared at H's observational position on L.

- For a given packet P, the 'wire exit time' of P at H on L is the first time T at which all the bits of P have appeared at H's observational position on L.

3.3.2 *ipdv - IP Packet Delay Variation.*

A definition of the IP Packet Delay Variation (ipdv) can be given for packets inside a stream of packets [I-D-IPDV]:-

> The IP Packet Delay Variation (ipdv) of a pair of packets within a stream of packets is defined for a selected pair of packets in the stream. Going from measurement point MP1 to measurement point MP2 is the difference between the one-way-delay of the first of the selected packets and the one-way-delay of the second of the selected packets It is a function mainly of queuing in the active equipment crossed along the path or routing redirections.

3.3.3 *Capacity*

Capacity, in this context, is intended as the expected data rate, in bits per second, at the IP level, averaged over an appropriate time, over the path in question. RFC 2330 simply defines bandwidth of a link for packets of size k as the capacity, in bits/second, where only those bits of the IP packet are counted, for packets of size k bytes. The specification of bandwidth requirements may be detailed providing the following parameters - maximum burst size - peak bandwidth - minimum assured bandwidth or committed access rate - average value. The definition of a bandwidth equivalent to a leased line imply peak equal to minimum equal to average and burst size of 1. The word "throughput" is often used as a synonym for capacity. IETF IPPM is working on a draft "A Framework for Defining Empirical Bulk Transfer Capacity Metrics" [I-D-BTC]

3.3.4 Packet loss

The number of packets sent, but not received at the destination or received in errors. It a function of instantaneous network load, equipment configuration is transmission error rate and failure. Its measurement is detailed in RFC 2680 [RFC2680].

3.3.5 MTU

Maximum Transmission Unit, the largest physical packet size, measured in bytes, that a network can transmit. Any messages larger than the MTU are divided into smaller packets before being sent. The larger the MTU, the better the data can flow in principle. A value of 1500 is common due to the ubiquitous use of Ethernet. On WAN a value greater than 1500 is suggested to avoid fragmentation in the case of users employing LAN technologies with large MTU (ATM, FDDI) or protocols that add labels to the datagram.

3.4 QoS Parameters ranges and Values

To uniquely specify a QoS IP service assurance to a selected traffic, a list of requested QoS parameters and their values, or value ranges, is required and sufficient. Not all the services may request a precise value for all the QoS parameters and a relationship exists between packet loss and capacity. It is difficult to guarantee a defined capacity without simultaneously obtaining a null or negligible packet loss.

The table below compares a sample list of range for each parameter, to the values proposed by ITU-T in the draft recommendation document Y.1541. ITU-T defines classes of service, and values are bound in columns, values are reported between parentheses (IETF does not specify values in strict classes).

Some consideration may help in simplifying the table of all possible combination of QoS parameters.

- what is usually named "best effort" service does not correspond to a set of undefined values for all the above listed QoS parameters In general, for a usable best effort service, at least three parameters (delay, capacity and packet loss) should have a bounded maximum value.
- for each parameter the values, when bounded, are restricted on just one direction and can vary arbitrarily on the other. For example, delay should be not larger than the agreed value and ipdv should not exceed the requested value.
- The parameter variation values can be divided in four ranges: single value, short medium and wide, in decreasing order of QoS provisioning.

Single Value represents the "ideal" or minimum lower bound value for the parameter, short, medium and wide range are simply a way to broadly categorise the possible ranges.

(*)	Single value (SV)	Short range (class 0)	Medium (class 1 - interactive)	Wide range (class 2 - non interactive)	(Class 3 - Unspecified)
One-way Delay (a)	Measured value at empty network (baseline)	less than SV + 50 ms (150 ms)	less than SV + 250 ms (400 ms)	less than SV + 10 s (b) (1 s)	(U)
Ipdv (c)	Between 0 and the time needed to transmit one full MTU at line speed	25 ms (50 ms)	50 ms (50 ms)	none (1 s)	(U)
Packet loss (Probability)	null	$< 10^{-4}$ (10^{-3})	$< 10^{-3}$ (10^{-3})	< 0.1 (10^{-3})	(U)
Capacity (speed 64Kb/s) (d)	Fixed value greater than time to transmit one full MTU packet	N/A.	N/A.	A minimum of one full MTU size packet per second	(U)

(a) (*) The instantaneous values of the QoS parameters are supposed not only to comply to the required limitations, but also to vary with time by a negligible quantity. The acceptance of a periodic variation of the values, continuous or discrete like oscillations due to route flapping in delay, is left to the Service Level Agreement and should be avoided. The Single Value is a function of distance and number of hardware boxes traversed. An estimate could be computed using the 'mean' speed of light in cables (~7 □s/Km) and about few hundredths of per hop. Any substantial variation on the baseline value can be due to rerouting and queuing in the network hardware.

(b) Satellite links introduce a very large baseline value that can be considered acceptable or not.

(c) limits on ipdv should be derived from applications. High quality video may have very stringent limits on ipdv. In addition the amount of buffering in the application may allow for larger allowable ipdv. In Y.451 defined as the upper bound on the 1- 10^{-4} quintile of IPTD minus the minimum IPTD

(d) Capacity service level agreements might require very detailed allowed ranges, including minimum guaranteed capacity, burst size, peak size. The values reported here just convey the suggestion that a minimum capacity should be guaranteed. This is not an obligation as shown in the recent proposal for the definition of a less-than-best-effort service.

4 SERVICE CONTRACTS

Service contracts are the key tool to translate a QoS request into a working service on the network. In addition to the need to be precise they should specify, unequivocally, the characteristics of the service requested and form the basis for monitoring and accounting. They are, therefore, a fundamental part of a QoS definition and implementation.

According to the Service Level Specification and Usage (SLSU) Working Group ([TEQ-SLSU]), the provisioning of services over an IP network with an associated level of quality is currently often associated with the negotiation of service contracts between customer and provider. Today, the installation of Service Level Agreements (SLAs) between customers and providers is a rather static and labour intensive task. The procedures involved in this process are proprietary to the provider and, in many cases, these procedures are invoked on a low frequency basis (e.g. when updating a VPN (Virtual Private Network) topology). By its proprietary nature, such a process does not allow for an open service architecture to be built upon an IP network. It should be understood that standardisation of the technical parts of the basic process may allow for a highly developed level of automation and dynamic negotiation of Service Level Specifications (SLSs) between customers and providers. This automation may prove helpful in providing customers (as well as providers) with the technical means for the dynamic provisioning of Quality of Service guaranteed transport services. SEQUIN, in particular, could substantially benefit from the application of such mechanisms over the network infrastructure under consideration, since SLAs and SLSs are essential for delivering the obtained QoS from one end-user to another across multiple domains.

4.1 Definitions

According to [CAD-SLA]:

- A Service Level Agreement (SLA) is a combination of technical and non-technical parameters agreed by a customer and a provider relating to the quality of a ‘service’, when acquiring/selling the service.

- Service Level Specification (SLS) is defined as one of the technical annexes of a SLA, in the DiffSERV domain. An SLS is a set of parameters and their values, which together define the service offered to a traffic stream by a DS domain.

- A Traffic Conditioning Specification (TCS) is an integral element of an SLS. A TCS is a set of parameters and their values, which together specify a set of classifier rules and a traffic profile.

In [MANY-SLS], more SLA-SLS related definitions are provided:

- A Service Level Object (SLO) is a protocol-dependent installation of an SLS, that contains the parameters and the values that describe the transport service which a specified flow is to receive over the transport domain.

- A Transport Service consists of a set of Service Level Objects that should be taken atomically when negotiating a service that pertains to multiple flows at once. (e.g., a bi-directional service). A Transport Service is part of the SLA.

4.2 Existing approaches

This section attempts to briefly present three of the most active initiatives in the European area concerning SLA and SLS architectures. The TEQUILA project and standardisation efforts are presented more thoroughly, since they comprise a substantial part of the relevant research and are required in order to provide an overview of the contents of an SLS. Consequently, the AQUILA project and CADENUS project recommendations are described. At the end of the section, a brief description of the corresponding work within the Internet2 Working Groups is provided.

4.2.1 TEQUILA: Traffic Engineering for Quality of Service in the Internet, at Large Scale (project IST-1999-11253)

The SLS formalism defined by the work of TEQUILA ([TEQ-SLS], [TEQ-D1.1]) allows for making a distinction between qualitative and quantitative SLS:

- SLS depicting qualitative services should yield the specification of relative QoS indicators, such as a low IP datagram loss ratio. From this standpoint, best effort traffic is expected to be qualified by an SLS of that range of qualitative services.

- SLS depicting quantitative services should yield the accurate measurement of QoS indicators, such as e.g., transit delay.

The SLS attributes defined by TEQUILA ([TEQ-SLS], [TEQ-D1.1]) are presented in the following sections.

4.2.1.1 Scope

The scope of an SLS associated to a given service offer indicates where the Quality of Service (QoS) policy for that specific service offer is to be enforced. Therefore the scope uniquely identifies the geographical/topological region over which the QoS is to be enforced by indicating the boundaries of that region.

4.2.1.2 Flow Description

The flow description of an SLS associated to a given service offer indicates for which IP packets the QoS guarantees of that specific service offer are to be enforced. A flow description identifies a stream of IP datagrams sharing at least one common characteristic. An SLS contains one (and only one) flow description, which MAY formally be specified by providing one or more of the following attributes:

flow description = (Differentiated Services information, source information, destination information, application information)

4.2.1.3 Traffic Envelope and Traffic Conformance

The traffic envelope describes the traffic (conformance) characteristics of the IP packet stream identified by the flow description. The traffic envelope is a set of Traffic Conformance Parameters, describing what the packet stream should look like to get the guarantees indicated by the performance parameters (defined in section 4.2.1.6).

The following gives a (non-exhaustive) list of potential conformance parameters:

- Peak rate p (bits per second)
- Token bucket rate r (bits per second)
- Bucket depth b (bytes)
- Maximum Transport Unit (MTU) M (bytes)
- Minimum packet size (bytes)

4.2.1.4 Marking and shaping services prior to Conformance Testing

This sub-section indicates what should happen with packets entering the system prior to conformance testing/traffic conditioning. The semantics is that the network may offer a number of services to its customer, such as shaping or marking, prior to conformance testing. For example, if the host of the customer does not have the ability to mark the DSCP byte, then it could be requested by the SLS.

4.2.1.5 Excess Treatment

This attribute describes how the service provider will process excess traffic, i.e. out-of-profile traffic. The process takes place after Traffic Conformance Testing, described previously. Excess traffic may be dropped, shaped and/or remarked.

4.2.1.6 Performance Parameters

The performance parameters describe the service guarantees offered by the network to the customer for the packet stream described by the Flow Id and across the geographical/topological extent given by the scope. All service guarantees are for the in-profile traffic; no guarantees are given for excess (out-of-profile) packets.

There are four performance parameters:

- delay | optional quantile
- delay variation | optional quantile
- packet loss
- throughput

A performance parameter is said to be quantified if its value is specified to a numeric (quantitative) value. The service guarantee offered by the SLS is said to be quantitative if at least one of the four performance parameters is quantified. If none of the SLS performance parameters are quantified, then Qualitative performance guarantees are given and the performance parameters "delay" and "packet loss" MAY be "qualified".

4.2.1.7 Service Schedule

The service schedule indicates the start and end time of the service, i.e. when is the service available.

4.2.1.8 SLS-subscription & Invocation inter-working

In the TEQUILA system the Customer service (SLS)-handling is composed as follows. The SLS management functional component is responsible for all the Customer-service (SLS)-related activities. Considering the Customer-service handling functional process we may consider three consecutive (sub) processes:

- Customer service (SLS) subscription process resulting in SLS permission or SLS refusal
- Customer service (SLS) invocation process resulting in SLS admission or SLS blocking
- Data transmission

Where multiple domains are involved, TEQUILA does not have a specific definition for SLS-subscription and Invocation inter-working.

4.2.2 AQUILA: Adaptive Resource Control for QoS Using an IP-based Layered Architecture (project IST-1999-10077)

According to [AQU-SLS], the AQUILA consortium complies with the specifications for a standard formal representation of SLS between the customer and the network. This should be very general and capable of expressing all of the possible service offerings based on the DiffSERV model. However, the AQUILA consortium identified the need for a mechanism to simplify the generic description of the SLS by the definition of "predefined SLS types". This need was recognised due to the fact that the DiffSERV network operator has to use the SLS parameters to map the user requirements into internal mechanisms (e.g. DiffSERV QoS classes). The mapping process between the generic SLS and the concrete QoS mechanisms can be very complex if the user is able to freely select and combine the parameters.

According to [AQU-SLS], from the point of view of the applications, a predefined SLS type supports a range of applications that have similar communicative behavior and therefore similar QoS requirements, such as for delay, packet loss, etc. (see also "Globally Well known Services" in [QBONE-B]). From an operator's point of view it simplifies the network management and allows efficient flow aggregation.

For AQUILA, a "predefined SLS type" fixes values (or range of values) for a subset of the parameters in the generic SLS. It may also fix some relationships or dependencies between some parameters. In this way, it represents a "compression" of a SLS template to optionally ease the mapping process inside the network and the negotiation between the customer and the network. The semantic content of the AQUILA SLS is composed of the same attributes as that of the TEQUILA SLS with the addition of the attribute 'SLS type'. The list of predefined SLS types defined in the AQUILA project is:

- PCBR - Premium CBR
- PVBR - Premium VBR
- PMM - Premium MultiMedia
- PMC - Premium Mission Critical

There are, however, certain differences between the actual values of the SLS attributes for TEQUILA and AQUILA (e.g. the values for flow identification).

4.2.3 CADENUS: Creation and Deployment of End-User Services in Premium IP Networks (project IST-1999-1101)

The CADENUS project aims at providing service creation and configuration in a **dynamic** way through the appropriate linking of user related service components (authorisation, registration, etc.) to network related service components (QoS control, accounting, etc.). CADENUS introduces the idea of Dynamic Service Creation (DSC). This enables the provision of a large variety of contacts to end-users. DSC is obtained by communication with several existing IP services' functionalities and components. The latter (firewalls, tunnel terminators, proxy servers, signature management, AAA, application-aware caching, third-party SA provisioning, SMTP relays etc) are defined as the IP Premium layer from CADENUS. Consequently, a layer above the IP Premium is suggested by CADENUS, the Service Creation plane, which is managing entities and resources, negotiations, dynamic creation of SLAs etc.

CADENUS uses SLA templates and service templates during the negotiation phase and envisages at least two different types of dynamic behaviour:

- time-varying user requirements (with different time-scales of time variability induced by specific application characteristics)
- time-varying network conditions (of which the user is made aware via feedback signals raised by the network itself).

4.2.4 Internet2

The QoS Working Group of Internet2 was created in order to produce an interoperable, multi-domain, manageable infrastructure for the delivery of QoS, over an IP DiffSERV network, without compromising the networks flexibility and extensibility. Within the framework of the Qbone Premium Service (QPS) that was defined and operated, the 'Bandwidth Broker' (see also [RFC 2638]) concept was adopted for the purposes of call signalling and automated CAC.

This work resulted in the definition of the "Simple Inter-domain Bandwidth Broker Signalling" protocol (SIBBS). The current status of the SIBBS protocol that defines inter-domain communication between Bandwidth Brokers, is described in [QBONE-B]. This document provides a definition of the SLS as being "not a reservation, but rather a commitment to allow reservations (or a potential for reservations)". A thorough description of this type of SLS is not part of [QBONE-B] and the work of the Internet 2 WG.

However, the actual reservation is carried by SIBBS protocol in the "Resource Allocation Request" (RAR) messages that contain "...the space-time co-ordinates of the service, the kind of service (and possibly parameters of the service) and possibly the characteristics of the input...".
It is worth noting that the "kind of service" parameter in the RARs of SIBBS refers to a "Globally Well-known Service" (GWS) and that the only service currently under consideration is the QPS.

4.3 Comparison of approaches

When trying to compare the TEQUILA, AQUILA and CADENUS approaches to SLAs, the impression is that they are escalating from the 'static', pre-defined SLSs of AQUILA, to the thoroughly specified framework for (individually for each case) SLS creation in TEQUILA and the more dynamic nature of CADENUS, allowing DSC.

When it comes to comparison of the TEQUILA approach to that of the Internet 2 WG, the conclusion is ([TEQ-D1.1]) that the SLS defined by the Internet2 QoS Working Group, targeting EF-based Premium Services, is a special case of TEQUILA's SLS definition below, except for one specific attribute: 'Route'. This attribute is used for inter-domain routing aspects in the QBONE architecture.

Also the content of the RAR messages can be compared to the "invocation SLS" of TEQUILA ([MANY-SLS]) and the "kind of service" parameter in the RARs of SIBBS can be mapped to the ‘predefined SLS types’ of AQUILA.

4.4 Multi-domain SLAs

The support of multi-domain SLAs requires a standardised set of semantics for SLSs being negotiated at different locations ([TEQ-SLS]):

- between the customer and the service provider (namely between the Customer Premises Equipment (CPE) and its point of attachment to the IP network managed by the service provider)
- within an administrative domain (for intra-domain SLS negotiation purposes)
- between administrative domains (for inter-domain negotiation purposes)

The CADENUS approach is attempting to contribute to the support of multi-domain SLAs by defining, initially, the terms of retail and wholesale SLAs [CAD-SLA]. The retail SLA (r-SLA) refers to the agreement between an end-user and a service provider. In the case of multi-domain scenarios, service providers need to create inter-network agreements, defined as wholesale SLAs, in order to support their end-user SLAs. A w-SLA takes into account traffic aggregates flowing from one domain to another. In general, there is no direct connection between r-SLAs and w-SLAs.

Based on the above definitions, two phases in service creation are distinguished (service creation and service provisioning) and two implementation options are defined for both phases ([CAD-SLANC]): data driven (service creation process is triggered by the arrival of a datagram conforming to a contract) and contract driven (upon service creation request). This taxonomy of CADENUS, deals with the implementation of inter-domain SLAs, by suggesting data driven implementations for service creation and service provisioning in the case of w-SLAs.

TEQUILA ([MANY-SLS]), deals with the issue of support of multi-domain SLAs, by assuming the Service negotiation process be composed of a Service Subscription, and a Service Invocation phase. The negotiation of services across the transport domain is allowed to require a recursive level of service (pre) negotiation between the sub-transport domains that make up the overall transport domain. This is denoted as the provider - provider negotiation process.

In [TEQ-D1.1], possible schemes for Inter-domain SLS negotiation are identified:

- Hop-by-Hop SLS negotiation (where a “Hop” is an Autonomous System – AS)
- End-To-End SLS negotiation with eventually pre-establishment of Inter-AS pipes
- Local SLS negotiation (There are no restrictions on the SLS-scope or the SLS-Flow Identification. The customer may send “better-than-best-effort” traffic. He has no guarantees, but is “hoping for the best”)

At a later stage of the TEQUILA project, details on functions related with Inter-domain issues (e.g. BGP4 routing) will be considered. The choice to be made is actually between Hop-by-Hop Inter-Domain SLS negotiation (Hop AS, thus only SLSs with peers) or End-to-End SLS negotiation (SLS contracts with non-peering Autonomous Systems).

4.5 User notification

According to [CAD-SLA], service management in the customer domain, apart from mechanisms to control and set management policies, addresses the need for the customer to have objective mechanisms and, possibly, tools to monitor the SLA delivered by the provider. One view related to the monitoring of service quality is that of (periodic) assessment with the customer of the SLA of the contracted service: this is often done via reports of contractual parameters, or through deployment of customer network management systems which enable the customer to access information about service statistics.

According to [MANY-SLS], an agreed framework should exist to verify that a service installation (based on a SLA) is appropriately enforced, according to the parameters as agreed within the individual SLOs. This framework should anticipate the customers' notification and assurance that the agreed SLA is being honoured. The work of the IP Performance Measurements Working Group of the IETF ([IPPM]), which defines a set of parameters and a set of metrics to measure them, could be used to provide a measurement framework to provide the basis for a detailed service level specification. Open issues-standardisation efforts. Concepts of SLA/SLS/TCS have been promoted through the DiffSERV specification effort, but the actual content of such specifications is currently left to service providers, thus yielding some limitation when using them for contractual purposes between:

- Customers and service providers
- Service providers for services deployed across domains

Customers and providers need to agree on (a set of) well-defined QoS parameters. This should include an agreed methodology to measure these parameters, since QoS policies may differ dramatically from one domain to another. The provisioning of a standard interface between customers and service providers would simplify the subscription procedure and facilitate access to a whole range of information:-

- The administrative information, as depicted in the SLA
- The technical (QoS-related) information, as depicted in the SLS

The need to standardise the specification of QoS Service Level negotiation on interfaces should be met in the following cases [GRADO]:

- Intra-domain interfaces
- Inter-domain interfaces for the customer-provider relationship
- Inter-domain QoS provisioning for the provider-provider relationship

In [SOME-SLS], an attempt has been made to standardise a structure for defining SLSs. In this example, the provider first presents the attributes of the offered service to the customer in the form of a Service Template Specification (STS). The STS carries the provider-specified attributes of the service, instructs the customer which attributes are customer specified and lays some limitations on which values of the latter are acceptable. The customer fills in the parameters needed to complete the service description and sends the request back to the provider as a Service Instance Specification (SIS.)

The design of the SLS in [SOME-SLS] is based on the following principles:

- The SLS should allow for different instantiations in different languages
- The SLS should allow for service negotiations at different levels of complexity, and be compatible with as many different negotiating protocols as possible

- The SLS should NOT standardise services. Vendors and customers should
- The SLS should allow a simple STS or SIS to be represented simply, while being up to the task of representing a STS or SIS based on complex semantics.

In order to facilitate such flexibility, each attribute or unit of the SLS may be optionally tagged with any or all of the following fields:

- Specification: CUSTOMER_SPECIFIED or PROVIDER_SPECIFIED
- Type
- Description
- Values Acceptable

In [SOME-SLS], the information contained in each SLS is structured into the following description units and sub-units:

- Common Unit
    - Customer/Provider/Service instance descriptors
    - Validity sub-unit

- Topology Unit
    - SAP sub-unit
    - Graph sub-unit

- QoS Unit
    - Scope sub-unit
    - Traffic descriptor sub-unit
    - Load descriptor sub-unit
    - QoS parameters sub-unit

- Monitoring Unit
    - Scope sub-unit
    - Reporting parameters sub-unit

4.6 Conclusions

Although the corresponding attempts at standardisation have not yet reached a final stage, it is still possible, based on the current recommendations, to define a simple SLA and SLS framework that could meet the needs of SEQUIN. This framework can be initiated as follows:

- with two main predefined SLS types (one for Premium IP and one for IP+) (as the AQUILA approach describes them)
- with a set of attributes as defined in [TEQ-SLS]- [TEQ-D1.1] and [AQU-SLS]
- with a set of predefined values for each one of these attributes (some work is necessary here, in order to choose between existing approaches or propose new values)
- with the use of the IETF IP Performance Measurements as metrics, the values of which will be presented to the users, as an assurance for the network’s compliance with the current SLA
- with the data driven implementation (see [CAD-SLANC] for more details) of a recursive level of service (pre) negotiation between the sub-transport domains, for inter-domain SLAs’ support

This framework could also be under constant observation and open to all kinds of updates (e.g. the set of predefined values for each one of SLS attributes will be adopted to the outcomes of the SEQUIN tests, so as to reflect the SEQUIN QoS capabilities).

5 QUALITY OF SERVICE DEFINITIONS

In order to fulfil the users' requirement, there are two QoS services which can be defined in addition to Best Effort. These are IP Premium and IP+. These two services should be defined in such a way that they are independent of each other and are capable of assuring at least the values in Figure 15, chapter 3, for the QoS parameters.

For both services the general framework chosen is the Differentiated Services architecture. Its scalability, modularity and the possibility to be implemented in steps of increasing complexity provides a solid ground for the initial development of QoS.

5.1 IP Premium

The IP Premium service is defined such that, for the selected packets, capacity is conserved and, hence, packet loss is zero or negligible, apart from bit error rate and other similar causes. However, that loss is never due to congestion.

IP Premium will require that, for the selected packets, the delay and delay variation along a path is independent of the load of the path and will be very similar to the values obtained at empty network.

The IP Premium Service will provide the users with the equivalent of a leased line.

The IP Premium service is associated to the Expedited Forwarding Per Hop Behavior [I-D rfc2589bis, EFSUPP].

5.2 IP+

The IP+ service is defined to have less rigid guarantees on Delay and Delay variation than IP Premium. IP+ will provide a minimum guaranteed bandwidth between two network nodes. If capacity is available, the IP+ traffic is allowed to use more than the minimum guaranteed.

IP+ is associated to the Assured Forwarding Per Hop Behavior [RFC 2597].

5.3 Multi Domain Extension.

The definition given in the previous paragraph for the IP Premium and IP+ service is valid for a single DiffSERV domain and specifies the behaviour of the domain at each hop for the selected traffic. The implementation of the QoS service on a end-to end scale in the European environment generally implies a traffic that crosses multiple domains.

The following procedures will be adopted to build an end to end QoS service:

- all the domain involved (or at least the traversed sub domain) have to implement the DiffSERV architecture and use the appropriate per hop behaviours
- an interface specification is agreed between the various domain to correctly map EF traffic between DiffSERV boundaries. The interface specification may contain mapping between DSCP values, policing rules, capacity assurances and all the parameters needed to ensure a correct propagation of the service
- The interface should be specified in such a way that the DiffSERV boundary crossing behaves according to the chosen PHB.

5.4 Open issues

For both the IP Premium and the IP+ services, the detailed specification and implementation plan will follow the results of the experimental activity carried out within this project and the TF-NGN task force [TF-NGN]

The main open issues are:

- shaping. The importance of having shaped traffic in input will be subject to extensive testing. In addition to shaping at the boundary of the DiffSERV domain, shaping may be needed in the backbone, in particular for the IP Premium service. An intermediate approach could be to increase the queues depth
- the behaviour of the services when the traffic flows through various different DiffSERV domains adopting the above definition has to be checked for compliance with the requirements
- the values of QoS parameters in an empty network and their variation as a function of load. These values should be considered network dependent and should be assumed as the best performance values that a service might offer.

6 TERMINOLOGY AND ABBREVIATIONS

ATM	Asynchronous Transfer Mode
DSCP	Differentiated Services Code Point
EF PHB	Expedited Forwarding Per Hop Behaviour
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPv4	Internet protocol version 4
IPv6	Internet Protocol version 6
ITU	International Telecommunications Unit
IPDV	IP Packet Delay Variation
IPPM	IP Performance Measurement
LAN	Local Area Network
MPLS	Multi Protocol Label Switching
MTU	Maximum Transfer Unit
NREN	National Research and Educational Network
PDB	Per Domain Behaviour
PHB	Per Hop behaviour
PQ	Priority Queuing
QoS	Quality of Service
RSVP	Resource Reservation Protocol
SIS	Service Instance Specification
SLA	Service Level Agreement
SLO	Service Level Object
SLS	Service Level Specification
STS	Service Template Specification
TCP	Transmission Control protocol
TCS	Traffic Conditioning Specifications
TOS	Type of Service
UDP	User Datagram Protocol

7 REFERENCES

[CHAED] Chahed T., "IP QoS Parameters", private communication to TF-NGN November 2000

[AQU-SLS] S. Salsano, F. Ricciato, M. Winter, G. Eichler, A. Thomas, F. Fuenfstueck, T. Ziegler, C. Brandauer, “Definition and usage of SLSs in the AQUILA consortium”, draft-salsano-aquila-sls-00.txt, Internet Draft, November, 2000

[CAD-SLA] S. P. Romano, M. Esposito, G. Ventre, G. Cortese, “Service Level Agreements for Premium IP Networks”, draft-cadenus-sla-00.txt, Internet Draft, November 2000

[CAD-SLANC] M. Smirnov, “Service Creation in SLA Networks”, draft-cadenus-slan-screation-00.txt, Internet Draft, November 2000

[CIT-ITU] Citkusev L., "ITU update: IP Performance and Availability Objectives and Allocations", talk Given at IETF December 2000

[EFSUPP] Supplemental Information for the New Definition of the EF PHB, draft-ietf-diffserv-ef-supplemental-00.txt February 2001

[GRADO] V. M. Grado, "A Service Provider View Service Level Specs BOF”, IETF 49th meeting, San Diego, CA

[IPPM] “IP Performance Metrics", Working Group Web page, http://www.ietf.org/ html.charters/ippm-charter.html

[I-D-RFC2598bis] An Expedited Forwarding PHB, draft-ietf-diffserv-rfc2598bis-00.txt

[I-D-IPDV] Instantaneous Packet Delay Variation Metric for IPPM http://www.ietf.org/internet-drafts/draft-ietf-ippm-ipdv-07.txt

[I-D-BTC] A Framework for Defining Empirical Bulk Transfer Capacity Metrics (http://www.ietf.org/internet-drafts/draft-ietf-ippm-btc-framework-04.txt)

[MANY-SLS] Y. T'joens, D. Goderis, R. Rajan, S. Salsano, C. Jacquenet, G. Memenios, G. Pavlou, R. Egan, D. Griffin, P. Vanheuven, P. Georgatos, L. Georgiadis, “Service Level Specification and Usage Framework”, draft-manyfolks-sls-framework-00.txt, Internet Draft, October 2000

[QBONE-B] "QBone Bandwidth Broker Architecture”, Work in Progress, http://qbone.internet2.edu/bb/

[RFC 1633] Integrated Services in the Internet Architecture: an Overview. R. Braden, D. Clark, S. Shenker. June 1994.

[RFC 2205] Resource ReSerVation Protocol (RSVP) -- Version 1 Functional Specification. R. Braden, Ed., L. Zhang, S. Berson, S. Herzog, S. Jamin. September 1997.

[RFC 2208] Resource ReSerVation Protocol (RSVP) -- Version 1 Applicability Statement Some Guidelines on Deployment. A. Mankin, Ed., F. Baker, B. Braden, S. Bradner, M. O`Dell, A. Romanow, A. Weinrib, L. Zhang. September 1997.

[RFC 2210] The Use of RSVP with IETF Integrated Services. J. Wroclawski. September 1997.

[RFC 2211] Specification of the Controlled-Load Network Element Service. J. Wroclawski. September 1997.

[RFC 2212] Specification of Guaranteed Quality of Service. S. Shenker, C. Partridge, R. Guerin. September 1997.

[RFC 2330] Framework for IP Performance Metrics. V. Paxson, G. Almes, J. Mahdavi, M. Mathis. May 1998.

[RFC 2474] Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers. K. Nichols, S. Blake, F. Baker, D. Black. December 1998.

[RFC 2475] An Architecture for Differentiated Service. S. Blake, D. Black, M. Carlson, E. Davies, Z. Wang, W. Weiss. December 1998.

[RFC 2597] Assured Forwarding PHB Group. J. Heinanen, F. Baker, W. Weiss, J. Wroclawski. June 1999.

[RFC 2598] An Expedited Forwarding PHB. V. Jacobson, K. Nichols, K. Poduri. June 1999.

[RFC 2638] A Two-bit Differentiated Services Architecture for the Internet. K. Nichols, V. Jacobson, L. Zhang. July 1999. available at ftp://ftp.ee.lbl.gov/parpers/dsarch.pdf)

[RFC 2679] A One-way Delay Metric for IPPM. G. Almes, S. Kalidindi, M. Zekauskas. September 1999.

[RFC 2680] A One-way Packet Loss Metric for IPPM. G. Almes, S. Kalidindi, M. Zekauskas. September 1999.

[RFC 3031] Multiprotocol Label Switching Architecture. E. Rosen, A. Viswanathan, R. Callon. January 2001.

[SOME-SLS] R. Rajan, E. Celenti, S. Dutta, "Service Level Specification for Inter-domain QoS Negotiation", draft-somefolks-sls-00.txt, Internet Draft, November 2000

[TEQ-SLS] D. Goderis, Y. T'joens, C. Jacquenet, G. Memenios, G. Pavlou, R. Egan, D. Griffin, P. Georgatos, L. Georgiadis, P. Vanheuven, "Service Level Specification Semantics and Parameters", draft-tequila-sls-00.txt, Internet Draft, November, 2000

[TEQ-D1.1] D. Goderis, G. Cristallo, Y. T'Joens, P. Georgatsos, L. Georgiadis, C. Duret, J.P. Garbisu, C. Jacquenet, S. v.d. B., P. V. Heuven, D. Giannakopoulos, E. Mykoniati, G. Memenios, H. Asgari, R. Egan, D. Griffin, L. Sacks, C. F. Cavalcanti, A. Liotta, G. Pavlou, I. Andrikopoulos, P. Flegkas, P. Trimintzios, "D1.1: Functional Architecture Definition and Top Level Design", TEQUILA Project "Traffic Engineering for Quality of Service in the Internet, at Large Scale" (IST-1999-11253), 11 September 2000

[TEQ-SLSU] Service Level Specification and Usage (SLSU) WG, http://www.ist-tequila.org/sls.html

[VR1] Victor Reijs - private communication to the TF-NGN mailing list 13 Nov 2000

[Y.1541] ITU Study Group 13, "Revised draft Recommendation Y.1541 'Internet protocol communication service - IP Performance and Availability Objectives and Allocations'", November 2000

ANNEX 1: SEQUIN INTERVIEWS GRID

	Alenia	*Methodis*	**Postgraduate studies**
Q3 Used applications.	Video-conferencing Virtual reality FTP (database)	Video-conferencing (H.323, Mbone tool) FTP and web Co-operative work (BSCW)	Video-conferencing Real streaming IRChat Share application (office)
Q5 Difficulties with present network access.	Bureaucratic Technical problems solved with MBS	Reservation problem too long (and hard) process Need a dynamic establishment with QoS reservations Upgrade from 2 to 5 Mbps problems	/
Q6 Locations you connect to.	DE, IT, FR (+ USA, JP)	Several places in FR and DE	Poland
Q7 All academic sites	No	No, Yes	Yes
Q8 Not connected locations you would like connected.	Yes, but connected with ISDN. (difficulties encountered with local connectivity)	Yes, 3 in FR and 1 in DE.	No
Q9 Current connections.	34Mbps, 155Mbps, the rest is unknown	155Mbps (list not complete)	T1 minimum
Q10 Connectivity outside Europe	/	Japan, Taiwan, US	/
Q11 Connectivity to USA: research or general internet.	NASA (depending of the actual connectivity)	Research and general connectivity	Research and general internet connectivity : 400 Kbps
Q12 QoS qualitative: availability, reliability, response time	- Always available (no more than 1 or 2 min on 30 min) - Reliability: Depending on the application no packet loss during simulation but tolerable for videoconference. - Response time: Application < 50ms Plans for requests known 1 month in advance	QoS represent reliability and availability -Effective loss rate -Delay and delay jitter -available bw -guaranteed for a given period (conference)	Available when performing the classes
Q14 Pay for QoS?	If differentiated service per flow then yes.	- If it means a guaranteed level and if it is simple : yes - probably	Cost much lower than 3 * ISDN (384Kbps)

