Simple Integrated Media Access (SIMA)

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Abstract

The basic objectives of future Internet are to increase the network capacity, to offer a practical real-time service, and to develop a feasible charging scheme. These objectives introduce very strict requirements for the traffic control system. This document presents a new simple approach for traffic management: Simple Integrated Media Access (SIMA) service. According to the SIMA concept each customer shall define only two issues before a connection establishment: a nominal bit rate (NBR) and the selection between real-time and non-real-time service classes. NBR has two purposes: it forms the basis of charging, and it defines how the network capacity is divided among different connections during overload situations. Simplicity means that, on the one hand, the network operator does not guarantee the continuous availability of nominal bit rate, and on the other hand, the user is allowed to send data with any bit rate independently of the NBR. However, the bit rate of transmission defines the cell loss probability in the case of network congestion. In this way a simple, but effective, self-regulation of traffic can be realized. The strength of SIMA lies in its wide area of applications. There is no need to build complex systems with several service classes each appropriate to only certain applications.
1. Introduction

The Internet is at a phase of great changes. There are several stringent new requirements for the network because of two reasons: the invasion of new users, and the rapid development of new applications. These requirements mean that network capacity must rapidly be increased, real-time service has to be fundamentally improved, and a feasible charging scheme must be introduced.

The current Internet approach for meeting these requirements consists of several service specifications, Resource Reservation Protocol, QoS routing, etc. We can make an interpretation on the basis of the service specifications that the basic philosophy of Internet development is to define different services for different basic communication needs. There seems to be demand for three elementary services: first one for very
reliable and high quality connections, second for connections with less stringent quality requirements, and third one for data connections which can smoothly adapt their bit rate. As the requirements of these elementary classes differ significantly, an obvious approach is to have different service specifications like the guaranteed service, controlled-load service and best effort service specified in IETF drafts (note that this approach has been used in the case of ATM as well).

The supposed advantage of this approach is that by dividing the service specification task into several smaller parts the specifications process is easier than if the all the service types were included in the one specification. However, this advantage is somewhat questionable because the whole service concept (with all the different service types) is what the network operator should manage and sell to customers and what the customer should buy and use. In particular, most Internet customers will be reluctant to learn several complicated services which may even have very different structures, traffic parameters, charging schemes, etc.

For real marketing purposes, the Internet service package must be simple, much simpler than what the current service models directly make possible. There are two main approaches to meet this requirement: to hide the complexity of network service from the end-user or to design an entirely new integrated service which is able to satisfy all the primary customer needs. The approach used in this document belongs to the later category.

2. End-to-End Behavior

The primary idea of the SIMA service is to maximize the exploitation of network resources with a simple control scheme while keeping the ratios of QoS levels offered to different flows unchanged under changeable traffic conditions. The maximization is based on three key properties of traffic control: all flows with different QoS requirements share the total capacity of every link, the network attempts to avoid any unnecessary packet discarding, and flow (or call) level blocking can be avoided. The approximate constancy of QoS ratios and simplicity are achieved by using 8 priority levels which make possible a fair packet discarding scheme inside the network without keeping track on the traffic of every flow.

The SIMA specification covers the whole Internet service including charging, QoS and performance aspects, and traffic control functions in the network. As opposed to most service specifications, charging is the starting point of the SIMA concept. The prevalent charging scheme applied by Internet operators is a flat rate one with a constant monthly fee. Although this scheme is most reasonable when the network service is based on the best-effort principle, many network operators may still be willing to apply this scheme even with more complicated service models. The SIMA service model is able to meet this demand.
2.1 Nominal Bit Rate

Shortly, with the SIMA service scheme, first a customer pays for some Nominal Bit Rate (NBR, kbit/s) and then he/she can trade the speed for QoS. Let us assume that a user pays $X/month. This charge is translated to a Nominal Bit Rate using an arbitrary function. The function $NBR = F(X)$ could be linear, but there is no reason to specify the relationship between NBR and charging. If NBR is permanent, it can be related to an interface (we may assume the same organization that owns the right to use a network interface buys the NBR). The next level of NBR is the NBR assigned to a user (or IP-address). The bottom level is the NBR of a flow (determined for instance by a pair of IP address and port number).

Depending on the available information and the network capabilities, there are three basic approaches to manage NBRs. The simplest approach is to assign the NBR only to an interface, which means that the network measures the whole traffic going through the interface and handles this traffic as an indivisible entity. The users and flows that share the NBR obtain approximately the same QoS. In the second approach each user (identified by an IP address) has his/her own NBR. Now the network measures the total traffic generated by a user, and different flows compete with each other on a best-effort basis.

Both these approaches have the serious drawback that they do not separate different applications properly: a high-speed file transfer may disturb other flows, e.g., real time video connections, although the user may consider the file transfer as a background process which uses only the capacity left by other more demanding applications. Therefore, as regards the performance and QoS of the SIMA service the most useful approach is the one where every flow has its own NBR. Later in this draft we suppose that the network is capable to identify and measure every flow, and that every flow has its own NBR. The question how these NBRs are determined and managed can be left for network operators, and is, therefore, out of the scope of this draft.

2.2 Real-time and non-real-time services

The other part of the SIMA service concept is the possibility to request a real-time service. The user is entitled to him/herself determine whether the flow is a real-time (rt) or non-real-time (nrt) one. In practice, this decision can be made usually at the application level: a real-time service is usually requested only for interactive audio or video applications. If a real-time service is requested, the SIMA network attempts to offer as short delay and small delay variation as possible. The expense of this choice is that, if there are traffic variations of time scale from 0.1 ms to 10 ms, small real-time buffers cannot filter these variations. Therefore, the measurement for the priority determination shall be more sensible as regards the traffic
variations in case of real-time service than with non-real-time service (see illustration in Fig. 1).

If the user changes a VBR connection from nrt-service to rt-service without changing NBR or traffic process, the delay will decrease, but the cell loss ratio may increase because the real-time measurement gives worse priorities during peak rates. If the user wants to obtain the same quality, this impairment of loss ratio should be compensated by increasing NBR. Real-time-service could, in this respect, be more expensive than non-real-time service although there is no difference in the tariffs.

In consequence, if the application is a real-time one, it is advantageous for the user to select the real-time class, because it is the only way to attain small delay and delay variation. Furthermore, if the traffic variations are small enough, the user may always select a real-time service, because there is no difference in cell loss ratio between rt and nrt-services. In contrast, if there are significant traffic variations as with typical data applications, the non-real-time service gives better quality, that is, smaller packet loss ratio.

```
* = actual bit rate
o = real-time measured bit rate
x = nrt measured bit rate
```

Fig. 1. The difference between actual bit rate, measured bit rate for a real-time flow and measured bit rate for a non-real-time flow.

2.3 Quality of the SIMA service

The total SIMA service requested by a user consists of a nominal bit rate and of a possible real-time service request. This half of the service is clear and reasonable. The other half of the service is the expected QoS of the flow, or actually, the expected QoS of the application that the customer uses over the SIMA network. An essential
issue for the success of the SIMA service is how reasonable and acceptable this part of the service concept will be.

Most customers have experience of circuit switched networks (like telephone networks) and packet networks with best-effort service (like the current Internet). In a circuit switched network a busy period means that the call blocking probability increases, which means that the quality perceived by some customers drop occasionally to zero. In packet networks the packet loss ratio increases during busy periods, and effectively, the available capacity for a flow decreases if a TCP/IP type of protocol is used. In a SIMA environment, when a user buys a NBR for a flow and then sends traffic into a SIMA network, there is usually no flow level blocking (although it is possible to protect the SIMA network from excessive overloads by restricting the total sum of NBRs). The quality of the flow depends on two issues: the NBR to actual bit rate ratio, and total load in the network.

Therefore, a potential difficulty with the SIMA service is that the customer cannot precisely know what the QoS of a flow will be because rapid traffic variations may bring about unexpected changes of QoS. However, even in the case of services using resource reservation the actual quality of flows using certain quality class may vary significantly, because the quality can only be determined by using statistical parameters. Furthermore, as the resource reservation principle may result in flow level blocking, a high quality connection cannot be guaranteed during overload situations.

Because the quality of existing flows is not in the same way predictable as with services using a complicated resource reservation mechanism, the SIMA network shall be implemented in a way that the users can rely on the fairness of the service. The fairness of the SIMA service is based on the fact that all flows with the same actual bit rate to NBR ratio perceives similar QoS. Thus, a home user with 10 Kbit/s NBR receives the same QoS as a large company with NBR of 100 Mbit/s provided that both are transmitting at their own NBR. The SIMA service can offer this fairness feature during a short interval. In contrast, during long period, like a month, fairness is not as clear if flat rate scheme is applied, because the amount of transferred information depends essentially on total length of active periods, whereas the charging does not depend on the activity of customer. This fairness problem common to any service with flat-rate charging can be solved, if needed, by using a time dependent charging scheme.

Another aspect of fairness is the possibility to obtain more quality with higher price or lower price with less quality by changing the actual bit rate or NBR. This means that each customer is entitled to change the NBR to actual bit rate ratio (b) and by that means to
optimize his/her quality to charge ratio. If the ratio increases, the quality of the flow is enhanced. If the user sends traffic by using a constant bit rate, the SIMA service offers 7 different quality levels (for variable bit rate traffic the levels are more distinct but basically the same). Although the absolute quality of each class depends on the network dimensioning and on actual traffic process, the quality levels can be described approximately as follows:

7 = reserved for non-SIMA services with resource reservation
6 = excellent quality: negligible packet loss ratio
5 = high quality: packet losses only during exceptional traffic peaks
4 = good quality: small packet loss ratio even during busy hour
3 = moderate quality: usually small packet loss ratio except during busy hours
2 = satisfactory quality: from time to time very high packet loss ratio
1 = suitable for best-effort traffic during busy hour
0 = unusable during busy hour, but suitable for best-effort traffic during non-busy hours

The charge of priority level j will be \(X \times 2^{(j-4)}\), if the charge of level 4 is \(X\), and if the charging is proportional to NBR. However, quality level 0 can be in practice obtained free of charge. The network operator may try to dimension the network in a way that the traffic of 3 lowest levels is able to fill the network capacity left by the higher priority levels during busy hour. As the charge of level 6 service is 16 times higher than that of level 2, we can assume that there will be much more traffic offered to the lowest levels. For instance, there could be 10 times more traffic on the lowest levels and still the incomes from level 6 traffic is higher than those of levels 0, 1, and 2 together. Therefore, the traffic load of level 6 could be increased by several hundreds percents before there is any packet loss. Note that even very high load of the low quality levels has no significant effect on the packet loss ratio of the higher levels. It is reasonable to assume that the most intense traffic variations occur at the lowest quality levels, whereas the charging may dampen the variations at the highest quality levels. Thus, for most of the time higher priority levels can be considered as insulated from the lower levels having varying packet loss ratio.

2.4 SIMA service chain

As a conclusion the SIMA service chain can be outlined as in Fig 2. The user input to the SIMA network consists of charge \((C \rightarrow X)\), actual traffic sent into the network \((T)\), and rt/nrt selection (the only traffic or quality parameter). The network may inform the user of the offered service tariffs by announcing the NBR (or as the user is able to know the charging function, he may select directly a proper NBR). The main output of the network is the actual QoS of the flow, which depends
directly on the network performance. Note that there is a (one-way) connection from the charge of the flow to the actual QoS of the flow via NBR, the SIMA control and network performance. Therefore, although there is no pre-defined exact relation between charging and QoS, the user may optimize the charging of the flow by trying firstly a low charge, and then doubling the charge until the quality level is sufficient (or when only flat rate charging is used, the user may change the actual bit rate of the flow).

Another important feature is that the traffic control information is conveyed purely by the SIMA packets (or cells), which means that there is no need to have any separate control information transported between different network nodes. Finally, as there is no packet or cell discarding based on a separate traffic flow, packets or cells are discarded only if the total load exceeds the network's capacity. In this way the total capacity of the network can be exploited very efficiently.

Fig. 2. Service chain of SIMA. C is the user’s readiness to pay, I is information given by the network, T is actual traffic sent into the network, P is the parameters needed to control the flow, and Q is the quality experienced by the user.
3. Motivation

3.1 Current services

The SIMA service is intended to give a reasonable service concept for ordinary Internet users while offering quality and fairness. The main motivation of the SIMA service concept is the apparent unsuitability of current Internet service concepts to entirely meet these requirements. The starting point of the development of Internet services is the best-effort service. The best-effort service chain is presented in Fig. 3.

The well-known problems of best-effort service are that there is no relation between quality and charging, and that there is no way to offer high quality (small packet loss or small delay) for those flows that need these features. The prevalent approach to solve this problem is to design guaranteed service classes, each of which has certain quality features. A simplified service chain of this approach is presented in Fig. 4.

Fig. 3. Service chain of a best-effort service

The user input to a network with a guaranteed service consists of requested traffic and quality parameters (P), and actual traffic sent into the network (T). Actually, this is a significant difference between SIMA and guaranteed service. With SIMA a customer mainly informs how much he/she is willing to pay. With guaranteed service the customer must first predict the parameters of his/her flow, something that is not easy.
even for an expert. The network informs users of the charge of the flow by using a complicated tariff table including all possible combinations of traffic and quality parameters. Because there will always be a lot of customers that are not willing to make familiar with these parameters, there must be some means to hide the complexity of the service.

![Service chain of a guaranteed service](image)

The guaranteed service approach means that the network attempts to give a statistical prediction of the actual quality of the flow: certain service class will generate certain average quality (it is assumed that each user is willing and able to understand the meaning of the quality parameters). However, because of the variations in aggregate traffic process the actual quality can sometimes be worse than predicted, but in great majority of cases it will be much better. Therefore, the
connection between requested quality and actual quality is more complicated than can be concluded directly from the service specifications.

The output of the network is the actual QoS of the flow, but in this case the quality (or rather, quality impairments) consists of two parts. First one containing the possible packet loss ratio due to the control of each flow ("flow control" in Fig. 4, UPC in ATM networks), and the other one containing the effects of control functions directed to the aggregate traffic load. In order to be able to respond properly in a case of insufficient quality, these effects have to be discerned since either the traffic parameters or service class should be changed. Therefore, although the user can be able to optimize the quality to charge ratio by changing traffic and/or quality parameters, this optimization needs quite profound understanding of the properties of services, network and traffic (or a very intelligent application to perform the task).

3.2 Service comparison

A serious difficulty of most services with guaranteed quality is how to build a reasonable service package offered to ordinary customers not familiar with technical details. When comparing the SIMA service with other possible integrated service concepts, the principal question is whether the SIMA service can in this respect be better than the other approaches. It is important to note that it is not reasonable to only compare individual services realized by SIMA, or some other service models, but the whole service package offered to customers.

Table 1 provides a brief summary for the comparison. The prevalent approaches are service specifications developed at IETF’s Integrated Service working group (IntServ), and ATM specifications. We may assume that most future Internet customers have different service requirements. The two main services needed are a real-time service with high quality, and a file transfer service with loose requirements for packet loss ratio and delay. In addition, some customers may benefit from a service which guarantees a small packet loss ratio but does not provide small delay. If the network operator attempts to satisfy all these requirements by using the current specifications, he must implement several services. Possible combinations are: guaranteed service, controlled load service and best-effort service if IETF’s specifications are used, and CBR+rt-VBR, ABR and UBR if ATM is used.

For ordinary customers charging has to be understandable, acceptable, reliable, believable, etc. These properties cannot be attained if the charging structure is too complicated. One of the main problems with the current approaches is that the whole service offered to customers consists of several services which may, and likely will, have different
charging principles. The charging of any service based on resource reservations is likely to be based on the traffic and QoS parameters used at the reservation phase. Best-effort service cannot apply the same scheme as there is no reservation, instead, flat rate or usage based charging schemes are usable. The charging of controlled load services may combine these two schemes (and be quite complicated). In total, if we take into account the need of different charging levels for busy and idle hours, the charging structure tends to be very complicated due to the large amount of parameters. On the contrary, the charging of the SIMA service can be based purely on one parameter, NBR.

When a customer requests a service she/he shall inform the network what kind of service is needed. This information consists usually of some traffic parameters (like peak cell rate) and quality parameters (parameters (cell loss ratio, maximum delay), and service class. In order to successfully use a service, the customer shall understand the meaning of these parameters (if they cannot be totally hidden from end-users), and even to make proper guess for the values of every parameter. Taking into account the reluctance of many Internet users to learn technical details, the current service concepts seem to be unsatisfactory in this respect. With SIMA there is only NBR and the selection between real-time and non-real-time service, and moreover, the latter selection can be left usually to the application.

The next question is whether a SIMA network can offer all the necessary service types. SIMA can provide efficient real-time service (i.e., as small delay as possible), different packet loss ratios from negligible to high, and a free combination of these two categories (delay, packet loss ratio). The most unclear service class is the controlled load service with small packet loss ratio. However, it should be stressed that a small packet loss ratio can be always attained by using efficient upper layer protocols if there is no strict delay requirement. Therefore, in an environment where most customers are able to use TCP/IP or similar protocol, there is no urgent need for a controlled load service as a service offered to customers, rather the objective of controlled load service is to optimize the use of network resources. A SIMA network offers good possibilities for an application using TCP/IP or similar protocols, as the packet loss ratio always decreases rapidly when the transmission rate goes down enough (say, to a level of 2.5*NBR). In this respect SIMA service is essentially better than a pure best-effort service.

As a conclusion, SIMA is able to offer simple, feasible solution for all the service needs while traditional approaches call for three quite complex services. Moreover, as the basic idea of SIMA is quite close to the philosophy of the current Internet, SIMA is a natural way to implement new services in Internet.
Table 1. Comparison of network services, user related aspects

<table>
<thead>
<tr>
<th></th>
<th>IntServ</th>
<th>ATM</th>
<th>SIMA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>guaran. contr. best-</td>
<td>CBR+ ABR UBR</td>
<td>based on NBR</td>
</tr>
<tr>
<td></td>
<td>serv. load effort</td>
<td>rt-VBR</td>
<td>based on NBR</td>
</tr>
<tr>
<td>Charging</td>
<td>?</td>
<td>? flat rate</td>
<td>? flat</td>
</tr>
<tr>
<td></td>
<td></td>
<td>traffic, QoS rate parameters (+usage)</td>
<td></td>
</tr>
<tr>
<td>Traffic parameters</td>
<td>bucket rate, -</td>
<td>PCR, (about -</td>
<td>(NBR)</td>
</tr>
<tr>
<td></td>
<td>bucket size, peak rate, min. policed unit, max packet size</td>
<td>SCR, BT 20)</td>
<td></td>
</tr>
<tr>
<td>QoS parameters</td>
<td>yes</td>
<td>yes no</td>
<td>yes yes no</td>
</tr>
<tr>
<td>Serv.class:</td>
<td>yes no no</td>
<td>yes no no</td>
<td>yes no yes no</td>
</tr>
<tr>
<td>small delay</td>
<td>small high</td>
<td>small high</td>
<td>small-high possible</td>
</tr>
<tr>
<td>loss ratio</td>
<td>small yes no</td>
<td>small yes no</td>
<td></td>
</tr>
<tr>
<td>controlled service</td>
<td>no yes no</td>
<td>no yes no</td>
<td></td>
</tr>
</tbody>
</table>

3.3 Management comparison

The other important aspect necessary to evaluate is how well the SIMA concept can meet the requirements of network operators (see table 2). The main objective of a network operator is to offer those services that most customers need by a competitive price. Because traffic and network management is one of major costs of telecommunication network, it is very important to keep management functions as simple and efficient as possible. Best-effort service is simple to manage but it does not provide all the needed features, whereas with guaranteed services it is possible to offer all kind of services at the expense of increased complexity. The realization of a guaranteed service requires traffic parameters for every flow, controlling of these parameters, resource reservation at every network node, complicated signaling for the transfer of parameters, capacity planning for every service class, dimensioning of complicated buffer and switching structures, etc. It will be very difficult to implement and manage this type of network.

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The SIMA service makes possible a very simple management. Simple traffic management means that the operator offers in principle only one service with two components: a real-time service class and a non-real-time service class. Notwithstanding the simplicity, this one basic service is able to offer different quality levels with an automatic charging structure.

The technical basis of the SIMA service lays on principles of best-effort service: on the one hand, users do not inform in advance the network on the needed bit rate or any other traffic parameters, and on the other hand, the network operator does not give any precise guarantees of the available bit rates or QoS (Quality of Service). The best-effort principle with the aid of priorities makes possible a simple network structure and management and, at the same time, it results in good fairness among different connections and efficient statistical multiplexing. The basic version of the SIMA service works without such ordinary management functions as Traffic Descriptor, QoS parameters, Service Classes, Connection Admission Control (CAC), or Usage Parameter Control (UPC). All these functions are replaced by two autonomous units: the measuring unit at access nodes and the scheduling and buffering unit (SBU).

Table 2. Comparison of network services, network related aspects

<table>
<thead>
<tr>
<th></th>
<th>IntServ</th>
<th>ATM</th>
<th>SIMA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>guaran. contr. best-</td>
<td>CBR+     ABR     UBR</td>
<td></td>
</tr>
<tr>
<td>traffic control</td>
<td>yes</td>
<td>no</td>
<td>yes       yes     no</td>
</tr>
<tr>
<td>per flow</td>
<td></td>
<td>no</td>
<td>(difficult)</td>
</tr>
<tr>
<td>resource allocation</td>
<td>yes</td>
<td>no</td>
<td>yes for MBR no  (difficult)</td>
</tr>
<tr>
<td>buffers per link</td>
<td>from 3 to thousands</td>
<td>from 3 to thousands</td>
<td>two</td>
</tr>
<tr>
<td>network management</td>
<td>complicated</td>
<td>complicated</td>
<td>simple</td>
</tr>
</tbody>
</table>
3.4 Performance comparison

The SIMA service is able to meet the simplicity requirement essentially better than a network with several service classes, and it can satisfy the basic service needs of most customers. The remaining questions are related to the performance of SIMA networks: is the throughput sufficient without a complicated control system, and could customers rely on the quality of the network without guaranteed services.

As to the throughput, the main advantage of SIMA is that there is no need to fragment the network capacity, instead, all services and all flows divide the whole capacity of every link. In this respect SIMA is very efficient. The possible problems are related to the fact that some packet could be lost near the receiver and, therefore, the capacity that these packets have exploited in the previous links will be wasted. The best solution to this problem is the proper network dimensioning. Another problematic issue could be partly transmitted packets, if ATM or similar technology is used as at the transmission level. If this problem turns out be a major problem, a packet based discarding scheme can be implemented throughout the network, but at the expense of keeping track on every flow in every network node.

The most difficult and crucial issue with the traffic management of the SIMA service is the dimensioning of the network because it is the best and only available tool to keep customers satisfied with the service. One possible approach is that the operator attempts to offer satisfactory QoS to nominal connections (i.e., to those connections in which actual bit rate is equal to NBR). In practice, this may mean that the operator measures the average cell loss ratio of cells with priority level 4. This ratio should remain on a reasonable level, for instance less than 1E-7. If this cell loss ratio is exceeded continuously, the operator shall firstly identify the bottlenecks in the network and then increase the network capacity in those points. It should be noted that this capacity increase is a quite straightforward task because there is no need to make any new plans concerning switching structure, the capacity division between service classes or virtual paths, etc. The network operator simply throws bandwidth, and the SIMA service manages QoS. This network dimensioning scheme provided by SIMA is a natural extension of the prevalent way of managing Internet.

4. Network Element Data Handling Requirements

There are two main alternatives for the realization of the SIMA service: the first one based purely on packet network and the second one based on the use of ATM for the switching and transportation. As the basic implementation of these two alternatives does not considerable differ from each other, in the following both versions are presented in
parallel. The main difference is that the ATM makes possible to realize more easily a satisfactory real-time service. This question is addressed further in chapter 9.3.

The implementation of the SIMA service consists of two main parts: access nodes and core network nodes presented in Fig. 5. There is a fundamental difference between these node types: the traffic measurement of every flow is performed at access nodes whereas at the core network nodes the traffic control functions do not need to know anything about the properties of separate flows.

```
C ------ C -------
|                |
+----+   +----+     /                       \
| CE1 |---| A1 |--- C ------- C ----------- C -----| A2 | ----| CE2 |
+----+   +----+     \
```

Fig. 5. Customer equipment (CE1) connected to an other customer equipment (CE2) through a SIMA network with access nodes (A) and core nodes (C).

4.1. Access Node

Let us suppose that there is an IP flow (i) at an access node. A nominal bit rate, NBR(i), is associated to the flow and the user is transmitting IP packets (which may be converted into ATM cells) into the network according to an arbitrary traffic process. At the user/network interface there is a measuring device which measures the momentary bit rate of the connection at the arrival of the j:th packet (or cell). This rate is denoted by MBR(i,j). The device gives every packet (or cell) a priority, PL(i,j), based on the MBR(i,j) to NBR(i) ratio:

\[
x = 4.5 - \ln(MBR(i,j)/NBR(i))/\ln(2)
\]

pl(i,j) = 6 \hspace{1cm} if \( x \geq 6 \)

\[= \text{Int}(x) \hspace{1cm} \text{if} \ 0 < x < 6 \]

\[= 0 \hspace{1cm} \text{if} \ x \leq 0 \]

where Int(x) is the integer part of x.

Consequently, if MBR(i,j) = NBR(i) the packet (or cell) gets priority 4, if MBR(i,j) > 5.66 NBR(i) the packet (or cell) gets the lowest priority (0), and if MBR(i,j) < 0.17 NBR(i) the packet (or cell) gets the highest NBR-priority (6). Priority 7 is reserved for those connections that use a network service with guaranteed bandwidth and quality. The accepting and discarding of packets (or cells) inside a SIMA network is entirely
based on these priorities.

This priority scheme makes it possible to offer different QoS levels as regards the packet loss probability. The other needed QoS distinction is related to the delay and delay variation requirements: the network shall be able to guarantee small delay for real-time flows. The user shall determine for every flow whether a real-time service is required. In the SIMA service this selection can be left freely to the user and there is no need to take it into account when determining the charge of the connection. For the realization of real-time service every network node (and every separate switching element in a network node) shall have two parallel buffers: one for real-time flows and another for non-real-time flows. All packets or cells belonging to a real-time flow go through the real-time buffer and all other packets use the non-real-time buffer.

4.2 Scheduling and buffering in core network

In core network, the key issue in the implementation of the SIMA service is the packet or cell discarding system before the actual buffering shown in Fig. 6. At any instant there is an accepted level of priority (PL_a): if an incoming packet or cell has the same or higher priority, it is accepted, otherwise it is discarded. The calculation of PL_a is based on the buffer occupancy levels of the real-time buffer (M_rt) and non-real-time buffer (M_nrt).

All the packets or cells which have been accepted in the scheduling unit are situated either in the real-time or non-real-time buffer (the scheduling algorithm can guarantee that there is no cell loss in actual buffers). Both buffers may apply the First In First Out (FIFO) principle. In order to obtain a small delay and delay variation, the real-time buffer should be relatively small (e.g., 10 Kbytes). All packets (or cells) in the real-time buffer shall be transmitted before any packet (or cell) in the non-real-time buffer. It should be emphasized that the delay priority of real-time flows has no effect on the packet loss ratios. The non-real-time buffer should be much larger (e.g., 1 Mbyte) because of the packet scale fluctuations in typical non-real-time traffic processes. Moreover, large buffers make it possible to offer reasonable service for those flows that are capable of adjusting their bit rate.

It should be emphasized that the function of each scheduling and buffering unit (SBU) is independent of all other SBU’s; all the tasks of SBU are performed based on the information of incoming packets (or cells), and moreover, all the necessary function for the implementation are described in Fig. 6. Thus, due to the autonomous property of switching units and the unnecessity of resource reservation, the management of the SIMA network is very straightforward.
Only additional information that has to be transmitted through the SIMA network is the NBR for each flow. The basic principle of SIMA is that the charge of the flow specifies the obtained NBR and the network has to be able to transmit NBR information between access nodes (from A1 to A2 or vice versa in Fig. 5). We may assume that the customer is entitled to divide freely the available NBR between the two directions. With certain services (e.g., radio broadcast) pre-defined NBR can be included in the total service fee.

5. Invocation Information

At the access node, the SIMA service is invoked by specifying the NBR for the data flow, and by selecting either the real-time or non-real-time service. If a pure flat rate charging scheme is used, the NBR can be assigned to the interface not to any individual flow, as described in chapter 2.1.

The value of NBR is measured in bits of IP datagrams (or ATM cells) per second. Value of this parameter may range from 8 to 320 Terabits per second. The selection between real-time or non-real-time has to be always determined.
6. Exported Information

The SIMA service has no required characterization parameters. Individual implementations may export appropriate implementation-specific measurement and monitoring information.

7. Policing

There is no actual policing mechanism needed with SIMA service. The policing is replaced by the traffic measurement of each flow and by the priority of every packet or cell. This mechanism forms a similar traffic control as UPC and the CLP (Cell Loss Priority) bit in ATM network, where the network may change the CLP bit if the connection exceeds its sustained cell rate. The measuring and priority determination have been presented in chapter 4.1.

8. Ordering and Merging

With the SIMA service there is no specific problems with ordering or merging as the priority of each packet or cell determines automatically the treatment of the packet or cell without any additional control function.

9. Guidelines for Implementors

9.1 Actual bit rate measurement

Since the bit rate of every connection may change significantly in several time scales, the network operator must apply an averaging measuring principle to determine the instantaneous cell rate of each connection. The time scale of the measurement shall depend on the service class (real-time or non-real-time) because the non-real-time buffer capacity can be 100 times larger than the real-time one. The approach presented in this chapter is applicable, but any measuring scheme which gives a feasible approximation of the instantaneous bit rate can be used, provided that it can be adjusted to the needed measuring period.

This measuring approach is based on the well-known principle of exponential moving average. In this chapter we assume that ATM is used as transport technology. However, a similar measuring principle can be applied with variable size packets as well.

If we suppose that the moving average is calculated at every time slot in the access node, the measured load generated by a connection (i) at the instant of transmission of j:th cell is:
\[ \rho(i,j) = \alpha + \rho(i,j-1)(1-\alpha)^{N(i,j)} \]  

(2)

where \( N(i,j) \) is the distance between \( j \)th and \( (j-1) \)th cells in time slots and \( \alpha \) is a parameter which defines the time scale of measurement. Here the notation \( a^b \) means \( a \) to the power of \( b \). Formula (2) is obtained by assuming that the estimation for the instantaneous load is updated at every time slot, but all calculations are performed only at the arrival instant of a cell. The following starting values can be used: \( \rho(i,0) = 0 \) and \( N(i,1)=C/NBR_i \), where \( NBR_i \) is the nominal bit rate assigned to connection \( i \).

In order to obtain an exact steady state value for constant bit rate connections the following conversion between load \( \rho(i,j) \) and measured bit rate \( MBR(i,j) \) shall be applied:

\[ MBR(i,j) = C \ln(1-\alpha)/\ln(1-(\alpha/\rho(i,j))) \]  

(3)

where \( C \) is the link capacity [bit/s] at the user/network interface. For numerical reasons (2) and (3) shall be replaced by

\[ MBR(i,j) = C/N(i,j) \]  

if \( N(i,j) > 10/\alpha \).

It should be noted that because \( \alpha \) is usually a constant, formula (3) can be replaced by a table with a proper granularity. For the same reason, at least the term \( (1-\alpha)^{N(i,j)} \) in (2) can be tabulated.

The proper value for parameter \( \alpha \) depends on the buffer capacity reserved for the service class used by the connection. With real-time services (with small delay variation) the buffer shall be small, and thus the value of \( \alpha \) must be quite high. On the contrary, when using a non-real-time service the user may want to send bursts of cells without high cell loss ratio. As a consequence \( \alpha \) must be much smaller (or the averaging period should be much longer). As an interim approach the following approximation might be applicable:

\[ \alpha = 5/K_n \]  

(4)

where \( K_n \) is the buffer capacity in cells reserved for the service class \( n \).
9.2 Implementation of scheduling algorithm

The key point of the SIMA service lies in the function of the scheduling algorithm. The decision of the acceptance is based on two parameters: the priority level of the cell and the occupancy level of the two buffers. Let us use the following notations:

\begin{align*}
M_{rt} &= \text{the number of cells in the rt-buffer} \\
K_{rt} &= \text{the number of buffer places in the rt-buffer} \\
M_{nrt} &= \text{the number of cells in the nrt-buffer} \\
K_{nrt} &= \text{the number of buffer places in the nrt-buffer}
\end{align*}

The average occupancy level of the total buffering system \( x \) might be determined in several ways, for instance:

\begin{align*}
x &= (x_{rt} + x_{nrt}) & (a) \\
x &= \sqrt{x_{rt}^2 + x_{nrt}^2} & (b) \\
x &= \max(x_{rt}, x_{nrt}) & (c)
\end{align*}

where:

\begin{align*}
x_{rt} &= M_{rt} / K_{rt} \\
x_{nrt} &= M_{nrt} / K_{nrt}
\end{align*}

Above \( \sqrt{y} \) stands for taking squareroot from \( y \) and \( \max(y,z) \) stands for taking the maximum of \( y \) and \( z \).

The cell is accepted if the following relation is valid

\[ PL < a - b \times x \]  \hspace{1cm} (6)

In reality formulae (5) and (6) can be implemented by using pre-calculated tables.

9.3 ATM implementation

One of the main question related with the implementation is whether ATM is used as the transmission technology. The main advantage of using ATM in a SIMA network is that it makes possible a real-time service with small delay variation. There are some drawbacks if ATM is not used.

Firstly, if a pure packet based approach is applied, the delay variation of real-time connections will be much larger because of transmission of long non-real-time packets. One solution to this problem could be to interrupt the transmission of non-real-time packet if needed (something similar to ATM). This problem is significant especially with low link speeds.

Secondly, the function of the network shall be realized in a way that either there cannot be long non-real-time packets, or long real-time packets must always be assigned with the lowest priority. The reason to this requirement is that even a couple of long non-real-time packets
could increase the buffer occupancy level of real-time buffer, and by that means change very rapidly the allowed priority level.

9.4 The location of priority bits

SIMA needs at most 4 bits in every packet in pure IP networks or in every cell if ATM is used. In IP packets it may be possible to use the type of service (TOS) field or priority field if IP-version 6 is used.

In ATM the cell header is small and there is only one bit for priority marking (CLP bit). There are at least three different approaches to situate the needed bits in ATM cells.

Firstly, it could be possible to use the Generic Flow Control (GFC) field in the beginning of the cell. It should be noted that this field is actually available only in UNI-interface, as in the NNI-interface the first 4 bits belongs to the VPI-field. However, the first 4 bits are not widely used in real implementations.

Secondly, it could be possible to reserve an own VP for each of the possible 16 service types: 8 priority levels for real-time connections and 8 priority levels for non-real-time connections. The advantage of this scheme is that it has a good interoperability with current networks, as it does not change the cell structure at all. The main disadvantage is that it reduces the number of available VP for other purposes. However, if SIMA is widely applied there is not so much need for using separate VPs for different types of services, rather the VPs can be used only for routing purposes.

Thirdly, if it is not possible to use the header of the ATM cells, the bits should be situated in the information field. However, this is not a desirable approach, because it is very difficult to find any place suitable to all ATM adaptation layers (AAL).

10. Evaluation Criteria

The evaluation of SIMA service consists of three main parts: functions related to priority determination, scheduling functions, and the performance of real-time service.

The assumption of this document is that the measuring principle will not be standardized, although one possible implementation has been presented in chapter 9.1. However, it can assumed that all measuring implementations shall produce the same result for constant bit rate (CBR) connections with certain accuracy. That means that for certain constant bit rate, the priority shall be within certain limits. If this priority determination is accurate, it makes possible for the user to optimize the bit rate he/she is using. Therefore, the main requirement
for an realization of the priority determination of CBR stream is that it should not give worse priority than what the formula (1) gives. Because the SIMA service is to certain extent indefinite, there is no need to define any stringent limit for the underestimation of the actual bit rate, but, for instance, 1 percent accuracy can be sufficient.

The implementation of scheduling function does not need to be standardized (some examples are presented in chapter 9.2). The operator is allowed to optimize the network performance by changing the scheduling function.

All real-time connections or flows shall have as small delay variation as possible. However, as the actual delay variation depends essentially on the underlying technology used, it is not feasible to define any numerical requirements for the delay variation (see chapter 9.3). The only requirement is that if there is any real-time packet or cell in the buffer, it shall be transmitted before all the packets or cells in the non-real-time buffer.

11. Examples of Implementation

The basic implementation approach for an Internet Service providers is based on the flat rate charging scheme. This implementation of Internet service is very straightforward expansion of the current Internet service.

Every customer has certain permanent NBR which has direct relation to the monthly charge of the customer. All the traffic sent by the customer to the network is measured at access node of the network. If the access is based on IP, the node gives every packet a priority based on the measurement result and the NBR of the customer, as presented in chapter 4.1. Correspondingly, if the access is based on ATM, the node gives priority for every cell. Priorities from 0 to 6 are used for SIMA customer. Priority 7 can be used by customer which needs reserved connections, and which are ready to pay more than the SIMA customers. The lowest charging category with minimal NBR could be very inexpensive, as those customers always get priority 0, and therefore, cannot disturb the traffic of other customers.

12. Examples of Use

The main advantage of SIMA as an Internet service is that it provides a uniform service concept for different needs from file transfer applications using TCP/IP protocol without loose delay and packet loss requirements to real-time applications with very strict quality and availability requirements. Thus SIMA can be used as a complete Internet service for all customers.
13. Security Considerations

Security considerations are not discussed in this memo.

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