Mapping the Quality of Service over Heterogeneous Networks: a proposal about architectures and bandwidth allocation

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***Abstract*—The paper presents a general framework and some possible architectures to get a feasible QoS (Quality of Service) mapping among network portions that use different technologies to provide a fixed service level to the terminal users. In general, there is a strong need to have "communication" among portions implementing different QoS technologies: a proper architecture, functionalities and protocols should be defined. The current work, after stating the framework, tries to propose some architectural solutions and shows a preliminary performance investigation concerning mapping of a specific QoS parameter as bit loss among an ATM and an IP portion.**

Keywords-QoS Technologies; QoS Relay Entities; QoS Mapping; Equivalent Bandwidth.

I. INTRODUCTION

ATM evolved, over the years, many techniques to manage QoS, which is the real aim of this technology: QoS parameter definition, QoS classes, traffic descriptor, algorithm to shape traffic, to manage congestion [1, 2, 3].

In the same time, another technology evolved together with the Internet: the Internet Protocol (IP) [4, 5], which is used in the TCP/IP suite. The Internet and its protocols offer a best effort service, i.e. the service offered to the terminal users is the best the network can do, without any guarantee. Two different approaches have been later introduced to implement the QoS over the IP framework: Differentiated and Integrated Services ([6, 7, 8, 9, 10]). Differentiated Services (DiffServ)-based algorithms use the priority fields of the IP packet to differentiate the service offered. Management inside routers is fundamental and, often, no resource is allocated in advance. On the other hand, Integrated Services (IntServ) pre-allocate resources and reserve a portion of the overall bandwidth for a specific traffic flow. IntServ-based schemes use a signaling protocol, called RSVP [11, 12], to notify the bandwidth reservations.

The idea of the paper is to have a QoS internetworking independent of the technology used to provide the QoS. Each portion of the network may use the preferred technology; the only concern is related to the QoS service offered to the neighbor networks. It implies the definition of a common "language" among the networks: the definition of objective QoS parameters and of common requests of service to be matched (or not) by the other portion of the network, the definition of a proper architecture, of a communication protocol dedicated to QoS and, in particular, the study of a QoS mapping to implement the translation of the defined QoS parameter among different technologies. The next Section is dedicated to clarify the employment framework. Section III is dedicated to QoS mapping. Section IV shows some preliminary simulation results concerning IP packets versus ATM cells and the associated bandwidth allocation. Session V contains the conclusions.

II. QOS EMPLOYMENT FRAMEWORK

A. *Relay Node*

A framework of example is shown in Fig. 1. The identification of the technology (IP and ATM) is just an example; each of them may be substituted by alternative technologies. Two (or more) portions of an overall network are connected each other. The interconnection, represented by the arrow in Fig. 1 may be either a single machine or a simple physical support (cable, radio link, satellite channel). The former case is shown in Fig. 2 and it implies the definition of a special communication node, defined as QoS-RN (Quality of Service - Relay Node), whose functionalities will be specified in the next section. The QoS-RN should be defined in common by the two involved networks. The latter case (shown in Fig. 3) implies the presence of a couple of communication nodes located within the proprietary networks and defined as QoS-PRN (Quality of Service – Proprietary Relay Node). Even if, in this case, the QoS-PRNs are owned by the proprietary networks, it is always necessary to have a common definition. The functionalities are clarified below.

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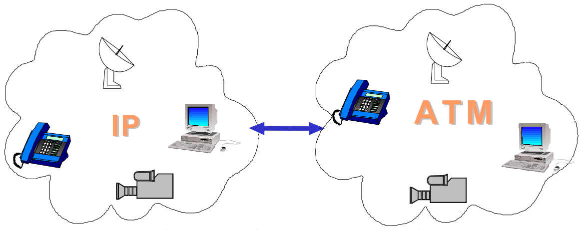

Fig. 1. Employment Framework.

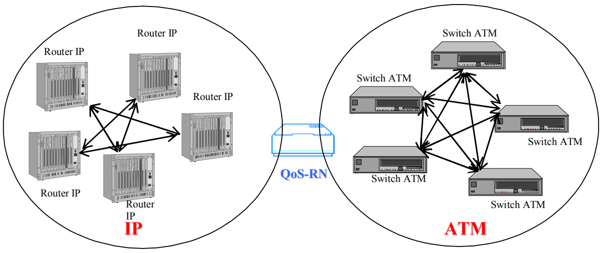

Fig. 2. QoS-RN.

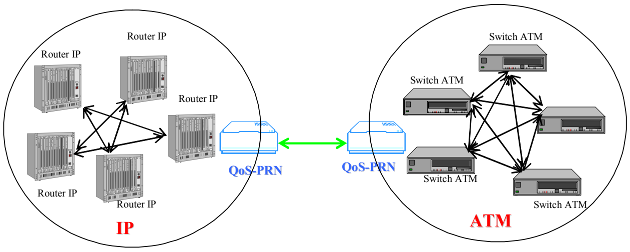

Fig. 3. QoS-PRNs.

Fig. 4 contains an example of a possible architecture dedicated to the QoS-PRN. In the case reported, which has to be remembered has only value of example, an ATM-based subnet and an IP-based subnet are interconnected, as in Fig. 1. The ATM subnet provides QoS through the ATM traffic contract and technology, while the IP-based technology bypasses the best effort service inherently offered by IP by using the Integrated Services technique or the Differentiated Services approach. If QoS-RN is used, the architecture is simpler (Fig. 5).

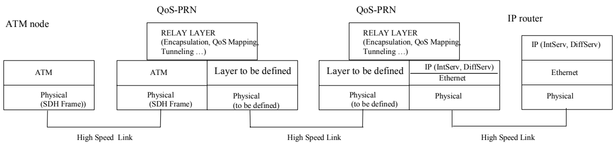

Fig. 4. QoS-PRN: an example.

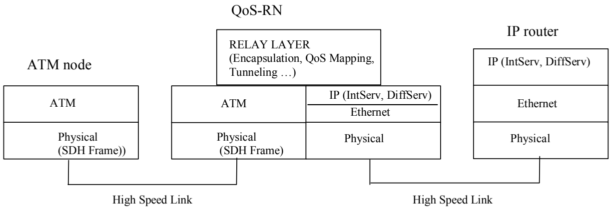

Fig. 5. QoS-RN: an example.

The Relay Layer, in both cases, has the role of encapsulating information, establishing a common format and language to exchange information about QoS requirements, establishing tunneling and implementing the other required functionalities.

B. Functionalities

The main functions of the QoS-RNs (and PRNs), referred to this work, are the following: to interconnect portions of networks that use different QoS-based technologies and to map the QoS requirements among networks so to avoid QoS degradation.

The QoS Relay Nodes (including both RNs and PRNs) can degrade the QoS not only if they represents a physical bottleneck (and it should not be the case being the high speed link between PRNs is over dimensioned) but also if it does not transfer the correct QoS requirements among the different subnets. For instance, if the QoS-PRNs of the example above do not transfer correctly the QoS requirements between the ATM and the IP networks and vice versa, they will cause QoS degradation.

III. QOS MAPPING

As already said, mapping QoS parameters is a key point to guarantee end-to-end QoS to the terminal users ([13, 14]). The Relay Layer(s) box (in Figs. 4 and 5) should take charge of these functionalities. The service mappings are useful for providing effective interoperation and end-to-end Quality of Service ([15, 16, 17]). Being the function complex, it should be possible to use a stack of protocols instead of just one layer. In more detail, from the functional point of view, a possible example of QoS mapping is reported in Reference [15]. It provides guidelines for mapping service classes, traffic management features and parameters between Internet and ATM technologies. [15] considers IP integrated services protocols for Guaranteed Service (GS), