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# Quality of Service over Specific Link Layers

*State of the Art Report*

Summary

The Integrated Services concept is proposed as an enhancement to the current Internet architecture, to provide a better Quality of Service (QoS) than that provided by the traditional Best-Effort service. The features of the Integrated Services are explained in this report. To support Integrated Services, certain requirements are posed on the underlying link layer. These requirements are studied by the Integrated Services over Specific Link Layers (ISSLL) IETF working group. The status of this ongoing research is reported in this document. To be more specific, the solutions to provide Integrated Services over ATM, IEEE 802 LAN technologies and low-bitrate links are evaluated in detail. The ISSLL working group has not yet studied the requirements, that are posed on the underlying link layer, when this link layer is wireless. Therefore, this state of the art report is extended with an identification of the requirements that are posed on the underlying wireless link, to provide differentiated Quality of Service.

# Contents

# 1 Abbreviations

| | |
|---|---|
| ABR | Available BitRate |
| AC | Admission Control |
| AF | Assured Forwarding |
| BA | Bandwidth Allocation |
| BB | Bandwidth Broker |
| BE | Best Effort |
| BM | Bandwidth Manager |
| CAC | Call Admission Control |
| CB | Class Based |
| CBR | Constant BitRate |
| CDVT | Cell Delay Variation Tolerance |
| CER | Cell Error Ratio |
| CLR | Cell Loss Ratio |
| CMR | Cell Mis-insertion Rate |
| CTD | Cell Transfer Delay |
| DS | Differentiated Services |
| DSBM | Designated Subnet Bandwidth Manager |
| EF | Expedited Forwarding |
| EFCI | Explicit Forward Congestion Indication |
| FDDI | Fiber Distributed Data Interface |
| FF | Fixed Filter |
| FRM | Fast Resource Management |
| GCRA | Generic Cell Rate Algorithm |
| GS | Guaranteed Service |
| IETF | Internet Engineering Task Force |
| IS | Integrated Services |
| ISSLL | Integrated Services over Specific Link Layers |
| LANE | LAN Emulation |
| LDP | Label Distribution Protocol |
| LER | Label Edge Node |
| LIB | Label Information Base |
| LIS | Logical IP Subnet |
| LIJ | Leaf Initiated Join |
| LSP | Label Switched Path |
| LSR | Label Switching Node |
| MARS | Multicast Address Resolution Server |
| MBS | Maximum Burst Size |

| | |
|---|---|
| MCR | Minimum Cell Rate |
| MPLS | Multi-Protocol Label Switching |
| MPOA | Multi-Protocol Over ATM |
| MTU | Maximum Transmission Unit |
| NHLFE | Next Hop Label Forwarding Entry |
| NMS | Network Management System |
| NNI | Network Network Interface |
| NPC | Network Parameter Control |
| nrt-VBR | non real-time Variable BitRate |
| OPWA | One Pass With Advertising |
| OSPF | Open Shortest Path First |
| PC | Policy Control |
| PHB | Per-Hop-Behavior |
| PHOP | Previous HOP |
| PNNI | Private Network Network Interface |
| PPP | Point-to-Point Protocol |
| PT | Payload Type |
| PVC | Permanent Virtual Connection |
| QoS | Quality of Service |
| RSVP | Resource reSerVation Protocol |
| RM | Requester Module |
| rt-VBR | real-time Variable BitRate |
| SBM | Subnet Bandwidth Manager |
| SCR | Sustained Cell Rate |
| SE | Shared Explicit |
| SECBR | Severely Errored Cell Block Ratio |
| SLA | Service Level Agreement |
| SNMP | Simple Network Management Protocol |
| ST2 | Internet Stream Protocol Version 2 |
| SVC | Switched Virtual Connection |
| TTL | Time To Live |
| UBR | Unspecified BitRate |
| UNI | User Network Interface |
| UPC | Usage Parameter Control |
| VC | Virtual Connection |
| VPN | Virtual Private Network |
| WF | Wildcard Filter |
| WFQ | Weighted Fair Queueing |
| WRED | Weighted Random Early Detection |

## 2 Introduction

The Integrated Services concept is proposed as an enhancement to the current Internet architecture, to provide a better Quality of Service (QoS) than that provided by the traditional Best-Effort service. The Integrated Service (IS) architecture defines new services offered at the network layer. Currently two IS services are defined: Guaranteed Service and Controlled-Load Service. To support Integrated Services, certain requirements are posed on the underlying link layer. These requirements are studied by the Integrated Services over Specific Link Layers (ISSLL) IETF working group.

This report gives an overview of the status of ongoing research to provide Integrated Services in the Internet. First the Integrated Services features are explained in Chapter 3. Next the status of the work of the ISSLL working group is reported in Chapter 2. The solutions to provide Integrated Services over ATM, IEEE 802 LAN technologies and low-bitrate links are evaluated in detail.

The ISSLL working group has not yet studied the requirements that are posed on the underlying link layer, when this link layer is wireless. Therefore this state of the art report is extended with an identification of the requirements that are posed on the underlying wireless link, to provide differentiated Quality of Service. These requirements are presented in Chapter 5. The requirements are not limited to the Integrated Services point of view. Other approaches to provide differentiated services are taken into account, such as Differentiated Services and the Multi-Protocol Label Switching.

It is explicitly noted that the solutions presented in this document are not the ideas of the author, but merely an overview of existing work is presented, appropriate references are provided. In the following text it is assumed that the reader is familiar with the TCP/IP protocol suite.

# 3 Integrated Services

## 3.1 Introduction

There are two main purposes for the introduction of Integrated Services (IS) in the Internet. First Integrated Services enables the support of real-time services such as voice and video (as explained in more detail below). Secondly, the Integrated Service provides control over network resources to operators, also referred to as controlled link-sharing.

The service traditionally provided by the Internet is often referred to as Best Effort (BE). This service makes a reasonable attempt to deliver packets from source to destination, as fast as possible. However, packets may suffer from loss, delay, delay variation (also referred to as jitter), duplication and re-ordering. The traditional BE service does not provide Quality of Service (QoS) guarantees, necessary to support emerging new real-time applications. The traditional BE service treats each packet equally, and during periods of congestion packets may be delayed, dropped or re-ordered. Therefore the Internet service architecture is extended with an architecture, referred to as 'Integrated Services', that can provide the QoS requirements of real-time services [RFC1633]. This extended architecture is mainly concerned with the one-way packet delay. Real-time applications that employ a play-back buffer require the data to arrive before the 'play-back' point. This places certain requirements on the delay variation. In addition, interactive real-time applications require a sufficiently low average delay to make them useful. It should be noted that this new architecture is designed from the offset to support multi-cast applications.

To provide a service quality better than BE, resources are reserved within the Internet, which is explained in Section 3.2. Resource reservation is done with the Resource reSerVation Protocol (RSVP), which is discussed in Section 3.3. The Integrated Service provides two different services: Guaranteed Service [RFC2212] and Controlled-Load Service [RFC2211] explained in Sections 3.4 and 3.5 respectively. Finally the limitations of the Integrated Services concept are discussed in Section 3.6.

## 3.2 Resource reservation

To provide a Quality of Service, better than that provided by Best Effort service, resources are explicitly reserved within the network. This resource reservation is installed in the network through a signalling protocol. The Resource reSerVation Protocol (RSVP) [RFC2205], [RFC2210], [WHITE97], [ZHANG93] is explicitly designed to fulfil this task, but other signalling protocols could be used as well. The main task of RSVP is to install ‘Reservation State’ in the intermediate nodes between the end-systems. Traditionally, state information has only to be maintained in the end-systems. This shift poses limitations to the Integrated Service (IS) concept which are discussed in Section 3.6. To align this resource reservation better with the connectionless robustness of IP, this state information is maintained through so-called soft states. With soft state, the state information is periodically refreshed through exchange of signalling messages. When these periodic refreshments are not received, the state information is automatically deleted.

An important unit of IS architecture is a flow. A flow is the unit, for which resources are reserved in the network, and which can be identified uniquely (by the unicast or multicast source and destination address and protocol identifier (port numbers are optional)[1]). A flow is unidirectional, i.e. to provide duplex QoS communication, resources need to be reserved for each direction separately. Flows are the granularity for which QoS commitments are provided within the Integrated Service architecture.

[1] In case of IPv6 the flow label could be used for classification.

To explain the IS service operation in more detail, an example is depicted in Figure 1. In this example there is a source A, which transmits a video signal to receivers B, C and D. In this example IP multicasting is used to transmit efficiently to a group of receivers. To receive an improved QoS, better than BE, a resource reservation is made along the multicast tree (dark lines). It should be noted that the resource reservation is uni-directional. To establish duplex reservations, two separate reservations must be made.

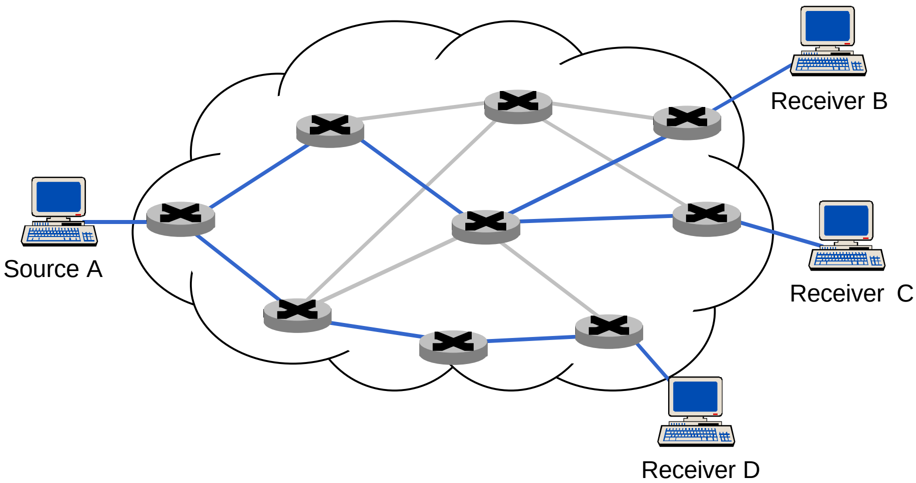



*Figure 1 RSVP example.*

The resource reservation is initiated by the periodic transmission of so-called Path messages, by the source to all receivers. This Path message is routed as any normal IP packet from source to destination. In this case multicast routing is applied. With the Path message, the source identifies itself to the receivers. The Path message does not contain the actual resource reservation request. The Path message contains a specification of the traffic characteristics of the source, and while travelling from source to destination, collects information of the path, which is of interest to the receivers. The receivers use this information to make an appropriate reservation. Note that Path messages are duplicated at branch points in the distribution tree[2].

Upon receipt of the Path message by the receiver, the receiver may decide to reserve resources for this traffic flow, based on the information (source traffic and path characteristics) contained in the Path message. The receiver starts transmitting periodically so-called Resv messages towards the source. This Resv message contains the request, to reserve resource along the path towards the source. It is important that the Resv message follows the same path as the Path message has, and because routing in the Internet is not necessarily symmetric, normal routing cannot be applied to route the Resv message towards the source. To facilitate this requirement, the Path message has installed so-called reserve path routing state in the intermediate routers, while it travelled toward the receiver. This information is used to route Resv messages back towards the source.

While the Resv is transmitted from receiver to the source, resources are reserved at the intermediate routers. Both the Path and the Resv messages need to be transmitted periodically (default every 30 seconds) to maintain the Reservation State in the network. The network reservation is installed through so-called soft-state i.e. when the transmission of either Path or Resv messages is stopped, the resource

[2] The Adspec of the outgoing Path messages may be different dependent on the outgoing link characteristics.

reservation is automatically deleted[3]. This soft-state provides some of the traditional robustness of the Internet.

When a link fails along the path of the flow, the normal routing protocol will route the Path messages along a new path. This will install new reserve routing state for Resv message and eventually a new resource reservation will be made along the new path.

The Integrated Services concept makes use of the existing IP routing functionality in the network. Both the RSVP signalling messages, and the QoS data follow the same route, as normal BE traffic would. Furthermore the Integrated Services / RSVP works equally well with IPv4 and IPv6[4].

<u>Token bucket</u>

The source traffic characteristics are specified in the TSpec (contained in the Path message), which uses a so-called token bucket specification. A token bucket source specification is exemplified in Figure 2.

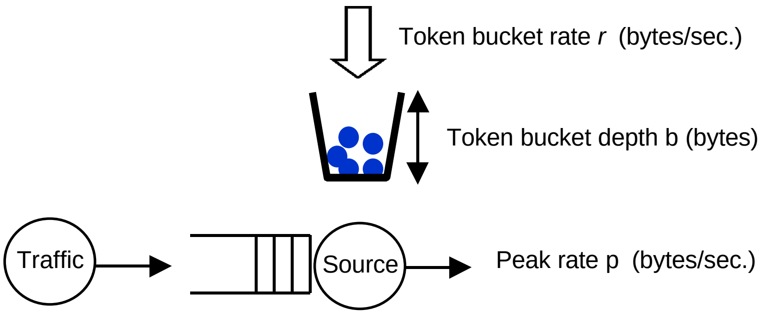



*Figure 2 Token bucket traffic description.*

A source is allowed to transmit data as long as tokens are in the bucket. When there are no tokens in the bucket, the source is not allowed to transmit data. The transmission rate is limited by the maximum peak rate. When data is transmitted, the associated amount of tokens is removed from the bucket. The bucket is filled at a constant rate with tokens, until it is full. The token bucket size allows the source to transmit data in a bursty way.

The specification, of the source traffic characteristics, is an essential element for determining the amount of network resources that are required to meet the QoS requirements.

<u>Policing and shaping</u>

Based on the source traffic characteristics and the QoS requirements, sufficient resources are reserved in the network. During the lifetime of the session, the source traffic is monitored to conform to the traffic characteristics, as specified in the TSpec. Policing is the function that performs this task. The main purpose for policing is that non-conformant traffic does not adversely affect other conforming traffic

[3] Pathtear and Resvtear messages may be used to explicitly delete the resource reservation (compared to the implicit soft-state release).
[4] The flow label may be used for classification purposes.

flows, or normal BE traffic.

When a packet in a flow is found non-conformant the following actions can be taken:

- Discard
- Treat as Best Effort or worse[5]
- Mark traffic as non-conformant, which enables non-conformant traffic to receive different treatment at subsequent routers.

Policing should be done at least at the source node, and possibly at other nodes.

Shaping is the function that delays packets of a flow, such that the traffic flow conforms to the TSpec. Reshaping is possibly needed at so-called branch and merge points in the distribution tree, as depicted in Figure 3.

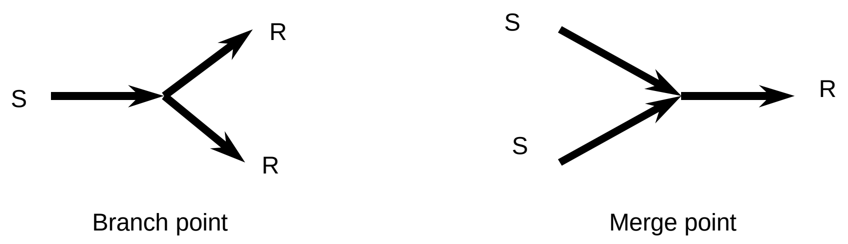



*Figure 3 Branch and merge points.*

At branch points the reservation on one of the outgoing links may be smaller than the reservation on the incoming link (e.g. low bitrate branch). At merge points the sum of the incoming reservations may be greater than the outgoing reservation (e.g. in case of shared reservation styles).

<u>Router architecture</u>

There are four main components, needed to provide 'Integrated Services' within a router: Packet Classifier, Packet Scheduler, Admission Control and Policy Control as depicted in Figure 4.

[5] When packets of the same flow are put in different queues, the order of the packets may be affected. When packets are reordered this may have an adverse affect on the performance of higher layer protocols such as TCP.

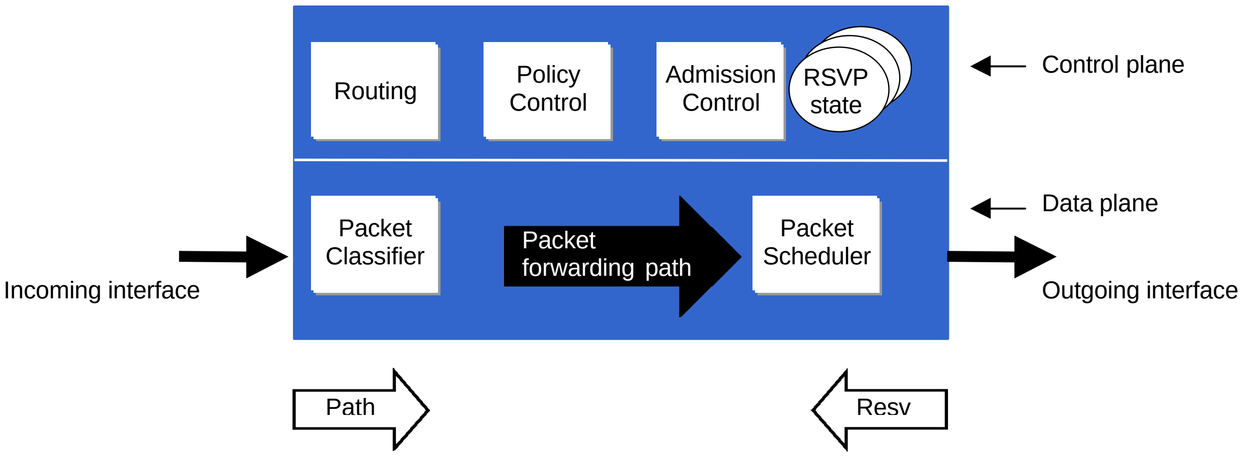



*Figure 4 RSVP capable node architecture.*

Data plane

The Packet Classifier identifies those packets of the incoming stream, which are elected to receive preferential treatment. Classification allows the identification of traffic flows. Dependent on the classification result, the incoming packet is scheduled for a particular treatment carried out by the Packet Scheduler.

The Packet Scheduler actually executes this treatment when managing one or more output queues, to transmit packets on the outgoing interface[6]. The scheduling technique is vendor dependent. Different scheduling mechanisms can be selected such as Class Based queueing (CB) [FLOYD95], Weighted Fair Queueing (WFQ) [ZHANG95] or Weighted Random Early Detection (WRED) [FLOYD93].

Control plane

The Routing block illustrates the normal routing functionality found in IP routers. This block is not Integrated Services specific, but is depicted for completeness.

The Policy Control (PC) entity either accepts or rejects the resource request dependent on the implemented policy. The policy control entity offers the operator the ability to enforce certain constraints on the resource distribution.

The Admission Control (AC) entity either accepts or rejects the resource requests, dependent on the available resources. In this way AC provides a means to control the load of QoS flows, which is crucial to provide QoS guarantees.

The RSVP State registers the state information of the RSVP sessions currently active.

## 3.3 RSVP messages

In this section the Resource reSerVation Protocol (RSVP) messages are discussed in more detail. The reader who is only interested in an overview may skip this section.

[6] It should be noted that large Best Effort packets delay higher priority traffic when no pre-emptive scheduling is applied.

The information elements contained in the Path and Resv messages are listed in Table 1.

| **Path** | **Resv** |
|---|---|
| Source traffic characteristics (TSpec) | Reservation specification (RSpec) |
| Sender template | Reservation style |
| End-to-end path characteristics (Adspec) | Filterspec[7] (= Sender template) |
| IP address of the previous RSVP-capable node (PHOP) | TSpec |
| | ResvConf |
| | Service Class |

*Table 1 Resv and Path message elements.*

The sender template is also referred to as filterspec. The sender template is used to classify incoming packets to a router. The sender template contains the sender IP address and the sender port number.

Reverse routing state is installed in the network, while the Path message travels from source to destination. This information is carried in the PHOP element of the Path message.

The reservation styles refer to the way in which the RSVP resources are shared among multiple sources within a single RSVP session:

- Fixed Filter (FF): there is a single source associated with the resource reservation.
- Shared Explicit (SE): there are multiple sources, explicitly identified, which may use the resource reservation.
- Wildcard Filter (WF): any source of the RSVP session may use the resource reservation.

Dependent on the reservation filter selected, the incoming Resv messages are merged and transmitted to upstream nodes in the distribution tree. For further detail see [WHITE97].

An RSVP session is defined by the destination triple: destination address, transport layer protocol type and optional a port number [RFC2205]. Each RSVP message (e.g. Path and Resv) includes an identification to which RSVP session it applies. An RSVP session may consist of multiple traffic flows, i.e. end-to-end application traffic. Note that there is only one source per flow.

A Resv message also contains a TSpec, which generally equals the TSpec specified by the source. However, the Maximum datagram size $M_{Receiver}$ is set to min($M_{Sender}$, pathMTU). Furthermore the TSpec of the receiver may be smaller than the TSpec of the source to support receiver heterogeneity i.e. a receiver may decide to receive only part of the source traffic stream e.g. low quality service.

Acknowledgement of a resource reservation request can be requested by the ResvConf element. The node accepting the reservation request, at which the propagation of the Resv message ends up the

[7] Omitted in case of Wild Card reservation filter.

distribution tree, should return a ResvConf message to the receiver.

The type of service requested is indicated by the Service Class. Two types of services are defined until now: Guaranteed Service and Controlled-Load Service.

The TSpec, RSpec and Service Class, contained in the Resv message, is also referred to as Flowspec.

It should be noted that both the Path and Resv message might carry additional objects. Two important objects are mentioned here. The Policy object may be used to distribute the policy information and the Integrity object may be used to carry security information.

The traffic parameters of the TSpec are listed in Table 2.

| **TSpec** | **Denoted as** | **Unit** |
|---|---|---|
| Peak rate | $p$ | bytes/sec. |
| Bucket depth | $b$ | bytes |
| Token bucket rate | $r$ | bytes/sec. |
| Minimum policed unit | $m$ | bytes |
| Maximum datagram size | $M$ | bytes |

*Table 2 TSpec parameters.*

The parameters of the RSpec are listed in Table 3.

| **RSpec** | **Denoted as** | **Unit** |
|---|---|---|
| Bandwidth | $R$ | bytes/sec. |
| Slack term | $S$ | milliseconds |

*Table 3 RSpec parameters.*

The RSpec is used for the Guaranteed Service only. The Controlled-Load service Resv message does not contain an RSpec. The Resv messages contains a Bandwidth R and a Slack term S. The Bandwidth requirement R specifies the amount of resources needed. The Slack term S is explained in Section 3.4 (see Figure 6). It should be noted that no buffer space requirement is included in the RSpec. Each network element is expected to derive the required buffer space, to ensure no queueing loss, from the TSpec, the RSpec, the Adspec, combined with internal information about how the element manages its traffic.

The end-to-end path characteristics are listed in the Adspec. The Adspec contains a Default General Parameters element and a Guaranteed or Controlled-Load service fragment. The elements contained in the Default General Parameters are listed in Table 4.

| Default General Parameters | Meaning | Unit |
|---|---|---|
| Minimum Path Latency | The sum of the individual link latencies excluding queueing delays | ms |
| Available Path Bandwidth (APB) | The minimum bandwidth of the individual links | bytes/sec |
| Global break bit | Identifying non-RSVP capable intermediate nodes along the path | boolean |
| Integrated Service (IS) hop count | Number of IS capable nodes along the path | integer |
| Path MTU | Minimum of the individual link MTUs | bytes |

*Table 4 Adspec Default General Parameters.*

The Guaranteed Service fragment contains the following elements:

- Error terms $C_{tot}$, $D_{tot}$, $C_{sum}$ and $D_{sum}$ expressing the rate dependent (*C*) and rate independent (*D*) deviations, from the ideal fluid model [PAREKH93], upon which the delay guarantee calculation is based. The 'total' error terms express the end-to-end error term. The 'sum' error terms express the error term until the last reshaping point. The error terms 'sum' are needed to calculate the local buffer requirements.

- Guaranteed Service Break bit expressing the explicit support of the Guaranteed Service by the intermediate nodes along the path.

- Guaranteed Service General Parameters Headers/Values. This element is optional and may override any value specified by the Default General Parameters.

The Controlled-Load Service fragment contains the following elements:

- Controlled-Load Service break bit expressing the explicit support of the Controlled-Load Service by the intermediate nodes along the path.

- Controlled-Load General Parameters Headers/Values. This element is optional and may override any value specified by the Default General Parameters.

Further details concerning the RSVP processing rules can be found in [RFC2209] and [RFC2215].

## 3.4 Guaranteed Service

The Guaranteed Service is suitable for applications that require quantitative QoS guarantees. The Guaranteed Service provides the following QoS guarantees:

- assured level of bandwidth

- maximum end-to-end delay

- no packet loss

The end-to-end delay guarantee is provided based on the resource reservation in the network. The required bandwidth is based on a (perfect) fluid model. The receiver computes the bandwidth *R*, to be reserved, based on the delay requirement *D* (e.g. specified by the receivers application) and the information received in the TSpec (*r, b, p,* min(*M, pathMTU*)) and Adspec (minimum path latency, available path bandwidth, $C_{tot}$, $D_{tot}$), as depicted in Figure 5.

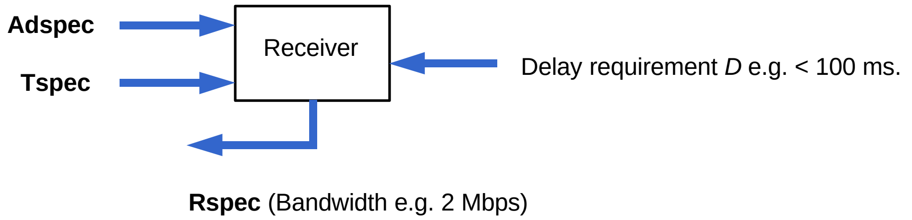



*Figure 5 Bandwidth reservation for Guaranteed Service.*

First the minimum path latency is subtracted from the required delay *D*. Next the required bandwidth is computed based on the ideal fluid model. According to the fluid model and taking into account the deviations from this ideal model ($C_{tot}$, $D_{tot}$ and *M*), the relation between delay *D* and the bandwidth *R* is given by [RFC2212]:

$$D = \begin{cases} \dfrac{(b-M)(p-R)}{R(p-r)} + \dfrac{(M+C_{tot})}{R} + D_{tot} & p > R \geq r \\ \dfrac{(M+C_{tot})}{R} + D_{tot} & R \geq p \geq r \end{cases} \qquad (1)$$

The required bandwidth *R* is not allowed to exceed the available path bandwidth specified in the Adspec.

The resource reservation request is specified in both a bandwidth *R* (bytes/sec.) and a slack term *S* (msec.). The slack term allows a router to provide less resource than the specified bandwidth, while the delay requirements are still met. This is exemplified in Figure 6.

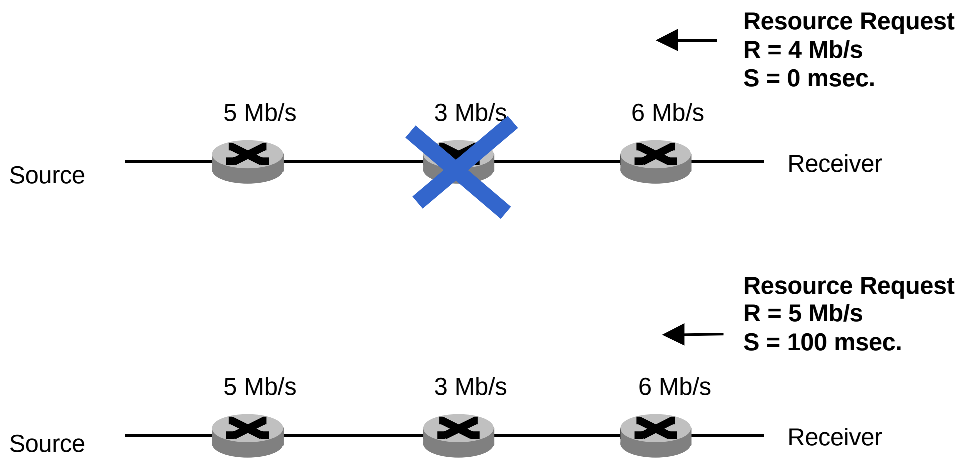



*Figure 6 Slack term example.*

In Figure 6, the middle router is not able to provide the 4 Mb/sec. bandwidth. Therefore the initial resource request, with slack term zero, is rejected. However, the middle router is able to provide 3 Mb/s, provided that there is enough slack, to meet the end-to-end delay requirement. The middle router reduces the slack term appropriately before it transmits the Resv message upstream to the source.

It is possible that there are some non-RSVP capable routers in the end-to-end path, as depicted in Figure 7.

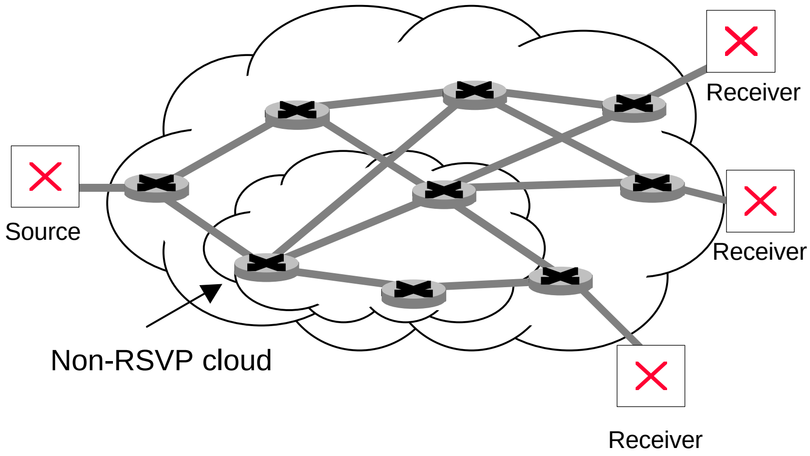



*Figure 7 Non-RSVP cloud example.*

The RSVP Path and Resv messages are transparently transferred across this cloud. However, no QoS guarantees can be provided when the end-to-end path is hit by a non-RSVP capable cloud. The existence of non-RSVP capable routers along the path is indicated by the global break bit.

## 3.5 Controlled-Load Service

The Controlled-Load Service is suitable to support adaptive real-time applications. These applications do not require the stringent QoS guarantees, as provided by the Guaranteed Service, but are tolerant to a limited amount of QoS degradation. The Controlled-Load Service does not provide explicit QoS guarantees, but aims to provide QoS as experienced by a Best-Effort service in a lightly loaded network. No explicit resources are reserved within the network, as with the Guaranteed Service.

## 3.6 Limitations of Integrated Services

Currently there are many router vendors that provide Integrated Services support. However, there are severe limitations to this architecture, which make the future of it uncertain. These limitations are discussed in [RFC2208].

The most important limitation is the scalability of the Integrated Services concept. In networks with a high number of RSVP flows, the state information stored, at the intermediate routers, gets large. Especially deployment of high-speed links, with many small RSVP reservations, may be very processing and storage consuming. Furthermore packet classification and scheduling may add additional performance penalties concerning router performance. Therefore it is not recommended to implement IS service capabilities in the high-speed backbone Internet [RFC2208].

Another limitation may arise from the absence of a key infrastructure that is needed to protect against denial of service attacks. RSVP hop-by-hop authentication can protect against denial of service, but requires the distribution of keys to be used by the MD5 checksum, carried in the Integrity Object. Not only RSVP may benefit from a key infrastructure, but also the security of IP routing (e.g. Mobile IP) is improved substantially with a general key infrastructure deployment.

The RSVP protocol allows the transmission of Policy Objects to distribute policy information. However, the content of these objects is not specified i.e. the actual policy is vendor dependent. Care should be taken when assuming that a consistent policy is implemented among different vendors.

The Integrated Services concept poses serious requirements on routers such as to implement multi-field packet classification, admission control, packet scheduling and RSVP signalling processing. These enhancements come with a cost in router complexity, throughput and storage requirements.

# 4 Integrated Services over Specific Link Layers

## 4.1 Introduction

The Integrated Services (IS) architecture enhances the Internet architecture to support real-time services. In the end-to-end path, between the IS hosts, different layer 2 technologies may be used. The Integrated Service over Specific Link Layers (ISSLL) Working Group of the Internet Engineering Task Force (IETF) specifies protocols and defines architectures, needed to support Integrated Service capabilities over specific layer 2 technologies. In this chapter an overview of the current research in this area is provided.

First the issues to provide Integrated Services over ATM are evaluated in Section 4.2. It is assumed that the reader is familiar with ATM. Next the solution to support Integrated Services in IEEE 802-style networks, such as Ethernet, FDDI and token ring, is presented in Section 4.2.5. Finally slow speed link are discussed briefly in Section 4.4.

## 4.2 ATM

### 4.2.1 Introduction

An example of an end-to-end RSVP connection, which uses an intermediate ATM network, is depicted in Figure 8.

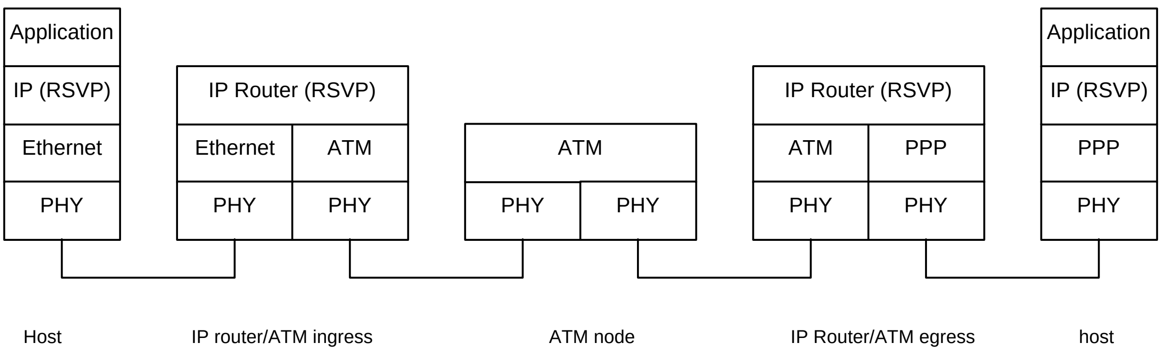



*Figure 8 Layer 2 configurations.*

The ATM technology provides the ability to establish point-to-point and point-to-multipoint Virtual Connections (VC) with a specified QoS. The Integrated Service architecture provides the ability to enhance the traditional Best Effort (BE) service with QoS services. An obvious approach is to evaluate how the ATM QoS capabilities can be used to provide Integrated Services. To provide some background information, the traditional IP over ATM solutions are briefly discussed next.

Part of the problem to provide Integrated Service over an ATM network has been solved with 'Classical IP over ATM' [RFC2225], which provides a solution to run IP Best Effort service over an ATM sublayer. For this purpose a Logical IP Subnet (LIS) is defined. A LIS is a group of IP hosts sharing a common IP subnet address and who communicate with each other directly using ATM connections. Communication between hosts on different LISs must traverse at least one IP router. The classical IP over ATM model limits ATM to intra-subnet connectivity. The ATM forum has provided similar methods to provide IP over ATM with the Multi-Protocol Over ATM (MPOA) [AF97] and LAN Emulation (LANE) [AF95].

The IP to ATM address resolution is performed by the ATMARP service. Each host is configured with the ATM address of the ATMARP server of that LIS. Each host on the LIS registers with the ATMARP server, by associating its IP address with an ATM address.

Furthermore the IP multicast over ATM has been solved with the Multicast Address Resolution Server (MARS) [RFC2022], which allows the resolution of an IP group address into a list of ATM addresses constituting the group members. Normally the root of the multi-cast tree is responsible for setting up new branches and removing branches. This poses a severe burden on the root processing capacity. With the Leaf Initiated Join (LIJ), specified by the UNI signalling 4.0 specification [AF96a], an end-system is able to join the multi-cast tree without contacting the root.

To provide Integrated Services (IS) over ATM, two main issues need to be addressed: mapping of IS services to ATM services, and mapping of IS flows to ATM Virtual Connections (VC) i.e. VC management. These issues are discussed in Sections 4.2.3 and 4.2.4 respectively. Before these issues are considered, the ATM QoS architecture is evaluated in Section 4.2.2.

### 4.2.2 ATM QoS architecture

The ATM Forum UNI signalling 4.0 [AF96a] and Traffic Management 4.0 [AF96b] provide the most elaborate ATM QoS capabilities. These specifications are the basis of the following evaluation.

#### 4.2.2.1 ATM services

ATM services provide the highest level of abstraction to identify Virtual Connections (VC) characteristics. ATM service characteristics were introduced with the UNI and Traffic Management 4.0 specifications [AF96a], [AF96b]. ATM provides five different services, which can be categorised according to Figure 9. Previously the Broadband Bearer capabilities were used to discriminate at this level.

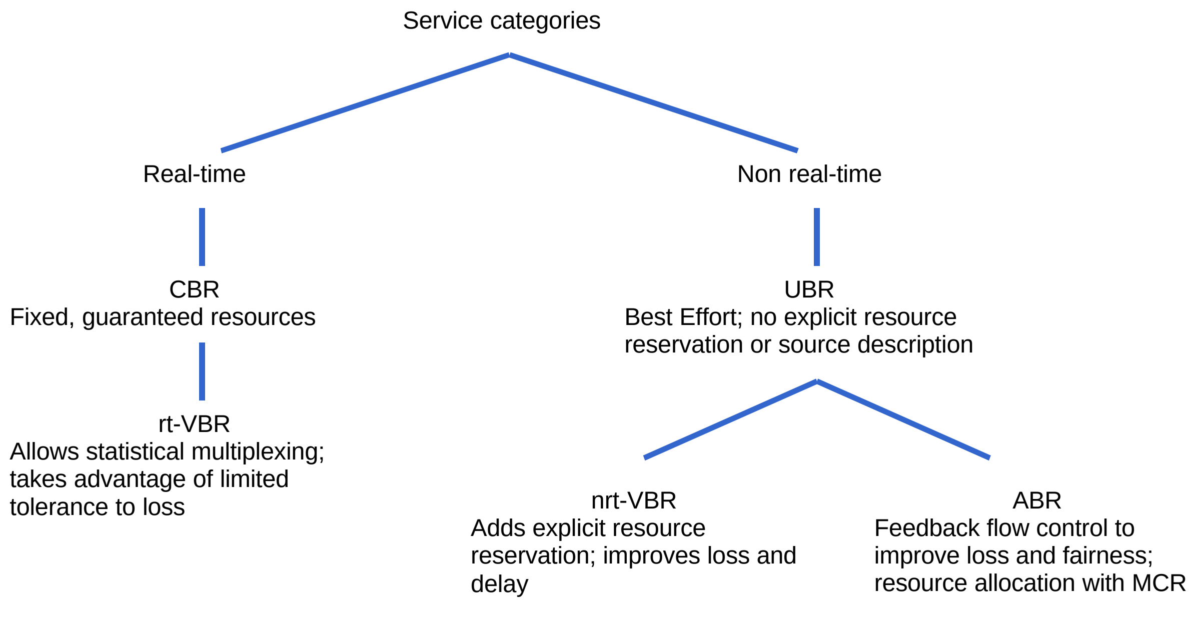



*Figure 9 ATM services characteristics [GARRET96].*

CBR

The CBR service is particularly suited for real-time applications, which require a fixed amount of bandwidth, to deliver a fixed and predictable transfer delay, i.e. emulate a physical circuit. These types of applications typically transmit at a constant rate. The Cell Loss Ratio (CLR) and the probability that cells arrive after the maximum Cell Transfer Delay (CTD) is sufficiently low to support these applications. The amount of bandwidth is denoted by the Peak Cell Rate (PCR).

rt-VBR

The rt-VBR service is suited for real-time applications and exhibits the same characteristics as the CBR service, but allows the source to transmit at a variable rate. These applications are characterised by a Peak Cell Rate (PCR), Sustained Cell Rate (SCR) and a Maximum Burst Size (MBS). When statistical multiplexing is applied, the Cell Loss Ration (CLR) is higher than the CLR of the CBR service. This service is suitable to support applications that generate both high priority traffic as well as low priority traffic. The high priority traffic provides a minimum service quality, while the low priority traffic enhances this minimum service level.

nrt-VBR

The nrt-VBR service is suited to support variable bit rate applications that require bandwidth guarantees.

ABR

The ABR service is suited to support variable bit rate applications that require a minimum bandwidth and require no delays guarantees. The ATM network agrees to forward cells with at least the specified Minimum Cell Rate (MCR). The ABR service could be viewed as 'Best Effort with a floor'.

ABR uses a feedback flow control mechanism to adapt the transmission rate to the network conditions to provide a low Cell Loss Ration (CLR). Furthermore the connection may be re-routed around a congested node, through a crankback mechanism. The congested node signals to the source that congestion has occurred, and that the committed QoS is in danger. Next a new route around the congested node is established.

UBR

The UBR service is suited to support variable bit rate application without bandwidth or delays guarantees. As this service does not provide a flow control mechanism, the resulting Cell Loss Ratio (CLR) is lower. This service is typically referred to as Best Effort.

The VBR services are specified by a double leaky bucket traffic descriptor, one for PCS and one for SCR. The CBR service is described by a single leaky bucket traffic descriptor.

The service attributes of the ATM services, are listed in Table 5. The traffic parameters and QoS parameters of the ATM services are explained in more details in the following sections 4.2.2.2 and 4.2.2.3 respectively.

| | Traffic Parameters | | | QoS parameters | | | Other |
|---|---|---|---|---|---|---|---|
| | **PCR and CDVT** | **SCR and MBS** | **MCR** | **peak-to-peak CDV** | **maxCTD** | **CLR** | **Feedback** |
| CBR | yes | - | - | yes | yes | yes | - |
| rt-VBR | yes | yes | - | yes | yes | yes | - |
| nrt-VBR | yes | yes | - | - | - | yes | - |
| UBR | yes[8] | - | - | - | - | - | - |
| ABR | yes | - | yes | - | - | -[9] | yes |

*Table 5 ATM service attributes.*

#### 4.2.2.2 Traffic parameters

The traffic parameters are listed in the Source Traffic Descriptor of the setup message. The traffic parameters are input for the Call Admission Control (CAC). The following ATM traffic parameters can be identified:

- Peak Cell Rate (PCR)

  The Peak Cell Rate (PCR) defines an upperbound on the rate at which a traffic source can submit traffic into the network. The PCR is the reciproke of the minimum spacing between cells T i.e. PCR = 1 / T. The PCR is coupled with the Cell Delay Variation Tolerance (CDVT), which defines the allowed jitter for this rate.

- Sustainable Cell Rate (SCR)

  The Sustainable Cell Rate (SCR) defines an upperbound on the average rate at which a traffic source can submit traffic into the network. The average rate is defined over a time period much larger than T (SCR < PCR).

- Maximum Burst Size (MBS)

  The Maximum Burst Size (MBS) defines the maximum number of cells that a source may submit continuously into the network at the Peak Cell Rate (PCR). Over a longer time period (> T), the average load should not exceed the Sustainable Cell Rate (SCR).

- Minimum Cell Rate (MCR)

  The Minimum Cell Rate (MCR) defines the minimum amount of committed resources by the network to support the ABR service. When the minimum amount of resource denoted by MCR cannot be provided, Call Admission Control will reject the call at call establishment.

[8] The UBR PCR may not be subject to Call Admission Control (CAC) or Usage Parameter Control (UPC).
[9] The Cell Loss Ration (CLR) for a source that adjusts its transmission rate to the feedback flow control information is low.

The traffic parameters of the Source Traffic Descriptor can be 'negotiated'. The ATM node that initiates the connection, specifies both a minimum and a requested value for the traffic parameter. The minimum value referring to the absolute minimum the source node is willing to accept and the requested value being the target value. Intermediate ATM nodes in the end-to-end path may reduce the requested level according to their Call Admission Control policy. However, when the requested value drops below the minimum value, the connection is dropped.

An ATM Connection Traffic Descriptor contains a Source Traffic Descriptor , a Cell Delay Variation Tolerance (CDVT) and a conformance definition based on Generic Cell Rate Algorithm (GCRA). The CDVT is an ATM QoS parameter, explained in Section 4.2.2.3. The GCRA is used for ATM traffic and congestion control, explained in Section 4.2.2.4.

An ATM Traffic Contract Specification contains a Connection Traffic Descriptor and the associated Quality of Service parameters for each direction of the connection. The Traffic Contract is used as the basis to reserve resources in the network during connection setup.

The Cell Delay Variation Tolerance (CDVT) is not signaled, but is a fixed value at the specific UNI interface. Therefore the CDVT is the same for each VC. The CDVT indicates the maximum cell delay variation introduced by the network. The CDVT accounts for the delay variability due to the slotted nature of ATM, physical layer overhead and ATM multiplexing. The CDVT is induced by ATM and not a characteristic of the traffic source. The CDVT is expressed in unit of time and denoted as $\tau$. The CDVT is used in the Generic Cell Rate Algorithm (GCRA), specified in the conformance definition of the Traffic Contract.

The CDVT in general is small (a few ATM cells) and cannot be used to account for the burstiness of the RSVP traffic source i.e. token bucket size b. Therefore additional buffers may be needed at the ATM ingress node, especially when ATM CBR services are used. In case of the VBR service, the MBS may account for the token bucket size (see Section 4.2.3).

#### 4.2.2.3 QoS parameters

In case of a Switched Virtual Connection (SVC), the traffic and QoS parameters are signaled across the UNI interface. In case of a Permanent Virtual Connection (PVC), the traffic and QoS parameters are statically configured through a Network Management System (NMS).

- Cell Loss Ratio (CLR)

  The Cell Loss Ratio (CLR) is defined as the number of lost cells divided by the total number of cells.

- Cell Error Ratio (CER)

  The Cell Error Ratio (CER) is defined as the number of errored cells divided by the total number of transmitted cells (excluding the severely errored cells, see next bullet).

- Severely Errored Cell Block Ratio (SECBR)

  The Severely Errored Cell Block Ratio (SECBR) is defined as the total number of severely errored cell blocks divided by the total number of transmitted cell blocks.

- Cell Misinsertion Rate (CMR)

  The Cell Misinsertion Rate (CMR) is defined as the number of misinserted cells per time unit.

- Maximum Cell Transfer Delay (maxCTD)

  The Cell Transfer Delay (CTD) is the time period between transmission of the last bit at the source UNI and the reception of the first bit at the destination UNI. The fixed CTD refers to the minimum transfer delay and includes components such as propagation delay, transmission delays and minimum switch processing delays. The variable part of the CTD refers to buffering and scheduling delays at the ATM switches.

- peak-to-peak Cell Delay Variation (peak-to-peak CDV)

  The peak-to-peak Cell Delay Variation (peak-to-peak CDV) defines the variation in the Cell Transfer Delay, as depicted in Figure 10.

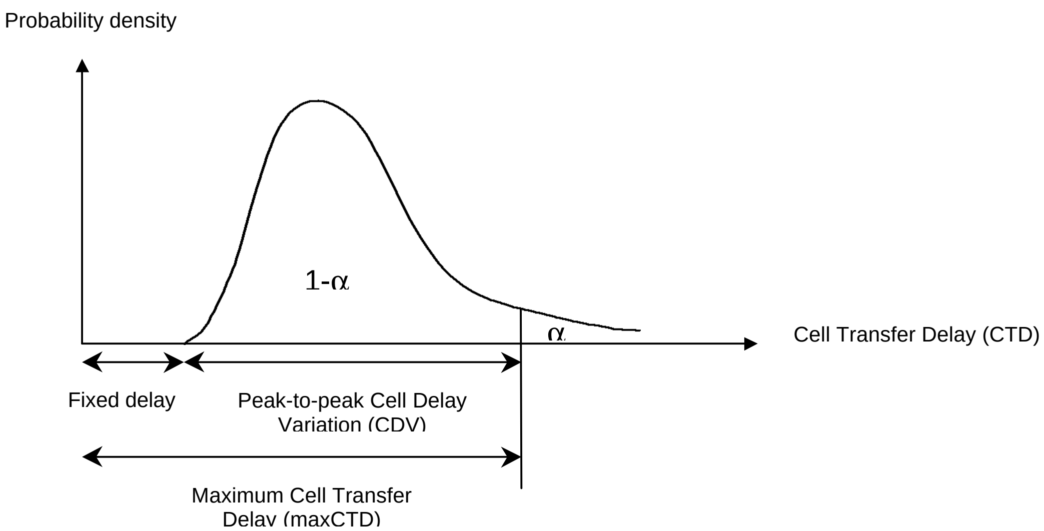



*Figure 10 Cell Transfer Delay parameters.*

The maxCTD refers to the maximum cell delay, requested for the connection. A fraction α of the cells exceeds this threshold. Obviously the delay quantile α must be smaller than the CLR for that connection. According to [AF96b] the exact relationship between α and CLR is for further study.

Some QoS parameters can be negotiated during connection setup as listed in Table 6.

| **Negotiable** | **Not negotiable** |
|---|---|
| peak-to-peak CDV | CER |
| maxCTD | SECBR |
| CLR | CMR |

*Table 6 QoS parameter negotiation.*

<u>QoS classes</u>

To make things simpler, a small number of predefined QoS classes are defined, with particular values for the QoS parameters (CLR, CDVT and average CTD). The five QoS classes are listed in Table 7.

| QoS class | QoS parameters | Application |
|---|---|---|
| 0 | Unspecified | Best Effort, At Risk |
| 1 | Specified | Circuit emulation, Constant Bitrate |
| 2 | Specified | Variable bitrate audio / video |
| 3 | Specified | Connection oriented data |
| 4 | Specified | Connectionless data |

*Table 7 ATM QoS classes.*

QoS parameters that are negotiated (see Table 6), override the parameter values of the QoS class.

#### 4.2.2.4 ATM traffic and congestion control

ATM traffic control is defined as the set of actions taken to avoid network congestion. ATM congestion control is defined as the set of actions taken to minimise the intensity, spread and duration of congestion [I.371].

The ATM traffic and congestion control functions are listed in Table 8 [I.371]. Each mechanism operates on a different time scale. The functions are explained in more details, in the following text.

| Time scale | Traffic control | Congestion control |
|---|---|---|
| Long Term | - Virtual Path management | |
| Connection duration | - Connection Admission Control (CAC) | |
| Round Trip Time | - Fast Resource Management (FRM) | - Explicit Forward Congestion Indication (EFCI)<br>- ABR flow control |
| Cell Insertion Time | - Usage Parameter Control (UPC)<br>- Priority control / queue management<br>- Traffic shaping | - Selective Cell discard<br>- Frame discard |

*Table 8 Traffic control and congestion control functions.*

<u>Virtual Path management</u>

Virtual Path (VP) management enables the segregation of different traffic types with different QoS requirements into a single VP. Call Admission Control is simplified when Virtual Paths are used. Virtual

Paths are established on a semi-permanent basis. When a new connection is needed, a Virtual Connection within a Virtual Path is established dynamically.

Call Admission Control

To setup a Virtual Path Connection or a Virtual Channel Connection, the following information must be supplied to Call Admission Control (CAC):

- Service category (CBR, rt-VBR, nrt-VBR, ABR, UBR)

- Connection Traffic Descriptor containing Source Traffic Descriptor (PCR, SCR, MBS, MCR), CDVT and Requested conformance definition.

- Requested and acceptable QoS parameter values (peak-to-peak CDV, maxCTD, CLR)

Call Admission Control (CAC) can only accept a connection request, when the network can provide the resources to provide the QoS level requested by the new connection, while maintaining the committed QoS level of existing connections.

When a connection request is accepted by CAC, a Traffic Contract is established between the user and the network. When the user complies to the Traffic Contract i.e. traffic compliant to the Connection Traffic Descriptor is injected into the network, the network will deliver the committed QoS.

Although CAC protects the network against excessive load, congestion in the network may occur (e.g. over commitment), which threatens the QoS commitments of existing connections. During periods of congestion cells may be dropped or in case of the ABR service feedback control may limit the traffic source.

There are two basic strategies for CAC of Virtual Channel Connections (VCC), within a Virtual Path Connection (VPC):

- CAC based on aggregate peak demand. The sum of the Peak Cell Rate (PCR) of the VCCs is smaller than the bandwidth of the VPC.

- CAC based on statistical multiplexing. The sum of the Peak Cell Rate (PCR) of the VCCs may exceed the bandwidth of the VPC.

Fast Resource Management

Two types of Fast Resource Management (FRM) have been proposed to enhance the ATM traffic control capabilities [McDysan95]. These two proposals allow the reservation of bandwidth or buffer space along the end-to-end path, through explicit ATM signalling. For further details see [McDysan95].

Usage Parameter Control

Once a connection is admitted by CAC, the Usage Parameter Control (UPC) starts monitoring the connection for compliance to the Connection Traffic Descriptor, specified in the Traffic Contract. The purpose of UPC is to protect the network from misbehaving traffic sources that may adversely affect the QoS commitment of other connections.

The UPC can be performed on both the Virtual Path, as well as the Virtual Channel level. UPC is performed at the VCC level at the first Virtual Channel switching point. UPC is performed on VPC level at any Virtual Path switching point, prior to the first Virtual Channel switching point. The UPC function is located at the UNI interface i.e. at the ATM ingress node. A similar function to UPC, but located at the NNI interface, is denoted as Network Parameter Control (NPC).

The UPC function may monitor:

- Peak Cell Rate (PCR) with the associated Cell Delay Variation Tolerance (CDVT)
- Sustainable Cell Rate (SMR) with the associated Maximum Burst Size (MBS)

The UPC function monitors the traffic by means of the Generic Cell Rate Algorithm (GCRA). The GCRA algorithm can be specified as a virtual scheduling or a leaky bucket algorithm (with a tolerance specified by CDVT or MBS).

In case a single Cell Loss priority is defined, cells that do not comply are discarded. When two Cell Loss priorities are defined, cells are either tagged[10] or discarded, as depicted in the Figure 11.

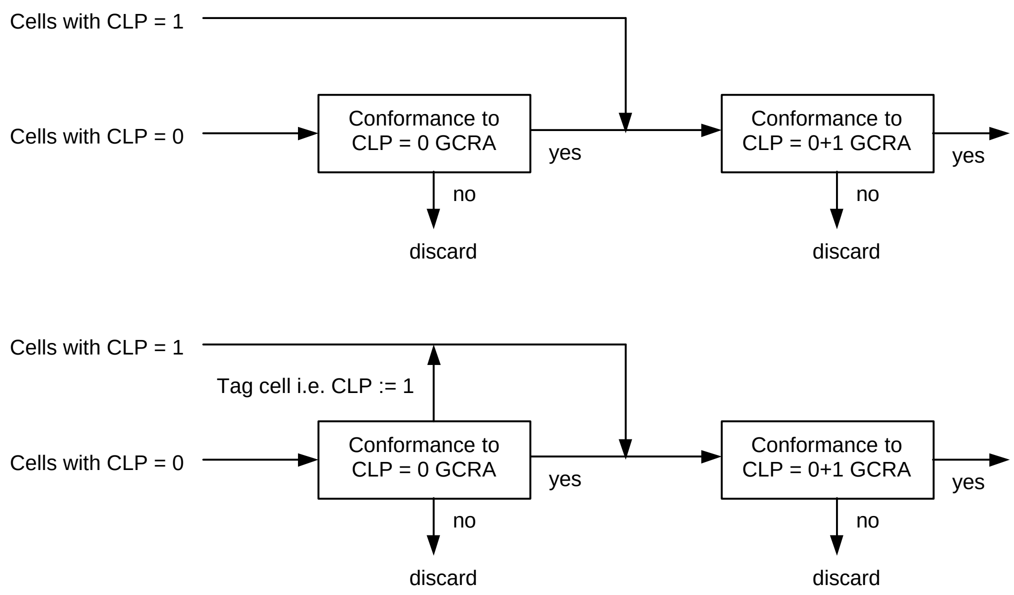



*Figure 11 UPC control with and without cell tagging.*

Priority control / queue management

The priority control and queue management schemes refer to the scheduling of cells on the output link of the ATM switch. Different scheduling techniques, such as priority queueing and weighted round robin scheduling, have been proposed.

Traffic shaping

Traffic shaping is the modification of the traffic flow characteristics, such that the flow conforms to the Traffic Contract. In practice, this means that cells are delayed before they are transmitted. Different

[10] Tagged cells are more eligible to be discarded than non-tagged cells when congestion is experienced. The tagging information can be used in subsequent switches visited by the cell.

techniques may be applied to obtain the required result, such as burst length limiting, cell spacing, etc. [I.371]. One often employed technique is the use of a token bucket to shape bursty traffic.

Explicit Forward Congestion Indication

When an ATM switch experiences congestion e.g. through buffer occupation, the switch may decide to set the Explicit Forward Congestion Indication (EFCI) in the Payload Type (PT) field of the ATM cell. In this way downstream nodes are informed about network congestion. The higher layers at the destination node may subsequently inform the source node to slow down the transmission rate. This way the feedback control mechanism can prevent congestion collapse.

ABR flow control

The ABR service provides the ability to use resources up to the Peak Cell Rate, when there is no congestion. The transmission rate of the source is controlled by the transmission of Resource Management (RM) cells, between source and destination. These RM cells convey congestion information and cell rate information, to control the source transmission rate. In this way the available bandwidth is used efficiently, and the cell loss ratio is low. Through flow control, the ABR service provides a better network utilisation and cell loss ratio than the UBR service. The RM cells are generated selectively for ABR flows, to allow fair sharing of the available resources.

Cell Loss Priority

The Cell Loss Priority (CLP) bit may be set at the source, to indicate relative priority within a VC, or at an ATM switch to police traffic that is not conformant.

There are two modes of operation with relation to the Cell Loss Priority:

- CLP-transparent: The network generally ignores the CLP bit. The CLR target applies to the aggregate CLP = 0 + 1 cell flow. The tagging option does not apply to this mode.

- CLP-significant: The CLR target applies only to the CLP = 0 cell flow. Network tagging is optional (a cell with CLP = 0, which is not conformant to the PCR, but conformant to the SCR will have it's CLP bit set to 1). The network makes a best-effort attempt to transmit the CLP = 1 cell flow (However, cells with CLP = 1 may be discarded in case of congestion).

The CBR service operates in CLP transparent mode only. There is one conformance definition for CLP = 0 + 1 traffic. The VBR services may operate in CLP-transparent or CLP-significant mode. For the VBR service three different conformance definitions can be selected (dependent whether the SCR applies to the CLP = 0 + 1 or CLP = 0 traffic, and whether tagging is applied).

When a traffic contract is established, different traffic parameters may be negotiated for all traffic (CLP = 0 + 1) and high priority traffic (CLP = 0).

An ATM switch must attempt to discard cells with CLP = 1 in preference to cells with CLP = 0 during periods of congestion. The CLP bit indicates the eligibility of the packet to be discarded:

- Value 0 indicates a high priority and value 1 indicates that the packet is subject to discard.

- Cells generated by a source beyond the Traffic Contract have CLP 1; cells in conformance have CLP 0.

- The network may set the CLP to 1 for those cells, which fail to conform to the Traffic Contract.

Frame discard

An AAL frame is likely to consist of more than one ATM cell. In case of congestion it is more efficient to discard not only a single cell, but also preferably all cells of the AAL frame. This type of discard mechanism can improve the goodput and reduce network congestion. However, this mechanism requires the detection of AAL frame boundaries at the ATM switches.

### 4.2.3 Mapping of Integrated Services to ATM services

In this section the mapping of Integrated Services to ATM services is evaluated. The recommended mapping of Integrated Services to ATM services, according to RFC 2381 [RFC2381], is listed in Table 9. It should be noted that other mappings are not precluded.

| **Integrated Service** | **ATM service** | **ATM QoS class** |
|---|---|---|
| Guaranteed Service | CBR or rt-VBR | 1 |
| Controlled Load | nrt-VBR or ABR[11] | 3 |
| Best Effort | UBR or ABR | 0 |

*Table 9 Recommended mappings of Integrated Services to ATM services and QoS classes.*

Before the service mappings are discussed in more detail, first some general issues are discussed.

Buffering at ATM ingress node

The traffic characteristics of an RSVP flow can be bursty. This burstiness is specified by means of a token bucket (see Section 3.5). In general the ATM ingress node provides limited buffering at the UNI interface. In case of variable bitrate services rt-VBR and nrt-VBR, the associated Maximum Burst Size (MBS) can be used to provide buffering inside the ATM network to support bursty traffic.

QoS parameter mapping

ATM QoS parameters for which there is no RSVP equivalent, need to be configured manually: Cell Loss Priority (CLP), Cell Delay Variation (CDV), Severely Errored Cell Block Ratio (SECBR) and Cell Transfer Delay (CTD).

Non conformant traffic

Traffic that is non-conformant needs to be transmitted as Best Effort traffic, according to the Integrated Services framework, and should not adversely effect the traffic of conformant flows[12]. The ATM service

[11] At some point in RFC 2381 the CBR is also noted as a good mapping for the Controlled Load Service (CLS). However this service is not listed as the 'recommended' mapping for CLS. The CBR service provides a higher QoS level than required and may provide low network utilisation (dependent on the burstiness of the source).
[12] In the absense of a tagging mechanism i.e. a means to identify a packet as nonconformant (and subsequently treat as Best Effort), the only sensible thing to do is to drop the packet as it may adversily effect conformant flows while travelling through the network untagged i.e. remaining to receive special treatment.

model provides the ability to tag non conformant cells with CLP = 1. The ATM service class remains the same, however the cell is more eligible to be discarded in periods of congestion. However, the ATM standard does not provide details how traffic with CLP = 1 should be treated. Therefore is should be checked whether the IP BE traffic is sufficiently supported with CLP = 1 traffic. It should be noted that ATM traffic with CLP = 1 is treated differently within the ATM network, than a Best Effort Virtual Connection that has been selected to support IP BE traffic.

#### 4.2.3.1 Guaranteed Service

The Guaranteed Service requires real-time service support and requires a delay guarantee. The CBR and rt-VBR services are the only real-time ATM services, which provide a maximum delay guarantee (i.e. maximum Cell Transfer Delay (maxCTD)).

For obvious reasons the selection of CBR in case of constant rate traffic sources and rt-VBR in case of variable rate traffic sources is preferable.

The Cell Loss Ration (CLR) should be selected sufficiently low to support effectively the (real-time) applications.

Parameter mapping

The following mapping is recommended for rt-VBR service [RFC2381]:

PCR = *p* [13]

SCR = *R* [14]

MBS = *b*

The following mapping is recommended for CBR service [RFC2381]:

$$\text{PCR} = \begin{cases} R & \text{Ingress node provides buffer space } (b + C_{sum} + RD_{sum}) \\ \max(R,p) & \text{Ingress node provides no buffer space} \end{cases}$$

The following bounds are recommended [RFC2381]:

$r$ <= SCR <= $R$ <= PCR <= APB

#### 4.2.3.2 Controlled-Load Service

The UBR service does not provide QoS capabilities strict enough to support the Controlled-Load Service. The ABR service aligns the best with the Controlled-Load Service. In this case the MCR of the ABR service is determined, based on the average rate $r$ specified in the TSpec [RFC2381]. The ATM

[13] In case reserved bandwidth $R$ is greater than the peak rate p, the PCR is set to $R$ (because a burst of size $b$ must be cleared from the buffer within $b/R$ time). In case $R$ is smaller than $p$, PCR may be chosen smaller than $p$ to select a VC that is more economic (in case cost is based on PCR). In such a case the ATM ingress node must allow sufficient buffer space ($b + C_{sum} + R\ D_{sum}$) to support the peak rate $p$ [RFC2381].
[14] The SCR can be assigned the average rate $r$ without violating the Guaranteed Service (GS) delay requirements or cell loss. However, this is against the spirit of the GS service and the additional delay inside the ATM network must be accounted for by the ingress node ($C$ and $D$ error terms).

ingress nodes should supply sufficient buffer space (at least the token bucket depth *b* plus additional network jitter). It should be noted that during periods of congestion the ATM network might throttle down quickly the transfer rate to the MCR rate. A source transmitting above this rate may experience high loss.

When the Controlled-Load Service is supported by the nrt-VBR service the same mapping and buffer considerations apply as with the Guaranteed Service to nrt-VBR service mapping in Section 4.2.3.1.

#### 4.2.3.3 Best Effort

The UBR and ABR services are the preferred choice for support of Best Effort traffic [RFC2381]. It should be noted that the ABR service provides improved CLR performance and has been designed specifically to support TCP/IP traffic. The Best Effort service does not provide traffic or resource parameters, therefore the mapping of these parameters is not an issue.

### 4.2.4 VC management

<u>Introduction</u>

The ATM edge devices are concerned with the interworking between Integrated Services and the ATM services, as depicted in Figure 12. This includes the translation of the RSVP reservation semantics in the appropriate ATM VC parameters.

On the one hand ATM edge devices must support Integrated Services capabilities such as RSVP message handling, resource reservation, RSVP soft state maintenance, packet classification and scheduling. On the other hand ATM edge devices must support setting up, maintenance and release of ATM Virtual Connections through UNI signalling.

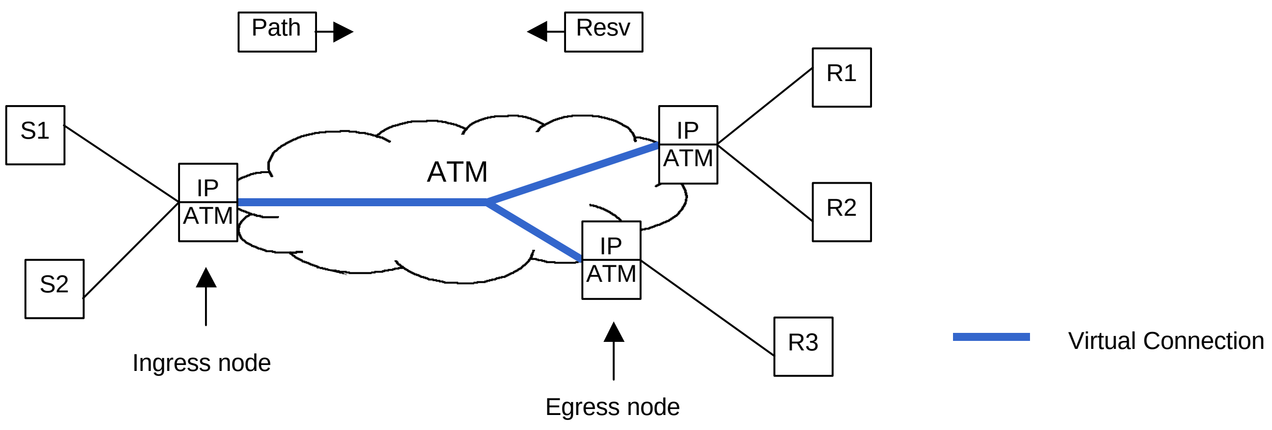



*Figure 12 IP over ATM system elements.*

The ATM ingress node triggers the establishment of a VC with appropriate QoS (when there is no one available satisfying the requirements) when an RSVP Resv message is received. The information needed to select a proper VC is contained in the TSpec (source traffic description) and in case of the Guaranteed Service the RSpec (QoS requirements bandwidth and delay) of the Resv message. Upon receipt of a Resv message by the ATM ingress node, the request must be merged with other requests according to the general merging rules.

RSVP requires that the Path messages and the Resv messages follow the same path. In case of IP over ATM this implies that both the Path and Resv messages must follow the same ingress and egress ATM nodes. The ATM egress node is responsible for the setting of the parameters contained in the Adspec.

ATM end-points

The ATM end-point is identified by the RSVP next-hop information element contained in the Resv message. In case the ATM end-point is a non-RSVP capable node, the next-hop element does not identify the proper ATM end-point. For a unicast session, the correct ATM end-point is identified by the IP next hop router. However, for a multicast session, multicast routing may not uniquely identify the IP next hop router.

Multicast data distribution

Two types of multicast data distributions are identified:

- Multicast mesh: All data is transmitted from sender to all receivers by means of a point-to-multipoint VC.
- Multicast server: All data is transmitted from sender to a multicast server through point-to-point connections. The server then transmits the data to all receivers over a point-to-multipoint VC.

The multicast server does not support signalling of QoS requirements. Therefore RSVP over ATM must support the multicast mesh method. When the multicast server method is applied, the RSVP service break bits must be set, not the global RSVP break bit. Setting the RSVP service break bit indicates that RSVP/Integrated Services are supported, but service specific features are not supported.

ATM shortcuts

ATM provides the ability to setup a point-to-point VC i.e. shortcut directly to an ATM node outside a Logical IP Subnetwork (LIS). When shortcuts are employed, the path can be asymmetrical i.e. Path and Resv message travelling a different path. RSVP does support this type of asymmetry, as only those RSVP messages are processed which arrive on the proper interface, denoted by the Next Hop (NHOP) information element of the Resv message

Receiver heterogeneity

Receiver heterogeneity is not supported with ATM multicasting, as all branches of the multi-cast tree have the same QoS characteristics. Receiver heterogeneity happens when receivers require different QoS or when some receivers are satisfied with the traditional Best Effort service. RSVP heterogeneity can be supported by ATM by proper mapping of RSVP reservation onto ATM Virtual Connection (VC).

Four different styles of mapping have been identified [RFC2382]:

Full heterogeneity

A separate multicast VC is provided for each QoS level requested.

Limited heterogeneity

Two separate multicast VCs are provided per RSVP flow: one QoS multicast VC and a Best Effort multicast VC.

Modified homogeneous

A single multicast VC is provided per RSVP flow with the maximum QoS level of the RSVP flows.

Aggregation model

Multiple RSVP flows are mapped onto a single 'large' multicast VC. This approach is similar in the way IP Integrated Services is managed over point-to-point links (e.g. T-1, DS-3). One problem remains how to chose the proper QoS of the aggregate VC. Furthermore as UPC is applied to a single VC, flow segregation is compromised. The advantage of this approach is that no signalling delays are involved in setting up VCs.

A combination of receiver heterogeneity and dynamic QoS arises, when a new receiver is added with a larger QoS requirement than the existing QoS level.

Switched or Permanent VCs

Employing Integrated Services over ATM using Permanent Virtual Connection (PVC) is rather straightforward. In this case the Integrated Service is used similar as on any point-to-point link layer technology. The QoS of PVCs should however be able to support the QoS of the Integrated Services. There are no delays involved in setting up VCs for the establishment of an RSVP session. However, this permanent allocation of resource may provide low network resource utilisation. In case the network engineering uses over-subscription to increase utilisation, the Integrated Service QoS commitment can be compromised.

When Switched Virtual Connection (SVC) are used, flexibility is obtained through increased complexity, cost and efficiency to setup SVCs. These disadvantages could impact the integration with RSVP. Furthermore scaling issues arise when a single RSVP flow is mapped on a single SVC. RSVP may either send explicit messages (Pathtear and Resvtear) or a timeout occurs to indicate that the reservation is no longer needed. This triggers the release of the associated VCs. There is an inactivity timer defined in RFC 1755 at both the ATM ingress and egress node that releases the VC, when there is inactivity for 20 minutes (default). To prevent possible interference with the RSVP release, this timer should preferably set to 'infinity'.

UNI 3.x and 4.0 do not allow the re-negotiations of the QoS parameters of a VC, i.e. once a Virtual Connection is established the QoS cannot be renegotiated[15]. This implies that a new VC needs to be established when the QoS of the existing VC is not sufficient to support the new QoS of the RSVP reservation. Some hysteresis level needs to be included to prevent too frequent setup and release of VCs to QoS changes [RFC2382].

VCs for RSVP signaling messages

Two types of RSVP signaling messages need to be supported: Path (unicast and multicast address) and Resv (unicast address only). Therefore VCs for RSVP signaling must support both unicast and multicast. Four different approaches are identified [RFC2382]:

[15] The ITU-T has specified modification procedures to modify the Traffic Parameters of an active connection [ITU96]. However the QoS parameters may not be changed.

Use the same VC for RSVP signaling and data

The advantage is that no additional VCs are needed, and setup delays are avoided. However, the RSVP signaling may suffer from nonconforming data traffic.

Single VC per RSVP session

The advantage is that a separate VC protects the RSVP signaling from excessive loss as a separate traffic contract is established for RSVP signaling. However, this requires twice as much VCs.

Single point-to-multipoint VC multiplexed among sessions

Several RSVP sessions may share the same point-to-multipoint VC to transmit signaling messages. This requires that the ATM ingress and ATM egress node(s) are the same. Some multiplexing gain is obtained at the expensive of complexity of handling changing egress nodes.

Multiple point-to-point VCs multiplexed among sessions

In this scheme several point-to-point VCs are needed to support a point-to-multipoint RSVP signaling. A single point-to-point VC however can provide high multiplexing gain. VC setup signaling cost is reduced as with point-to-point VCs a reverse connection can be established as the same time the forward connection is established. The QoS level required for the VC depends on the multiplexing gain that is expected.

### 4.2.5 Conclusions

ATM provides a rich QoS architecture, which makes it suitable to support different types of services with varying QoS requirements. However, the connection-oriented nature of ATM makes it less suitable to support connectionless IP efficiently. In Section 5.2 a new architecture called Multi-Protocol Label Switching (MPLS) is discussed. This architecture tries to use the best of both worlds by integrating ATM and IP.

## 4.3 IEEE 802 LAN Technologies[16]

### 4.3.1 Introduction

The IEEE has defined standards for different Local Area Networks (LAN) technologies. This is done within the 802 project. The defined standards offer the same MAC layer datagram service to higher layer protocols such as IP.

Although the defined standards offer the same MAC layer datagram service, they provide different dynamic behaviour characteristics. These dynamic behaviour characteristics are important when considering the ability of the defined standards to support real-time services.

In this section we will focus on the capabilities of different IEEE 802 LAN Technologies in relation to supporting Integrated Services. An example network containing an IEEE 802 segment[17] is given by

[16] The content of this section is mainly extracted from [IDISSL98]
[17] A segment is a physical Layer 2 segment that is shared by one or more senders [IDISSL98].

Figure ***13***.

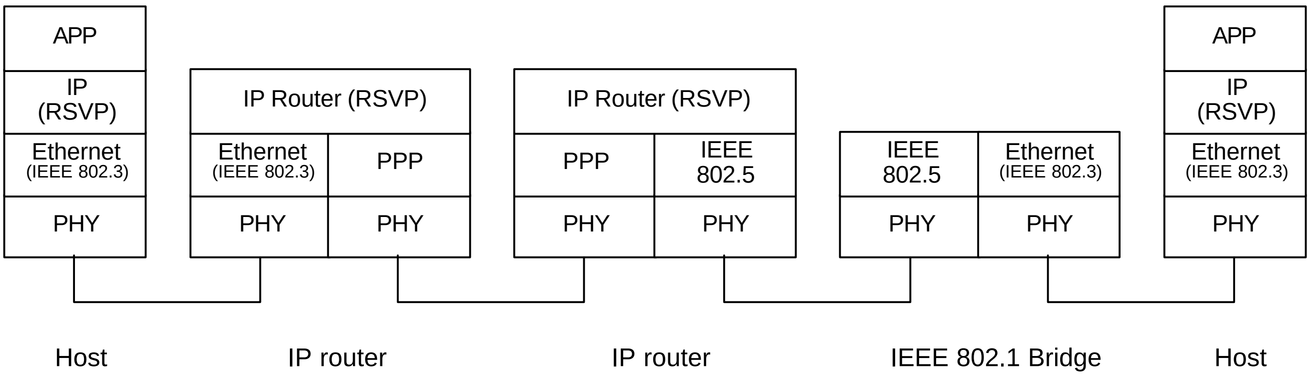



*Figure 13 Network containing IEEE 802 segments*

### 4.3.2 Frame Forwarding in IEEE 802 Networks

Although we use the term IEEE 802 style networks, different types of IEEE 802 networks differ in the way they support Integrated Services. Some IEEE 802 networks use a priority mechanism for queueing and medium access while others do not. In case an IEEE 802 network uses a priority mechanism, the user_priority is carried explicitly in the MAC frame. This user_priority serves as a label, making it possible for the downstream nodes to discriminate frames within a data stream in different classes without parsing the frames in more detail.

#### 4.3.2.1 Ethernet/IEEE 802.3

Figure 14 shows the MAC frame format used by IEEE 802.3 networks.

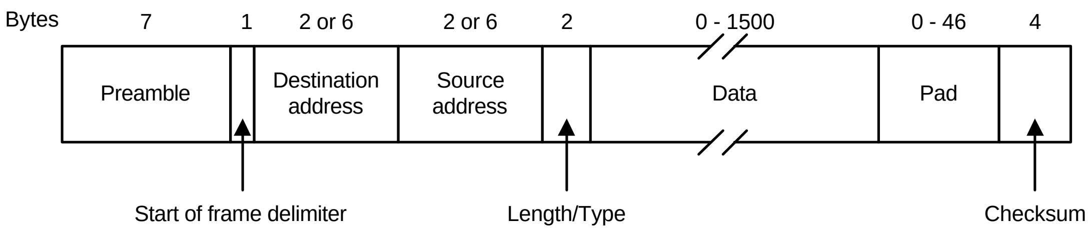



*Figure 14 MAC frame format of IEEE 802.3*

As can be seen in Figure 14, there is no explicit traffic class or user_priority carried in the IEEE 802.3 MAC frame. As a result, frames belonging to different flows can only be distinguished by parsing further into higher layer protocol fields in the frame. Another possible way of distinguishing frames belonging to different flows, is to make use of the Length/Type field. In order to be able of performing such a distinction, new Ethertypes (values of Length/Type field) must be defined and standardised.
Note that an IEEE 802.1Q encapsulation [IEEE8021Q] may also be used, providing an explicit user_priority field on top of the basic MAC frame format.
As Ethernet is a shared medium with no access priorities, all users attached to an Ethernet can get access to the medium with equal probability. For this reason, there is no upper bound for the maximum

access latency, which means that Ethernet cannot provide a delay bound and, as a result, does not provide explicit real-time service support.

#### 4.3.2.2 Token Ring/IEEE 802.5

Figure 15 shows the MAC frame format used by IEEE 802.5 networks.

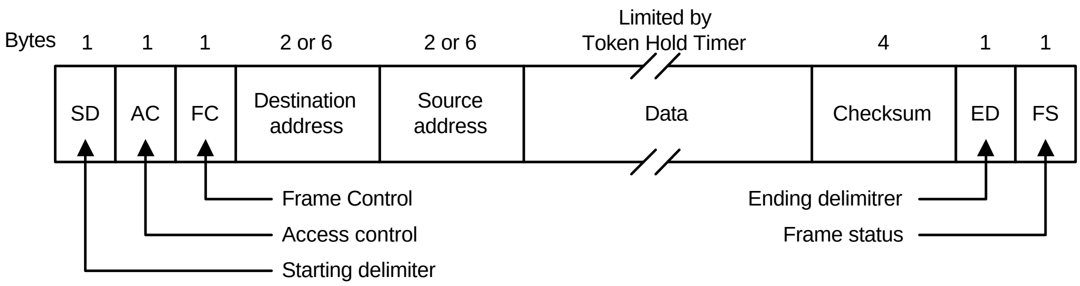



*Figure 15 MAC frame format of IEEE 802.5*

The IEEE 802.5 standard has defined a priority mechanism that can be used to control the queueing of frames and the access of frames to the shared media. For this purpose, IEEE 802.5 networks use the Access Control (AC) and the Frame Control (FC) fields of a Logical Link Control (LLC) frame. The first and the last three bits of the AC field, the Token Priority bits and the Reservation bits respectively, regulate access to the ring. The last three bits of the FC field, the User Priority bits, are obtained from the next higher layer in the user_priority parameter when transmission of a frame is requested. The user_priority is also used to establish the Access Priority used by the MAC.

IEEE 802.5 uses a concept of Reserved Priority (see also [OEC8025]). A station can reserve the medium by setting the Reservation bits. When a free token is circulating, only a station having an Access Priority greater than or equal to the Reserved Priority in the token can make use of the token. We expect that this reservation mechanism can gratefully be used as part of a resource reservation mechanism. Because the transmission time of stations in a IEEE 802.5 network is not allowed to be longer than the Token Hold Time (i.e. transmission time is bound), and because the number of stations on a IEEE 802.5 network is bound, the access delay is also bound. However, Token Ring does not explicitly support real-time service.

#### 4.3.2.3 Fiber Distributed Data Interface (FDDI)

Like Token Ring, FDDI provides a priority mechanism than can be used to control the queueing of frames for transmission and the access of frames to the shared media. However, FDDI provides besides the asynchronous service also a synchronous service, which provides a delay bound. In other words, FDDI explicitly supports real-time services.

#### 4.3.2.4 Demand Priority/IEEE 802.12

IEEE 802.12 is a standard for a shared 100 Mbps LAN. The MAC protocol for this standard is called Demand Priority. Data packets from al network nodes are served using a Round Robin mechanism. For the transmission of frames, either the IEEE 802.3 or IEEE 802.5 frame format is used.

The main characteristics of the IEEE 802.12 standard with respect to QoS are the supports of two service priority levels, normal priority and high priority, and the order of service for each of these. If the IEEE 802.5 frame format is used for data transmission, then the user_priority is encoded in the FC field (see Figure 15) in the IEEE 802.5 frame header. When the IEEE 802.3 frame format is used for data transmission, the user_priority is encoded in the starting delimiter of the IEEE 802.12 frame header. Besides these two frame formats that can be used for the transmission of data frames, the IEEE 802.1Q encapsulation [IEEE8021Q] with its own user_priority field may be applied.

Note that the IEEE 802.12 standard does not define an explicit real-time service support.

#### 4.3.2.5 Characteristics of different IEEE 802 networks

Some of the characteristics of different IEEE 802 networks are listed in Table 10. Other networks that have not been considered are IEEE 802.11 Wireless LANs and Bluetooth networks.

| **Network type** | **Priority mechanism for queueing and medium access** | **Explicit real-time service support** |
|---|---|---|
| 802.3 Ethernet (10 Mbps / 100 Mbps) | No | No |
| 802.5 Token ring (4 - 16 Mpbs) | Yes (eight levels)[18] | No |
| FDDI (100 Mpbs) | Yes (eight levels)[19] | Yes[20] |
| 802.12 Demand Priority (100 Mbps) | Yes (high and low) | No |

*Table 10 QoS support IEEE 802-style networks [IDISSL98].*

Note that none of the listed 802 networks (in Table 10) provide explicit support for QoS.

### 4.3.3 The Bandwidth Manager

According to [IDISSL98], there are requirements that should drive the design of an architecture for supporting Integrated Services in IEEE 802 style networks. These requirements concern the functions of Resource reservation, Admission Control, Flow separation and scheduling, Policing and shaping etc.

[IDISSL98] introduces an entity that performs these functional requirements. This entity is referred to as Bandwidth Manager (BM). The Bandwidth Manager is responsible for making it possible for an application or higher layer protocol to request QoS from the datalink layer of a segment and consists of:

- Requester Module
- Bandwidth Allocator
- Communication Protocols

These components will be clarified in the following subsections.

[18] The token contains both a priority field and reservation field. The priority field indicates the current priority level required to seizing the token. The reservation field can be used to signal higher priority traffic presence. By proper setting of the token's priority and reservation fields a distributed priority queuing system is implemented [STAL97].
[19] The priority level refers to the 'asynchronous' service only.
[20] Bandwidth can be assigned to 'synchronous' services by way of a management protocol. Unused bandwidth by 'synchronous' service may be used by the 'asynchronous' service [STAL97].

#### 4.3.3.1 Requester Module

This component resides in every end station[21] in the subnet[22] and provides an interface between higher layer protocols (RSVP, ST2, SNMP etc.) and the Bandwidth Manager.

To initiate a reservation in the link layer domain, the following parameters must be passed to the Requester Module:

- The service desired (Guaranteed Service or Controlled Load)
- The traffic descriptors contained in TSpec
- The RSpec specifying the amount of resources to be reserved

These parameters can be extracted from the RSVP PATH and RSVP RESV messages. Furthermore, the Requester Module must convert the network layer addresses of the endpoints to link layer addresses. A link layer address is needed to route a packet trough the IEEE 802 subnet to the destination at the other end of IEEE 802 subnet. Furthermore the Requester Module must convert the request into an appropriate format which is understood by other components of the Bandwidth Manager. Finally the Requester Module must return the status of requests processed by the Bandwidth Manager to the invoking application or higher layer protocol.

#### 4.3.3.2 Bandwidth Allocator

The Bandwidth Allocator is responsible for performing admission control and maintaining state about the allocation of resources in the subnet. It processes the requests of various services, made by the end stations.

Communication between the Bandwidth Allocator and the end stations take place through the Requester Module. The Bandwidth Allocator is also responsible for deciding how to label flows. For instance, the Bandwidth Allocator may, based on the admission control decision, indicate to the Requester Module which priority level a particular flow must be tagged with.

#### 4.3.3.3 Communication Protocols

Communication takes place at different levels. First of all, communication takes place between the higher layer protocols and the Requester Module. For this sake, the Bandwidth Manager must define primitives for the application to initiate reservations, query the Bandwidth Allocator about available resources, change and delete reservation etc.

Communication also takes place between the Requester Module and the Bandwidth Allocator. This protocol will specify the messages that must be exchanged between the Requester Module and the Bandwidth Allocator in order to service various requests by the higher layer entity.

Finally communication takes place between peer Bandwidth Allocators when there is more than one Bandwidth Allocator in the subnet. There should be an election procedure that decides which Bandwidth Allocator is responsible for which segment in case there are segments containing multiple Bandwidth Allocators. The Bandwidth Allocators must be able to correctly handle the scenario in which a request for resources is made along a domain of multiple Bandwidth Allocators (subsequent segments).

---

[21] An end station is a station, with Layer 3 capabilities, at the border of the Layer 2 segment.

[22] A subnet can contain multiple segments

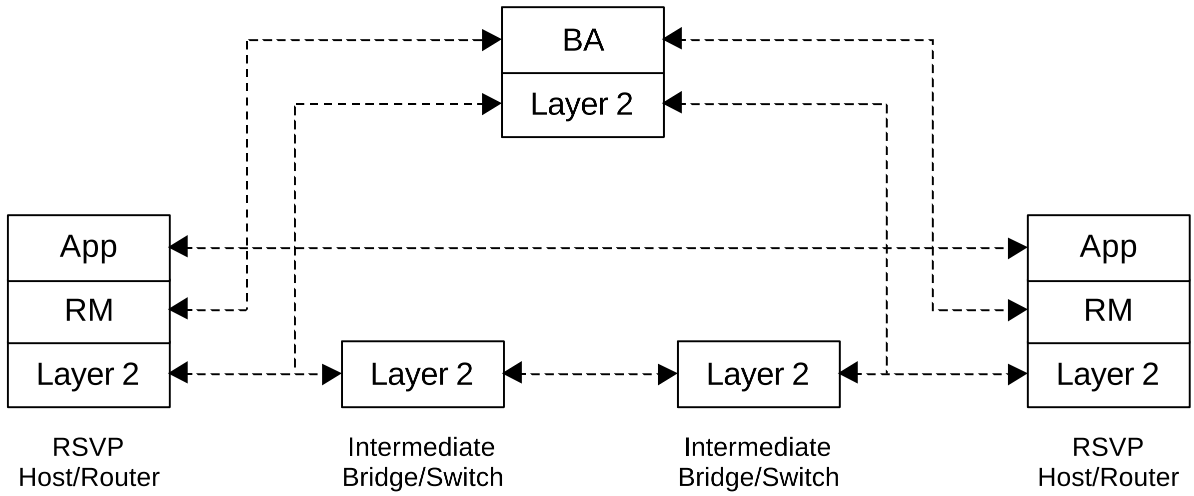
Bandwidth Allocators must also be able to use their communication with each other to backup and recover in the event of failure.

### 4.3.4 Centralised versus distributed implementations of the Bandwidth Manager

The Bandwidth Manager can be either centralised or distributed. Centralised or distributed refers to the implementation of the Bandwidth Allocators, the components responsible for resource reservation and admission control. In both the centralised and distributed implementation, the Requester Module must be present in all end stations that desire to make reservation.

#### 4.3.4.1 Centralised Bandwidth Allocator

A Bandwidth Manager with a centralised Bandwidth Allocator implementation is shown in Figure 16.




| | |
|---|---|
| RM | Requester Module |
| BA | Bandwidth Allocator |
| App | Application or higher layer protocol (e.g. RSVP) |

*Figure 16 Bandwidth Manager with a Centralised Bandwidth Allocator [IDISSL98]*

When a centralised Bandwidth Allocator is used, the Bandwidth Allocator will be responsible for admission control decisions for the entire subnet.

As can be seen from Figure 16, every end station (host/router) contains a Requester Module, while intermediate bridges and switches do not need to have any functions of the Bandwidth Manager since they will not participate actively in admission control.

When a Requester Module requests a reservation it initiates communication with its (centralised) Bandwidth Allocator. For larger subnets, a single Bandwidth Allocator may not be able to handle reservations for the entire subnet. In such case, it is necessary to deploy multiple Bandwidth Allocators, each managing the resources of a non-overlapping subset of segments.

In order to be able to reserve resources on appropriate segments, the Bandwidth Allocator must have some model of the Layer 2 topology of the subnet.

#### 4.3.4.2 Distributed Bandwidth Allocator

A Bandwidth Manager with a distributed Bandwidth Allocator implementation is shown in Figure 17.

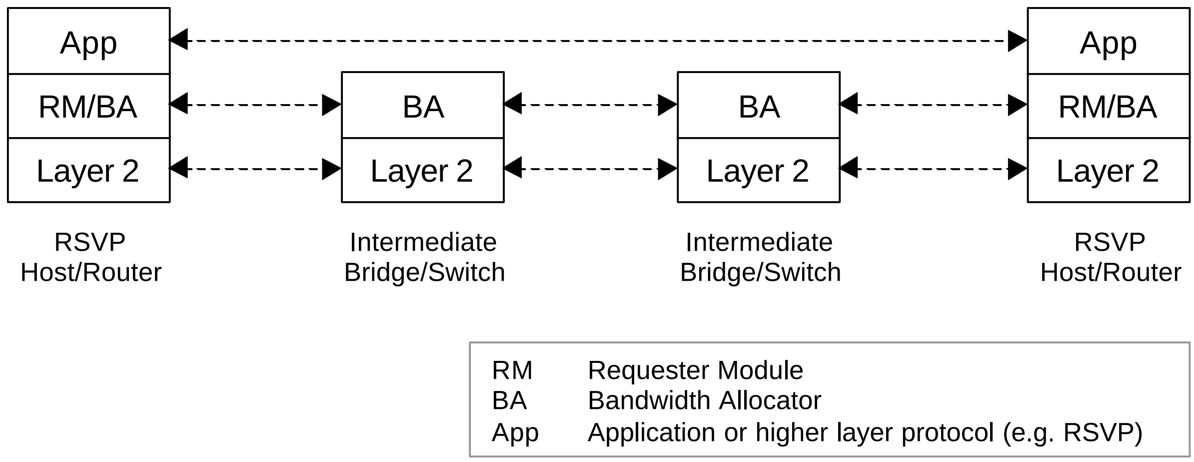



*Figure 17 Bandwidth Manager with a Distributed Bandwidth Allocator [IDISSL98]*

When a Bandwidth Manager with a distributed Bandwidth Allocator is used, all devices in the subnet have Bandwidth Manager functionality. Besides this fact, all end hosts are still required to have a Requester Module.

Unlike the centralised Bandwidth Allocator implementation of Section 4.3.4.1, all stations participate actively in admission control and each Bandwidth Allocator needs only local topology information since it is only responsible for the resources on the segment that is directly connected to it.

### 4.3.5 Model of the Bandwidth Manager in a Network

We now describe how the model of the Bandwidth Manager fits within the existing IETF Integrated Service model of IP hosts and routers. We first describe how the model is implemented in end stations (hosts / routers). Subsequently we describe the implementation in Layer 2 switches.

#### 4.3.5.1 End Station Model

An end station can be either a router or a host. In an end station there is a client handling QoS. For instance, the client runs an RSVP process which:

- Presents a session establishment to applications
- Signals over the network
- Programs a scheduler and classifier in the driver
- Interfaces to a policy control module

Figure 18 shows RSVP in a sending end station

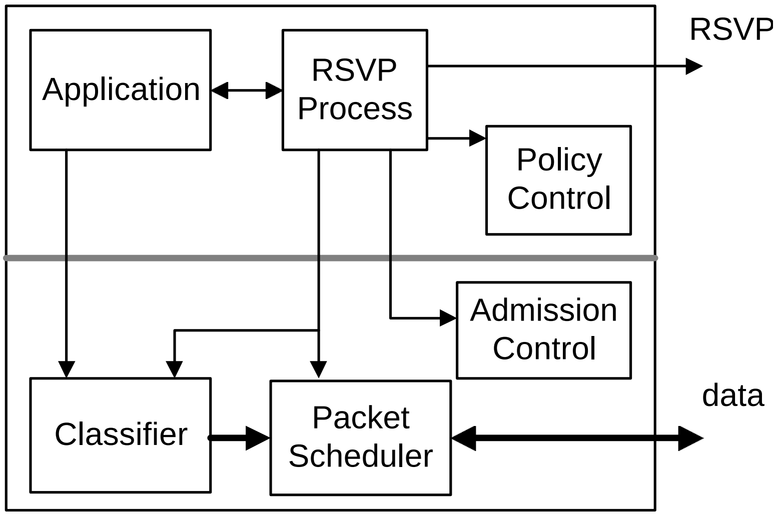



*Figure 18 RSVP in a sending End Station [IDISSL98]*

Because switches and bridges don't have Layer 3 functionality, the RSVP process must be translated to another process taking place at Layer 2. For this purpose ISSLL functionality is added to the sender and receiver end station. We explain this in the following subsections.

#### 4.3.5.1.1 Request to Layer 2 ISSLL

The local admission control entity (see Figure 18) within a host or router is responsible for mapping Layer 3 session establishment requests into Layer 2 language. The upper layer entity makes requests in the form:

["May I reserve for traffic with <traffic characteristic> with <performance requirement> from <here> to <there> and how should I label it?"]([IDISSL98])

#### 4.3.5.1.2 ISSLL at sending End Station

The ISSLL functionality in the sender (with relation to data flow) is depicted in Figure 19. The functions of the Requester Module may be summarised as follows:

- Maps the endpoints of the conversation to Layer 2 addresses in the LAN (may use ARP).
- Communicates with any Local Bandwidth Allocator module for local admission control decisions.
- Formats an SBM (Subnet Bandwidth Manager) request to the subnetwork with the mapped address and flow/filter specs.
- Receives a response from the subnetwork and reports the admission control decision to the higher layer entity along with any negotiated modifications to the session parameters.
- Saves any returned user_priority to be associated with this session in a "802 Header" table. This will be used when constructing the Layer 2 headers for future data packets belonging to this session.

The Bandwidth Allocator is only present when a distributed Bandwidth Allocator model is implemented.

Its function is basically to apply local admission control for the outgoing link bandwidth and driver's queueing resources.

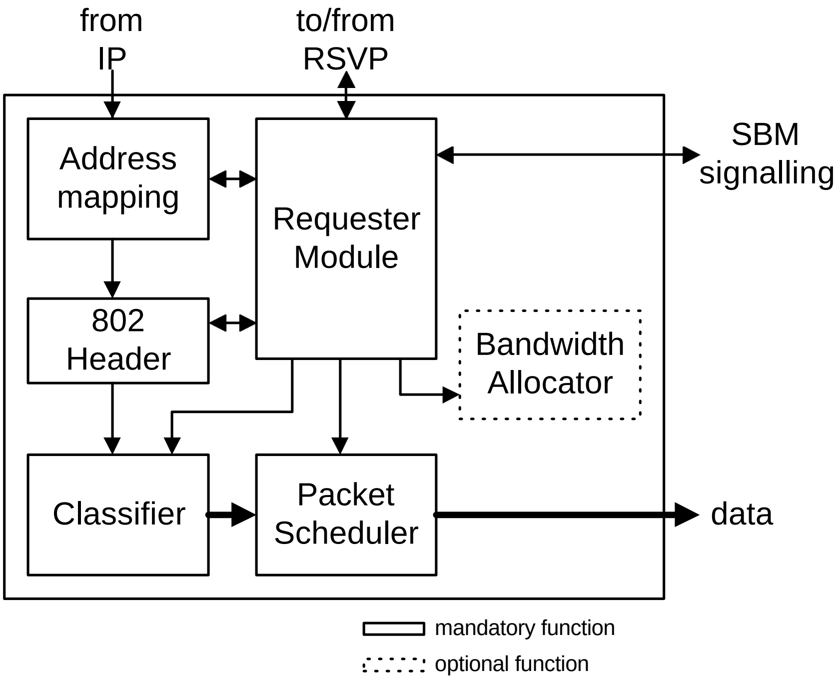



*Figure 19 ISSLL in a Sending End Station [IDISSL98]*

#### 4.3.5.1.3 ISSLL at receiver End Station

The ISSLL functionality in the receiving end station is shown by Figure 20.

The functions of the Requester Module may be summarised as follows:

- Handles any received SBM protocol indication.
- Communicates with any local Bandwidth Allocator for local admission control decisions.
- Passes indications up to RSVP if OK
- Accepts confirmations from RSVP (RESV messages) and relays them back via SBM signalling towards the requester
- May program a receive classifier and scheduler, if used, to identify traffic classes of received packets and accord them appropriate treatment (e.g. reservation of buffers for particular traffic classes).
- Programs the receiver to strip away link layer header information from received packets.

The Bandwidth Allocator, present only in a distributed implementation, applies local admission control to see if a request can be supported with appropriate local receive resources.

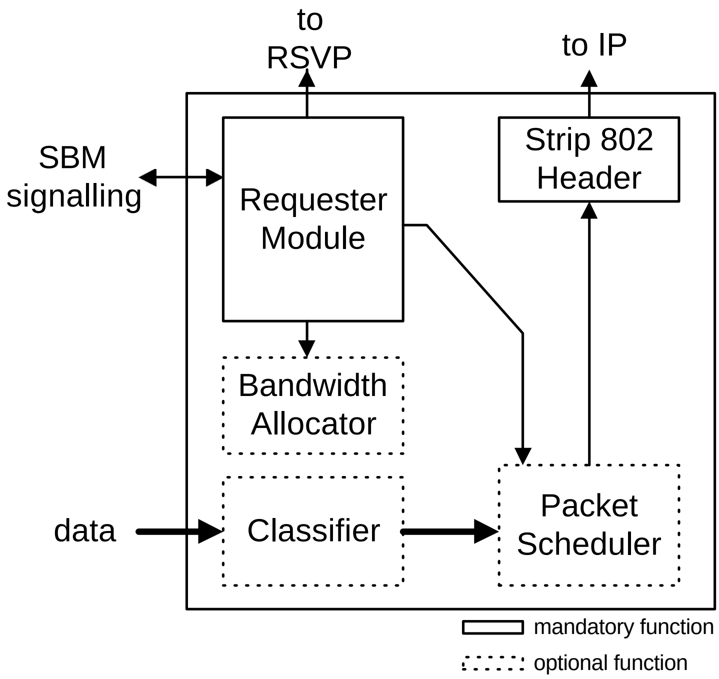



*Figure 20 ISSLL in a Receiving End Station [IDISSL98]*

#### 4.3.5.2 Switch[23] Model

When the Centralised Bandwidth Allocator Model is implemented, switches do not take part in the admission control process. A centralised Bandwidth Allocator (e.g. Subnet Bandwidth Manager) implements admission control.

This centralised Bandwidth Allocator may be co-located with a switch but its functions would not necessary then be closely tied with the switch's forwarding functions as is the case with a distributed Bandwidth Allocator where access to the switch's forwarding table is required (see SBM propagation module in this Section).

The ISSLL functions of a switch, in the case a distributed Bandwidth Allocator is used, are shown by Figure 21.

23 A switch is Layer 2 forwarding device as defined by IEEE 802.1D [IDISSL98]

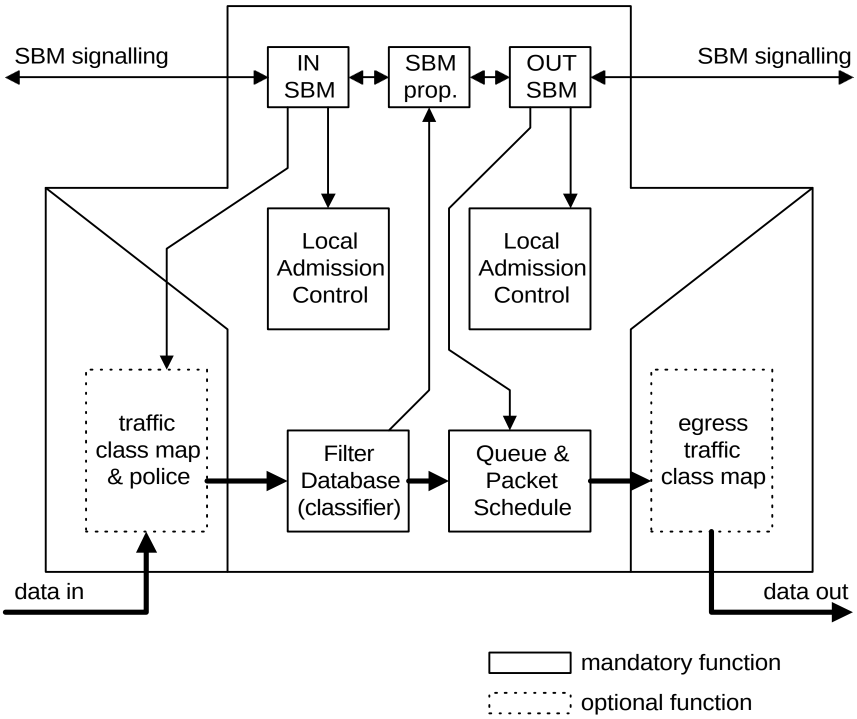



*Figure 21 ISSLL in a Switch*

The following entities can be defined within a switch:

- Local Admission Control Module:
  Accounts for the available bandwidth on the link attached to that port.

- Input SBM Module (IN SBM):
  One Instance on each port performs the “network” side of the signalling protocol for peering with clients or other switches.
  Holds knowledge about mapping of IntServ classes to user_priority.

- SBM Propagation Module (SBM prop.):
  Relays requests that have passed admission control at the input port to the relevant output ports’ SBM modules. This requires access to switch’s forwarding table (Layer 2 “routing table” cf. RSVP Model) and port spanning tree state.

- Output SBM Module (OUT SBM):
  Forwards requests to the next Layer 2 or Layer 3 hop.

- Classifier, Queue an Scheduler Module:
  The Classifier Module identifies the relevant QoS information from incoming packets and uses this, together with the normal bridge forwarding database, to decide at which output port and traffic class to queue the packet.
  The Queue and Scheduler hold the output queues for ports and provide the algorithm for serving the queues for transmission onto the output link in order to provide the promised IntServ service.

- Ingress Traffic Class Mapping and Policing (optional):

Default behaviour is to pass packets through unchanged.
May police the data within traffic classes for conformance to the negotiated parameters.
May discard packets or re-map the user_priority.

- Egress Traffic Class Mapping Module (optional):
  Default behaviour is to pass packets through unchanged.
  May perform re-mapping of traffic classes on a per output basis.

On receipt of an admission control request, a switch performs the following actions, using SBM as an example:

- If the ingress SBM is the "designated[24] SBM" (DSBM) for this link, it matches the requested service with the available traffic classes and chooses the "best" one. It ensures that, if this reservation is successful, the value of user_priority corresponding to that traffic class is passed back to the client. The ingress DSBM observes the current state of allocation of resources on the input port/link and then determines whether the new resource allocation from the mapped traffic class can be accommodated. If accepted, the request is passed to the SBM propagation module.

- If the SBM is not the "Designated SBM" for this link, then it directly passes the request on to the reservation propagator.

- The SBM propagation module relays the request to the bandwidth accountants on each of the switch's outbound links to which this reservation would apply. This implies an interface to routing/forwarding database.

- The egress local admission control module observes the current state of allocation of queueing resources on its outbound port and bandwidth on the link itself and determines whether the new allocation can be accommodated. This is a local decision which still can be refused by further Layer 2 hops through the network

- If the request is accepted by this switch, it is propagated on each output link selected. Any user_priority described in the forwarded request must be translated according to any egress mapping table. Furthermore, the switch must notify the client of the user_priority to be used for packets belonging to that flow. (Here, it is assumed that admission control succeeds; However, downstream switches may refuse the request)

- If this switch wishes to reject the request, it can do so by notifying the original client using its Layer 2 address.

### 4.3.6 Int-serv Mappings on IEEE 802[25]

We now describe the mapping of IP-level flows into appropriate IEEE user_priority classes. In order to perform this mapping, a multidimensional vector of parameters (e.g. bandwidth, delay, jitter and service class) must be mapped onto a set of user_priority traffic classes whose default behaviour in Layer 2 switches is unidimensional.

---

[24] In some cases, multiple SBMs will exist on a single Layer 2 segment. In such cases, one of those SBMs will be elected to become a designated SBM (DSBM). The DSBM is the active SBM on a segment. The other SBMs will serve as backup SBMs.

[25] The content of this section is mainly extracted from [IDISSMP99].

Table 11 presents the default mapping from delay targets to IEEE 802.1 user_priority classes.

| user_priority | Service |
|---|---|
| 0 | Default, assumed to be Best Effort |
| 1 | Reserved, less than Best Effort |
| 2 | Reserved |
| 3 | Reserved |
| 4 | Delay Sensitive, no bound |
| 5 | Delay Sensitive, 100ms bound |
| 6 | Delay Sensitive, 10ms bound |
| 7 | Network Control |

*Table 11 Example user_priority to service mappings*

Note that the mapping of Table 11 does not define what mechanisms or algorithms a network element must perform to implement these mappings.

### 4.4 Low-bitrate links

According to [IDISLBL99], up to now, newly developed services (e.g. Integrated Services) could not be used over forwarding paths that include low-bitrate links. The encapsulation formats used on these links are not appropriate for the simultaneous transport of arbitrary data and real-time information, which has to meet stringent delay requirements. Another problem concerning the in-time delivery of real-time packets arises if large packets cannot be pre-empted in order to allow the real-time packets to be sent. In addition, the header overhead associated with the protocol stacks used is prohibitive on low-bitrate links, where compression down to a few dozen bytes per real-time information packet is often desirable.

[IDISLBL99] describes an approach for addressing these problems. The main components of the architecture are:

- A real-time encapsulation format for asynchronous and synchronous low-bitrate links
- A header compression architecture optimised for real-time flows
- Elements of negotiation protocols used between routers (or between hosts and routers)
- Announcement protocols used by applications to allow this negotiation to take place.

[IDISLSN99] defines the mapping of Integrated Services “Controlled Load” and “Guaranteed Service” onto low-bandwidth links.

# 5 Wireless access technology requirements

## 5.1 Introduction

During the last decade, the number of wireless and mobile communication users has increased very fast as well as the number of Internet users.

Besides this increasing number of users, a convergence between mobile and wireless communication on one hand and the Internet on the other hand is perceptible. This convergence puts constraints on the wireless and mobile technologies used for accessing the Internet, especially when QoS is also to be provided to mobile and wireless users.

In this chapter the requirements that are posed on the underlying wireless link layer to provide a better service than that provided by Best-Effort service are identified. The requirements are not only identified from an Integrated Service point of view, but also from the Multi-Protocol Label Switching and Differentiated Services point of view. Each requirement is denoted by *Rx*.

First the requirements originating from the Multi-Protocol Label Switching (MPLS) architecture are discussed in Section 5.2. Next the requirements originating from the Differentiated Services architecture are presented in Section 5.3. Finally the requirements to support Integrated Services over wireless links are discussed in Section 5.4.

## 5.2 Multi-Protocol Label Switching

The Multi-Protocol Label Switching (MPLS) architecture integrates IP network layer routing with datalink layer label swapping [IDMPLS97], [IDMPLS99]. MPLS uses the best of both worlds to provide high speed IP networking. In the following it is assumed that the reader is familiar with the basic MPLS terminology. For an introduction to MPLS see [VISWA98], [ZEE99].

To identify the requirements MPLS puts on the underlying layer 2, the reader is reminded that MPLS integrates layer 3 and 2 functionality. Therefore it is difficult to separate layer 2 and 3 functionality. In the following, the requirements to support MPLS are identified, without discussing whether this is layer 2 or 3 functionality.

The basic requirements for a wireless access technology to support MPLS are:

*R1* Mapping of incoming IP packets, into the MPLS domain, at the Label Edge Router (LER) to a Forward Equivalence Class (FEC), and removal of labels for outgoing IP packets.

*R2* Establishment of Label Switched Paths (LSP) through network routing protocols. LSPs may be established through explicit routing or hop-by-hop routing. Sufficient facilities should be provided to detect or prevent loops in the LSP. Dependent on the routing capabilities, point-to-point, multipoint-to-point, point-to-multipoint and multipoint-to-multipoint LSPs may be established.

*R3* The Label Switched Router (LSR) needs to support label swapping for forwarding incoming packets. When hierarchical routing is supported, the LSR needs to support label stacking. To support multipoint-to-point LSPs, the LSR need to support label merging.

*R4* The LSR needs to execute the procedures listed in the Next Hop Label Forwarding Entry (NHLFE) e.g. next hop determination, decrementing TTL, etc.

| Uppgjord (även faktaansvarig om annan) - *Prepared (also subject responsible if other)* | | Nr - *No.* | | |
|---|---|---|---|---|
| Martin van der Zee (EMN) / Rachid Ait Yaiz (UT) | | 2/0362-FCPNB 102 88 Uen | | |
| Dokansv/Godk - *Doc respons/Approved* | Kontr - *Checked* | Datum - *Date* | Rev | File |
| EMN/K/A Geert Heijenk (5430) | | 1999-07-09 | B | |

*R5* The LSR needs to support label distribution, through the use of a Label Distribution Protocol (LDP). The label mapping information is stored in the Label Information Base (LIB).

## 5.3 Differentiated Services

The Differentiated Services (DS) architecture [RFC2475] is proposed as a response to the scalability limitations of the Integrated Services (IS) concept [RFC1633]. The DS architecture reduces the state information stored in the network, compared to IS, by providing QoS services for a limited number of classes. The QoS class is indicated by the Differentiated Service byte (DS-byte) contained in the header of each IP packet. In the following it is assumed that the reader is familiar with the basic DS terminology.

Requirements Differentiated Services put on the wireless access network:

*R1* Service Level Agreements (SLA) need to be established between wireless access network and interconnection network. An SLA may be either static or dynamic.

*R2* Marking of IP packets, i.e. setting the DS-byte. Possibly the source marks the packets but at least the ingress node needs to (re)mark the packets.

*R3* Classification, policing and (re)shaping incoming traffic, into the DS domain, at the ingress node based on the SLA.

*R4* An admission control function for resource requests, in case of dynamic SLAs and Bandwidth Brokers (BB).

*R5* Implementation of the Per-Hop-Behavior (PHB), as defined by the DS architecture. The PHBs are explained in more detail below.

The basic building block of the Differentiated Services (DS) concept, which provides service differentiation, is the packet forwarding treatment. This packet forwarding treatment is defined by the Per-Hop-Behavior (PHB) of the DS service. The PHB defines the externally observable forwarding behavior packets with the same DS-byte exhibit when forwarded by a DS node. Two PHB proposals have reached the status of standards track RFCs: Expedited Forwarding (EF) [RFC2598], formerly referred to as Premium service [IDDIFF97], and Assured Forwarding (AF) [RFC2597]. Any wireless access network, part of a Differentiated Services domain, should support at least one of these PHBs.

<u>Expedited Forwarding</u>

The Expedited Forwarding (EF) PHB is suitable for applications requiring low delay and low jitter services. Examples of these applications are Internet Telephony, videoconferencing, or Virtual Private Networks (VPN)). The EF PHB does not provide quantified guarantees on jitter or delay, but these parameters are assumed to be sufficiently low, to support these applications.

The EF service is based on two assumptions: the traffic entering the DS domain is conditioned (i.e. policing and shaping is applied at the ingress node) and there is a minimum departure rate of the EF traffic at each intermediate DS compliant node. These two assumptions are the basis to provide low delay and low jitter service. EF traffic, upon arrival at an intermediate node, should always see an (almost) empty queue. As a result, the average queue length on the end-to-end path is kept small.

Possibly the percentage of EF traffic in the network is kept low, through proper use of Service Level Agreements and traffic policing, to provide low delay, low jitter and assured bandwidth. However, unevenly distributed traffic may cause bottlenecks in some parts of the network, which may be removed by traffic engineering or constraint-based routing [ZEE99].

Assured Forwarding

The Assured Forwarding (AF) PHB is suitable for applications requiring better than best-effort service. Assured service is suitable for adaptive applications, which can tolerate some loss, and applications requiring assured level of transmission over a long period of time. The AF PHB group provides delivery of IP packets in four independent forwarded AF classes (class 1 until 4) [RFC2597]. Node resources, such as buffer space and bandwidth, are reserved for a single class. Packet ordering is preserved within a single class. Within a single class, three drop precedence values can be assigned.

The AF service aims to provide service characteristics, as experienced in a lightly loaded network. More precisely: an AS profile is characterised by an (average) bitrate and a token bucket burst filter. Traffic that conforms to the AS profile is denoted as in-profile traffic, otherwise it is denoted as out-of-profile. The AF PHB assures that in-profile traffic will experience service similar to a lightly loaded network. Out-of-profile traffic is (re)marked at ingress node to a PHB which is more eligible to packet drop, compared to in-profile traffic.

## 5.4 Integrated Services

### 5.4.1 General requirements

The general requirements, Integrated Services pose on the underlying link technology, are perfectly expressed by the ISSLL working group. The ISSLL working group has identified four points that must addressed for each candidate technology:

[...

- **Service mappings.** Service mappings define the way that the link layer technology is used to provide a particular IntServ traffic management service, such as controlled-load or guaranteed-delay.
- **Setup protocol mappings**. Setup protocol mappings define how an internet- level setup protocol such as RSVP is implemented or mapped onto the link layer technology.
- **Adaptation protocols**. Adaptation protocols are used to augment the native capabilities of the link-layer technology, when this is necessary to support required Integrated Services functions.
- **Statements of non-applicability**. Statements of non-applicability describe which Integrated Service capabilities are not supported by the link layer technology under consideration.

...] ([ISSLL99])

### 5.4.2 Detailed requirements

Applications can be roughly divided into elastic applications, which tolerate variable delays and real-time applications, which require the delay to be bounded. The Integrated Services model has been introduced to support this kind of application.

In order to provide Integrated Services, a Resource reSerVation Protocol (RSVP) running on IP level is used to make reservation at intermediate routers, which in their turn treat specific data flows in a manner that the desired end-to-end QoS is reached (see Section 3). For this purpose an intermediate router uses classifiers, packet schedulers, admission control and policing. The ability of a wireless access technology to the Internet (wireless access technology from now on) to provide Integrated Services depends heavily on the ability of the wireless access technology to implement these functions.

This subsection describes the requirements on the wireless access technologies to be used with the Internet such that the Integrated Service model can be used.

#### 5.4.2.1 Resource Reservation

QoS is provided by means of resource reservation in intermediate routers along the path from sender to receivers. If a wireless access technology is used to gain access to the Internet, it must be able to reserve resources. Only then Integrated Services can be supported.

Because the Integrated Services model allows for unicast and multi-cast reservations, the wireless access technology must also be able to do such reservations.

Once a reservation has been made, end users must have the ability to renegotiate for a different QoS. In other words, the wireless access technology must be able to change its reservation during a session. On the other hand, when the wireless link is becoming bad, the wireless access technology must be able to inform the end users, after which the end users can take appropriate decisions.

*Q1* Is the wireless access technology able to reserve resources?

*Q2* Is the wireless access technology able to do both multicast and unicast reservations?

*Q3* Is the wireless access technology able to change its reservation (style and requested resources) during a session?

#### 5.4.2.2 Admission Control

In order to decide whether or not to admit a session, the wireless access technology must be able to estimate the level of resources needed to meet the QoS requested by the session.

These estimations must be used together with knowledge of, or the estimation of the available resources in order to decide whether the request can be granted or not.

The wireless access technology must also support mobility. In relation to admission control, the wireless access technology must be able to find out if a negotiated QoS can be guaranteed when handovers are likely to take place. Of course, the negotiating access point (e.g. base station) together with the surrounding access points must make this decision.

When negotiating a QoS, end-users may want to know how much resource is available in order to make an appropriate reservation. To make this possible, the wireless access technology must be able to response to queries about availability of resources.

When a wireless access technology provides the ability of resource management, this can be gratefully used by the Admission Control entity to reserve the requested resources if the request is granted.

The Integrated Service model defines two services: Guaranteed Service and Controlled Load. In order to fully support the Integrated Services model, the wireless access technology must be able to provide admission control for the different types of services defined in the Integrated Services model. In order to support Guaranteed Service, the wireless access technology must be able to guarantee an upper bound for the delay experienced by flows belonging to that type of service.

*Q4* Is the wireless access technology able to estimate the level of resources needed to meet the QoS requirements, knowing that there is a non-perfect link layer?

*Q5* Does the wireless access technology support mobility? For instance, is the wireless access technology able to predict the bandwidth needed by immigrating users, with a QoS contract, moving from an adjacent cell to the cell in consideration?

*Q6* Is the wireless access technology able to respond to queries about available resources?

*Q7* Is the wireless access technology able to guarantee an upperbound for the delay (Guaranteed Service)?

#### 5.4.2.3 Flow Separation and Scheduling

When providing Integrated Services, real-time flows can be given preferential treatment over best-effort flows. A necessary requirement to be able to give such a preferential treatment is the ability to distinguish between real-time traffic and non real-time traffic. Besides this distinction, the wireless access technology must isolate packets of the distinguished flows from each other and schedule them according to their requirement.

Power-saving mechanisms are very important to consider when providing wireless communication. The scheduling algorithms to be defined in relation to the provisioning of QoS must function in the presence of power-saving mechanism.

*Q8* Is the wireless access technology able to distinguish between flows belonging to different service classes?

*Q9* Does the wireless access technology offer opportunities to implement scheduling?

*Q10* Does the wireless access technology use power-saving techniques?

#### 5.4.2.4 Policing and shaping

To ensure conformance of traffic to negotiated traffic parameters, the wireless access technology must shape and/or police the traffic.

An important consideration is where to settle the policing function. If it is settled at the border of the core network, the wireless medium may suffer from non-conformant traffic.

Because resources at the wireless medium are very scarce, it is recommended that the policing function be performed in the wireless access point. Another motive to implement the policing function in the wireless access point is that wireless users can not always be trusted as far as conformance to the negotiated traffic parameters is considered. However, it is not always possible to implement the policing function at the wireless access points. The reason for this is that there are wireless technologies where a user is allowed to send data without getting permission[26] from his access point.

*Q11* Is policing in the wireless access point possible?

[26] It is assumed that authentication already took place

*Q12* Does the wireless access technology offer opportunities to implement shaping?

#### 5.4.2.5 Soft State

The Integrated Services model uses the concept of soft states in which the information about actual reservations is maintained.

When implementing the Integrated Services model in a wireless access technology, the latter must be able to maintain soft state information. This information must be refreshed periodically; otherwise the reservation corresponding to that information will expire.

*Q13* Does the wireless access technology offer opportunities to maintain soft states?

#### 5.4.2.6 Scalability

The wireless access technology supporting Integrated Services should scale to the largest expected number of users.

This is necessary because every user may require a different treatment for his traffic. Fortunately the number of simultaneous users within a wireless access technology is limited.

*Q14* Is the wireless access technology scalable to the largest possible number of users when implementing Integrated Services?

#### 5.4.2.7 Fault Tolerance and Recovery

The wireless access technology must function under the presence of failures. When, due to a bad link, refresh messages are not received this should not lead to a reservation termination.

Because the wireless link is a link with time-variant characteristic (i.e. fading etc.), the wireless access technology informing the end users about the changes in the wireless-link characteristics is desirable. Doing this, the end users may take precautions (e.g. re-routing of their traffic) in order to avoid the QoS requirements not to be met.

When developing a model for providing Integrated Services over a wireless access technology, it must be developed such that failure of a single wireless access point (base station) does not adversely affect the proper working of the model. For instance, even in a centralized BM implementation, let multiple network elements, within the same segment, have BM functionality. In that case, if the current BM fails, another network element (with BM functionality) can take the BM tasks over.

*Q15* Is the wireless access technology able to inform end users about the quality of the link?

*Q16* Is the wireless access technology able to select a particular route in the case where repeaters are used?

#### 5.4.2.8 Independence from Higher Layer Protocol

The wireless access technology supporting Integrated Services must function independent of higher layer protocols like RSVP. In other words, It is desirable that the wireless access technology functions well even when other resource reservation protocols than RSVP are used.

*Q17* Is the wireless access technology able to provide Integrated Services even when other resource reservation protocols are used?

#### 5.4.2.9 Receiver Heterogeneity

It is desirable that the wireless access technology is able to provide different QoS, concerning the same flow, for different receivers. For instance, one user within a multi-cast group may request best-effort service, while another user may request guarantees. This may be the case when wireless users are connected to different wireless access points (base station).

*Q18* Is the wireless access technology able to provide different QoS, concerning the same flow, for different receivers?

#### 5.4.2.10 Support for different Filter Styles

RSVP defines three different filter styles (see Section 3.3): Fixed Filter (FF) where one specific sender is specified, Shared Explicit (SE) filter where any of two or more senders are specified and Shared Wildcard filter where any sender in a group is selected. It is desirable that the wireless access technology supports these filter styles.

*Q19* Is the wireless access technology able to support the different filter styles?

# 6 Conclusions

The Integrated Service (IS) architecture provides quantitative QoS guarantees with per flow granularity. Furthermore, it offers the ability to signal QoS requirements end-to-end through the Resource Reservation Protocol (RSVP). These are two characteristics of the IS architecture which make it attractive. However the IS architecture suffers from scalability limitations which prohibits ubiquitous deployment.

Certain requirements are posed on the underlying layer two technology to support IS. The solutions to support IS, that have emerged from the ISSLL working group, have been described for two technologies in more detail: ATM and IEEE 802 LAN. Each solution is differently dependent on the QoS features supported by the layer 2 technology itself. ATM has a rich QoS architecture that makes it possible to chose between different options. Unlike IEEE 802 LAN technologies, which have limited QoS features, extensions are defined to enhance the technology with primary QoS functions.

The requirements on an underlying wireless technology to support IS have not been studied by the ISSLL working group yet. In this document the requirements on a wireless technology have been identified. Wireless links have characteristics which differentiate them from fixed links, such as high packet loss rate, burst of packet loss, packet re-ordering, high packet delay and packet delay variation. Furthermore the wireless link characteristics are not constant but may vary in time and place. The mobility of the user poses additional requirements, when the subscriber changes its point of attachment. When a user changes its point of attachment the end-to-end path is changed. A user expects to receive the same QoS after he has changed his point of attachment. This implies that the new end-to-end path should also supports the existing QoS i.e. a reservation on the new path is required. A problem arises when the new path cannot support the required QoS.

Further study of wireless technologies is needed to identify solutions to support IS. Each technology has its own characteristics and may have build-in QoS features, which may call for a different solution.

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## 6.2 By category

### 6.2.1 Internet Drafts

<u>Differentiated Services</u>

A Two-bit Differentiated Services Architecture for the Internet [IDDIFF97] (architecture)

<u>ISSLL</u>

A Framework for Providing Integrated Services Over Shared and Switched IEEE 802 LAN Technologies [IDISSL98] (framework)

Integrated Service Mappings on IEEE 802 Networks [IDISSMP99]

Providing Integrated Services Over Low-bitrate Links [IDISLBL99](specification)

Integrated Services Mappings for Low Speed Networks [IDISLSN99](specification)

<u>Multi-Protocol Label Switching</u>

A Framework for Multiprotocol Label Switching [IDMPLS97] (framework)

Multiprotocol Label Switching Architecture [IDMPLS99](architecture)

### 6.2.2 RFCs

<u>Integrated Services</u>

Integrated Services in the Internet Architecture: an Overview [RFC1633] (overview)

Resource ReSerVation Protocol (RSVP) [RFC2205](specification)

Resource ReSerVation Protocol (RSVP) Version 1 Applicability Statement Some Guidelines on Deployment [RFC2208](recommend.)

Resource ReSerVation Protocol (RSVP); Version 1 Mesage Processing Rules [RFC2209](specification)

The Use of RSVP with IETF Integrated Services [RFC2210] (overview

Specification of the Controlled-Load Network Element Service [RFC2211] (specification

Specification of Guaranteed Quality of Service [RFC2212](specification)

General Characterization Parameters for Integrated Service Network Elements[RFC2215](specification)

<u>ATM</u>

Support for Multicast over UNI 3.0/3.1 based ATM Networks [RFC2022](specification)

Classical IP and ARP over ATM [RFC2225](specification)

Interoperation of Controlled-Load Service and Guaranteed Service with ATM [RFC2381](specification)

A Framework for Integrated Services and RSVP over ATM [RFC2382] (framework)

<u>Differentiated Services</u>

Definition of the Differentiated Services Field (DS Field) in the IPv4 and IPv6 Headers [RFC2474](specification)

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### 6.2.4 ITU

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| Traffic control and congestion control in B-ISDN | [I.371] | (specification) |

### 6.2.5 Reports, articles and books

<u>ATM</u>

| | | |
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| A Service Architecture for ATM: From Applications to Scheduling | [GARRET96] | (overview) |
| ATM Theory and Application | [McDysan95] | (book) |

<u>LAN</u>

| | | |
|---|---|---|
| Local & Metropolitan Area Networks | [STAL97] | (book) |

<u>MPLS</u>

| | | |
|---|---|---|
| Evolution of Multiprotocol Label Switching | [VISWA98] | (overview) |

<u>Integrated Service</u>

| | | |
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| RSVP and Integrated Services in the Internet: A Tutorial | [WHITE97] | (overview) |
| RSVP: A New Resource ReSerVation Protocol | [ZHANG93] | (overview) |

<u>QoS routing</u>

| | | |
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| Quality of Service Routing | [ZEE99] | (specification) |

<u>Scheduling</u>

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| Random Early Detection gateways for Congestion Avoidance | [FLOYD93] | (evaluation) |
| Link-sharing and Resource Management Models for Packet Networks | [FLOYD95] | (evaluation) |
| Service Disciplines For Guaranteed Performance Service in Packet-Switching Networks | [ZHANG95] | (evaluation) |
| A Generalized Processor Sharing Approach to Flow Control in Integrated Services Networks | [PAREKH93] | (evaluation) |

# 7 Appendix A Patents

The results of a search for patents in the area of Quality of Service provided by wireless links are presented. First the patent database is explained shortly, next the search results are presented.

## 7.1 Introduction

The Ericsson Patent database is an easily accessible reference to current patent literature based upon the Derwent Information World Patent Index database (DWPI) [PATENT99].

The database contains abstracts of published patents and patent applications from 70 countries and patenting authorities, covering the period from 1975 to the present day. These patent abstracts describe physics, electrical engineering and electronic engineering. These categories ensure that all telecommunications technologies will be included.

Each patent abstract makes reference to an engineering drawing or image, which, if available, is displayed in line with the text of the document.

There are currently about 3.5 million records in the database, increasing by 5 000-10 000 new documents each week. This makes the database arguably one of the largest single intranet databases in Europe at the present time. The total volume of text and images is approximately 22GB (as of Jan 1998).

## 7.2 Search results

Several text based searches have been carried out to evaluate the number of patents w.r.t. Quality of Service provided by wireless links.

The **(**WIRELESS **AND** QUALITY **AND** PACKET**)** query provided 36 results from which the following have found relevant:

Document 2 PAN 99-302821

| | |
|---|---|
| Derwent Title | Wireless ATM network system e.g. for medium access control protocols and transmission scheduling in cell switched networks |
| Patentee details | NETRO CORP;( NETR ) |
| Inventor names | AARONSON I; BEN-EFRAIM G; PASTERNAK E |
| Abstract | NOVELTY - A base station transmits and receives from terminals over a shared medium, where the base station includes a scheduler which regulates the upstream flow of cells by broadcasting grants with permission to transmit. Bandwidth requests from the terminals include information identifying the requesting virtual circuit. DETAILED DESCRIPTION - An INDEPENDENT CLAIM is included for a subscriber terminal, a base sector controller subsystem, a method of generating requests in packet switched network, a structure for generating requests in a packet switched network, a method of processing requests in a packet switched network, a structure for processing requests in a packet switched network, a method of processing grants in a packet switched network, a structure for processing grants in a packet switched network, and a method of multiplexing multiple terminals in a distributed network. |
| Use Advantage | For medium access control protocols and transmission scheduling in shared media point to multipoint cell switched networks. Provides high quality of service scheduling. DESCRIPTION OF DRAWING(S) - The figure shows the topology of a wireless point to multipoint network of a type suitable for use in a city in accordance with one embodiment of the invention. |
| Title Terms | wireless atm network system medium access control transmission schedule cell switch network |

Document 4 PAN 99-143363

| | |
|---|---|
| Derwent Title | Mobile communication method for e.g. wireless personal computer by establishing a packet session where several application flows are communicated with an external network entity, and corresponding, potentially different, quality of service parameters are defined for each flow |
| Patentee details | TELEFONAKTIEBOLAGET ERICSSON L M;( TELF ) |
| Inventor names | FORSLOEW J E |

| | |
|---|---|
| Abstract | NOVELTY - The mobile communication method for e. g. wireless personal computer involves establishing a packet session where several application flows are communicated with an external network entity. Corresponding, potentially different, quality of service parameters are defined for each flow. |
| Use Advantage | The mobile communication system is used for e. g. wireless personal computer, mobile office, electronic funds transfer, road transport telemetry, field service business, fleet management etc. For applications with "bursty" traffic. Allows different quality of service parameters to be defined and reserved for different application flows. DESCRIPTION OF DRAWING(S) - The drawing shows a detailed diagram with a GSM mobile communications system including a general packet radio service (GPRS) data network. |
| Title Terms | mobile communicate method wireless person computer establish packet session apply flow communicate external network entity correspond potentially quality service parameter define flow |

Document 5 PAN 97-089620

| | |
|---|---|
| Derwent Title | Wireless ATM system multiservices MAC protocol supports constant bit rate, variable bit rate and available bit rate services as well as connectionless packet and connection oriented virtual services |
| Patentee details | NEC CORP; NEC USA INC;( NIDE ; NIDE ) |
| Inventor names | RAYCHAUDHURI D; XIE H; YUAN R |
| Abstract | The wireless ATM communication system includes a base station and at least one remote station via a wireless link. A medium access controller controls the transmission of data packet between a base station and the remote station via a wireless link. A channel is framed into T1 units subdivided into Bm byte slots where downlink transmission are TDM multiplexed in a single burst from the base station to the remote station and uplink transmissions use a dynamic TDMA methodology for slot allocation from the remote station to the base station. Preferably, the TDMA slot allocation for available bit rate data is a one-time allocation of k TDMA slots for each frame, where k is an integer. |
| Use Advantage | Provides relatively transparent multiservices capability similar to ATM over inherently shared wireless medium. Supports several services with reasonable quality of service parameters. |
| Title Terms | wireless atm system mac protocol support constant bit rate variable bit rate available bit rate service well packet connect orient virtual service |

Document 15 PAN 98-042518

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|---|---|
| Derwent Title | Reservation-based wireless packet switched ATM local area network using medium access control layer with protocol for dividing MAC based communications between control and data channels and allocating data channel bandwidth to each service |
| Patentee details | PHILIPS ELECTRONICS NV; PHILIPS NORDEN AB; PHILIPS ELECTRONICS NORTH AMERICA CORP;( PHIG ; PHIG ; PHIG ) |
| Inventor names | HULYALKAR S; NGO C Y; HULYALKAR S N |
| Abstract | The local area network (LAN) has a means for supporting several services, having their own quality-of-service requirements, and means for implementing a medium access control (MAC) layer using a reservation-based communications protocol. The protocol divides all of the MAC based communications between a control and a data channel, which together comprise a control-data superframe. The protocol uses the control channel for allocating a data channel bandwidth to each service. The control channel has a control frame during which allocation of data channel data payload slots is determined according to long-term strategy corresponding to a time of service required to complete a service over multiple control-data superframe frames, and a short-term strategy corresponding to instantaneous data payload slot requirements for a particular service. |
| Use Advantage | Enables system users to reserve space for their respective services and transmissions, within wireless network. Achieves respective quality-of-service requirements for each service. |
| Title Terms | reserve based wireless packet switch atm local area network medium access control layer protocol divide mac based communicate control data channel allocate data channel bandwidth service |

## The (GPRS) query provided 27 results from which the following are found relevant:

Document 5 PAN 99-167697

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|---|---|
| Derwent Title | Transmission system for mobile communications network has resource request transmitted in forwards direction from mobile station evaluated at base station for modification of resources distributed to mobile station |
| Patentee details | SIEMENS AG;( SIEI ) |
| Inventor names | MENZEL C |
| Abstract | The transmission system has packet-oriented time-critical information transmitted between a base station (BS) and a mobile station (MS) of a mobile communications network, using a logic connection. The mobile station transmits a resource request in the forwards direction without previous assignment of a transmission time point by the base station, evaluated at the base station for modification of the distribution of resources for the mobile station. |
| Use Advantage | For time division multiple access mobile communications network with GPRS packet data service. Allows transmission of large quantity of data. |
| Title Terms | transmission system mobile communicate network resource request transmit forward direction mobile station evaluate base station modified resource distribute mobile station |

Document 8 PAN 99-143363

| | |
|---|---|
| Derwent Title | Mobile communication method for e.g. wireless personal computer by establishing a packet session where several application flows are communicated with an external network entity, and corresponding, potentially different, quality of service parameters are defined for each flow |
| Patentee details | TELEFONAKTIEBOLAGET ERICSSON L M;( TELF ) |
| Inventor names | FORSLOEW J E |
| Abstract | NOVELTY - The mobile communication method for e. g. wireless personal computer involves establishing a packet session where several application flows are communicated with an external network entity. Corresponding, potentially different, quality of service parameters are defined for each flow. |
| Use Advantage | The mobile communication system is used for e. g. wireless personal computer, mobile office, electronic funds transfer, road transport telemetry, field service business, fleet management etc. For applications with "bursty" traffic. Allows different quality of service parameters to be defined and reserved for different application flows. DESCRIPTION OF DRAWING(S) - The drawing shows a detailed diagram with a GSM mobile communications system including a general packet radio service (GPRS) data network. |
| Title Terms | mobile communicate method wireless person computer establish packet session apply flow communicate external network entity correspond potentially quality service parameter define flow |

Document 14 PAN 99-081577

| | |
|---|---|
| Derwent Title | Time division multiple access radio system operation method for mobile telephone by allocating greater number of time slots in each downlink TDMA frame than to each uplink TDMA frame to mobile station |
| Patentee details | NOKIA MOBILE PHONES LTD;( OYNO ) |
| Inventor names | HAEMAELAEINEN J; JAERVINEN P; KNUUTILA J; LEPPISAARI A; MALMIVIRTA K; OKSALA J; SALMINEN A |
| Abstract | The method of operating a time division multiple access (TDMA) radio system with multi-slot capabilities and using half-duplex transmission/reception where uplink and downlink user data transmissions between a mobile station and a base station are made in separate TDMA frames, involves allocating a greater number of time slots in each downlink TDMA frame than in each uplink TDMA frame, to the mobile station. The TDMA frames alternate between reception and transmission frames. The TDMA radio system utilises the GPRS protocol or the HSCSD protocol. |
| Use Advantage | Reduces power consumption of mobile phone by reducing number of slots which it transmits in. |
| Title Terms | time divide multiple access radio system operate method mobile telephone allocate greater number time slot tdma frame tdma frame mobile station |

Document 17 PAN 98-543166

| | |
|---|---|
| Derwent Title | radio resource to mobile stations allocating for up-link transmission in a packet radio system uses unallocated up-link counter block identifier in down- link blocks corresponding to blocks reserved using second allocation alternative |
| Patentee details | NOKIA TELECOM OY;( OYNO ) |
| Inventor names | MUSTAJARVI J; MUSTAJAERVI J |
| Abstract | The method involves allocating a radio resource to a mobile station (MS) in such a way that in a first allocation alternative the radio resource is allocated using an up-link counter block identifier (USF) transmitted with down-link blocks. In a second allocation alternative the radio resource is allocated in a separate signalling message that denotes a radio block which the mobile station is to use for an up-link transmission. E.g., when the second allocation alternative is used, the network (BSS) leaves at least one up-link counter block identifier (USF) unallocated to any mobile station (MS). The network (BSS) uses the unallocated up-link counter block identifier (USF) in down-link blocks corresponding to blocks reserved using the second allocation alternative. |
| Use Advantage | In a general packet radio service (GPRS) system. Easy to implement in way that after active P-bit, mobile station waits for fixed number of blocks before up-link transmission. Maximises number of up-link counter block identifiers that can be used. |
| Title Terms | radio resource mobile station allocate up link transmission packet radio system up link counter block identify down link block correspond block reserve second allocate alternative |

Document 22 PAN 98-271528

| | |
|---|---|
| Derwent Title | Radio system operation method involves suspending packet data service while remaining logged on to radio system by sending suspend service message from mobile switching venter to servicing data service support node |
| Patentee details | MOTOROLA INC;( MOTI ) |
| Inventor names | GILCHRIST P; NAPER H P |
| Abstract | The radio system operation method involves logging on to a radio system using a remote station. Packet data service is established between the remote station and a serving data service support node. Packet data service is suspended while remaining logged on to the radio system by sending a suspend service message from the mobile switching center to the serving data service support node. The serving data service support node signals the mobile switching center that packet data service is suspended. |
| Use Advantage | For radio systems with data capability, e. g. GSM cellular radio system with GPRS capability. |
| Title Terms | radio system operate method suspension packet data service remaining log radio system send suspension service message mobile switch vent service data service support node |

The **((**WIRELESS **ADJ** LAN**)** **AND** VOICE**)** query provided 4 results from which the following are found relevant:

Document 3 PAN 97-468613

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|---|---|
| Derwent Title | Radio communication system using frequency hopping for e.g. wireless LAN has radio communication terminal that allows simultaneous transfer of voice information and data through voice and data channels, respectively |
| Patentee details | CANON KK;( CANO ) |
| Inventor names | No data available, please see the help files for more information |
| Abstract | The system has a system control channel through which a frame used in radio communication is synchronised. Circuit control information containing a circuit disconnection, are transferred through a circuit control channel. Voice information and data are transferred through voice and data channels, respectively. A radio communication terminal allows simultaneous voice and data communication. |
| Use Advantage | Effectively enables one radio communication terminal to simultaneously perform voice and data communication. |
| Title Terms | radio communicate system frequency hop wireless lan radio communicate terminal allow simultaneous transfer voice information data through voice data channel respective |

The **((**WIRELESS **ADJ** LAN**)** **AND** QUALITY**)** query provided 27 results from which none relevant.

The **(**WCDMA**)** query provided 1 result from which none relevant.

The **(**UMTS**)** query provided 33 result from which the following are found relevant:

Document 5 PAN 99-314109

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|---|---|
| Derwent Title | Resource assignment method for radio communications system using control arrangement to determine actual condition which corresponds to current capacity usage value and current traffic mixture value, and adjusting assignment of radio communication resources to resource distribution value |
| Patentee details | SIEMENS AG;( SIEI ) |
| Inventor names | SCHINDLER J |
| Abstract | The method involves assigning resources to connections of a radio interface in a radio communications system. At least one nominal condition (Zl) and discreet actual conditions (Z', Z'', Z''') are determined through individual combinations of capacity usage values (L) and traffic mixture values (Mix) of the resources. An arrangement (RRM) for the radio resource management contains a memory arrangement (SP) for storing at least one resource distribution value (S1) for the nominal condition, and a control arrangement (SE). The control arrangement determines the actual condition which corresponds to a current capacity usage value (L') and a current traffic mixture value (Mix'), and adjusts the assignment of radio communication resources to a resource distribution value (S1). |
| Use Advantage | E.g. for UMTS. Reduces frequency of rearrangement of radio communication resources and corresponding signalling. |
| Title Terms | resource assign method radio communicate system control arrange determine actual condition correspond current capacity value current traffic mixture value adjust assign radio communicate resource resource distribute value |