Q15 Experimental partner.	Maybe	Yes, project already finished	Yes
Q16 QoS requirements.	Cfr Q13	- VPN (dynamically built) - BW guarantees - low loss rate - constant bw	Bw 760Kbps 400 Kbps to US
Q17 Is the current network satisfactory.	Too much bureaucracy for local connectivity	Connections : too long (co-ordination) Impossible to identify the origin of the problem IP over ATM difficult to manage at the end points	/
Q18 Future expectations of the network.	Transparent network Simple to use Debugging network performance	Cfr Q13 and 16 Easy way to set-up connection between two points	/
Q19 End-to-end bandwidth.	2-4Mbps	If the latency is low then 100 Mbps/application. Between 5 and 10Mbps	1Mbps
Q20 BW range.	512k -> 4Mbps	Cfr Q19	1Mbps
Q21 Occasional use of QoS.	Yes, 2weeks, a day, few months	No for IP premium Yes for MBS like (with dynamic reservation) - few hours per week for simulations	4h/day Friday or Saturday
Q23 Change of connectivity configuration	Local connect. 2-3 years, Configuration could change frequently	Yes Once a month	/
Q24 Is the security important ?	Yes	Yes, yes	Yes
Q25 Elements of security.	VPN	Authentication, encryption, PKI Encryption and data integrity	Security of transmission data
Q26 Limit the access to other members of the group.	Yes	Yes and no, no	Yes

	CTI	**MP**	**MECCANO**
Q3 Used applications.	Video-conferencing (H.320, H.323) Application and data sharing NetMeeting Shared 3-D virtual environments	Video-conferencing Remote monitoring, Database access FTP, web Point-to-point telephony Streaming Multi-user interactive multimedia	Audio and video-conferencing Collaborative drawing and text editing
Q5 Difficulties with present network access.	Highly congested during working hours	No Ipv6 native access	Difficult access to Mbone (vendors operability) Multicast routing unstable Multicast routers might be overloaded
Q6 Locations you connect to.	Greece, various European countries, Israel	BE, UK, DE, USA, Japan	Several European countries
Q7 All academic sites	No	No	No
Q8 Not connected locations you would like connected.	No	Basel (CH)	No
Q9 Current connections	Don't know	At least E3, STM-1	Don't know
Q10 Connectivity outside Europe	USA, Israel (both available)	n/a	Canada
Q11 Connectivity to USA: research or general internet.	General internet connectivity	Research only.	Research and general connectivity
Q12 QoS qualitative: availability, reliability, response time	- When requested , although the resources should be available, the request could not be satisfied - Reliability : Errors and losses minimum depending on external events - Response time : User should not notice perceived delays	- Availability: Fast download of web pages Should be there when needed - Reliability: Video flicker-free. Lip-synchronous between audio and video	- Effective loss rate - Delay and jitter (too late = drop) - Available bw guaranteed for a given period.
Q13 QoS quantitative	Dependent on the application (a little bit more bw than requested by the application and less delay and jitter)	Web page download < 1s Unavailability < 10 min/day Voice < 300ms delay for teleconferencing	Delay < 300ms Delay jitter < 100ms Packet loss < 10%

Q14 Pay for QoS ?	- If required and charge was reasonable in relation to the advantages - charging should be used as a measure that regulates QoS request	Yes	Don't know
Q15 Experimental partner.	Yes	Would like to provide a platform with equipment (CISCO, Ericsson, NEC,…)	Project is already finished
Q16 QoS requirements.	Bw, small delays and jitter	40ms single-strip transfer delay to avoid echo	Loss rate < 10%
Q17 Is the current network unsatisfying.	Request process for QoS (bw) is long and cumbersome. Only suitable for use on big events. Administrative actions too numerous.	Only best effort No ipv6 No SLA/SLS based services for experiment	Nice to have standardised tools / procedure to detect possible configuration errors
Q18 Expectation of the network in the future.	2Mbps for video-conferencing	100Mbps 30Mbps	Stable routing Guaranteed bw
Q19 End-to-end bandwidth.	From 400kbps to 2Mbps for 6 participants	2Mbps 30Mbps but less if multicast	64kbps audio 500kbps video Bursty bw for text and graphics multiplied by number of participants
Q20 BW range.	Cfr Q19	4-10 Mbps	See above
Q21 Occasional use of QoS.	Yes, because probably no permanent use.	Yes (strict planning for cost reason)	- 1 hour/week for meetings - additional hour for demos
Q23 Change of connectivity configuration	Once every 2 years	Once a month	Locally, not too frequently
Q24 Is the security important ?	Yes	Yes	Yes
Q25 Elements of security.	Confidentiality	Confidentiality, integrity No one else should use our connectivity	Encryption
Q26 Limit the access to other members of the group.	No	Yes	No

	ILSP	DataGrid	PL Space research center
Q3 Used applications.	Http, FTP	Video-conferencing Remote data, login, database, graphics, CPU FTP and web	www, ftp
Q5 Difficulties with present network access.	- Delay (for web, not enough capacity)	No	/
Q6 Locations you connect to.	US and Europe	IT, FR, UK and several other countries	USA, GE, AU, CH, FR, JP, NL
Q7 All academic sites	No	No	No
Q8 Not connected locations you would like connected.	No	No	Russia, Uzbekistan
Q9 Current connections	No	/	No
Q10 Connectivity outside Europe	US	USA, Japan	USA, Japan, Russia, Uzbekistan
Q11 Connectivity to USA: research or general internet.	/	Research with high BW General internet : lower BW	Research
Q12 QoS qualitative: availability, reliability, response time	Stable network connection available “when I want”	Constant and available connection	24h a day, 7 days a week
Q13 QoS quantitative	Depending of the applications	Various BW limits Reasonable delay and jitter for video-conference	- Packet loss < 5% - guaranteed bw - packet delay < 100ms
Q14 Pay for QoS ?	Yes, if needed	On average, general-purpose service is reasonable.	No
Q15 Experimental partner.	Yes, without investment	Yes	Probably yes, need information
Q16 QoS requirements.	No	In term of BW (34Mbps)	Assurance of service availability and better networks trouble reports
Q17 Is the current network unsatisfying.	/	/	Number of backups links.
Q18 Expectation of the network in the future.	More BW, less delay	Bandwidth	In-interrupt use for real time
Q19 End-to-end bandwidth.	BW needed by the applications	622 Mbps within 3 years and Gigabit after	10Mbps
Q20 BW range.	2Mb	Cfr Q 19 and Q16	no

Q21 Occasional use of QoS.	Yes	For video-conferences	Always or never
Q23 Change of connectivity configuration	Not often	/	Once a year
Q24 Is the security important ?	Yes	Not for the network	Yes
Q25 Elements of security.	Prevent DoS attacks	/	Integrity, general network security
Q26 Limit the access to other members of the group.	No	No	No

	University of Milan
Q3 Used applications.	Video-conferencing FTP, web Remote graphics, CPU database and data
Q5 Difficulties with present network access.	Bandwidth adequate but not abundant
Q6 Locations you connect to.	IT, DE, worldwide
Q7 All academic sites	No
Q8 Not connected locations you would like connected.	Yes
Q9 Current connections	16Mbps
Q10 Connectivity outside Europe	USA, Japan
Q11 Connectivity to USA: research or general internet.	Both
Q12 QoS qualitative: availability, reliability, response time	Constant and available connection
Q13 QoS quantitative	- depending on the applications - jitter and delay for video-conferencing
Q14 Pay for QoS ?	If application required then yes
Q15 Experimental partner.	Yes
Q16 QoS requirements.	- Good video quality - Bw, delay, ipdv guarantees
Q17 Is the current network unsatisfying.	- no satisfactory bw and local environment
Q18 Expectation of the network in the future.	Guarantee on bw, delay and ipdv.
Q19 End-to-end bandwidth.	1Mbps 2-10Mbps Traffic capacity doubles every 6 months Aggregate : Gbps (few years)
Q20 BW range.	See above
Q21 Occasional use of QoS.	Yes at the beginning
Q23 Change of connectivity configuration	Every 6 months
Q24 Is the security important ?	Yes

Q25 Elements of security.	Integrity, privacy, encryption
Q26 Limit the access to other members of the group.	Yes

ANNEX 2: SEQUIN QUESTIONNAIRE

SEQUIN : Questionnaire/Interview Guide

Introduction:

We are carrying out a study into the need for Quality of Service in networking and are approaching a number of pan-European groups of users to understand how they use networks today, what their requirements for Quality of Service are and how these requirements might develop over time.

I would like to discuss with you the way you use networks today.

Q1 Could you describe in general terms the sort of collaborative work your Group does.

Q2 How many people are involved in this project

Q3 What applications, apart from e-mail, do you use as part of your collaboration. (Probe for Video, FTP, Web)

Q4 Are you involved in the development of new applications. (Probe for the type of application and try to describe in qualitative terms)

Q5 If answered yes to Q4, do you encounter difficulties with your present network access, what are the main problems encountered and suggested solutions. (Probe for understanding of present situation)

Section 1 : Geography:

The purpose of this section is to understand the locations that the Groups require access to, their knowledge of the equipment at those locations and their ability to acquire service quality in the different locations.

Q6 Can you tell us what locations you currently connect to. (Probe for countries and cities)

Q7 Are all of the locations academic sites. (Probe for non academic locations)

Q8 Are there locations which are not currently connected that you would like connected. (Probe for countries and cities)

Q9 Do you know what the network connections are at the sites which are currently connected. (Probe for capacity to site, local connections within the sites etc.)

Q10 If no mention has been made of sites outside Europe, ask: Do you have any requirements for connectivity outside Europe. If so, to what countries do you wish to connect. (Probe for names of Regional networks and locations)

Q11 With respect to connectivity to the USA, can you say whether your principal need is to connect to research networks in the USA or for general Internet connectivity.

Section 2 : Qualitative Perception of QoS:

Quality of Service is a very general concept. I would like to try and understand what it means to you as a user.

Q12 In qualitative terms, what do you understand by QoS. (Probe for reliability, availability, response time) I am thinking in terms of:-

- Reliability, which I define as the transmission quality of the connections
- Availability, which I define as the presence or absence of the connection
- Response time, which I define as the time it takes to obtain a reaction to an action

Section 3 : Quantitative Perception of QoS:

Q13 In quantitative terms, what do you understand by QoS. I am thinking in terms of numerical definition of Quality of Service. (Probe for throughput, latency, packet delay variation [jitter], packet loss)

Q14 Do you think that QoS should cost more than normal service. If a premium was to be charged for QoS, would you be in a position to pay for it.

Q15 We plan to organise a pilot activity in respect of QoS as part of this project. Would you be interested in being an experimental partner in such a project.

Q16 Are there particular requirements that you have today in respect of QoS.
(Probe for specific values)

Q17 Can you provide hints on why, in your opinion, the present network does not satisfy these requirements.

Section 4 : Network Options:

The purpose of this section is to explore what could be offered to user groups and to understand whether it meets the overall requirements of groups of users. It deals with issues such as flexibility of configuration, cost, performance etc.

Q18 Do you have a view of what you would expect from your network in the future.

Q19 Concerning bandwidth, what is the typical bandwidth that you would like to see delivered end-to-end.

Q20 Do you have a view of the range of bandwidth that you would require to support a typical application which you use.

Q21 Would an occasional use service for QoS be of interest to you. (Probe for how frequently service would be required in terms of hours per day. Specify weekdays etc.)

Q22 Do you envisage that the provision of QoS would enable you to use new applications internationally. (Probe for applications by name and by type of network requirement)

Q23 How frequently do you expect to change the configuration of your connectivity.

Q24 Is security an important element for you.

Q25 If Yes to Q24, what elements of security do you regard as important.
(Probe for encryption, data integrity)

Q26 Do you wish to limit the network access that you have to other members of your group.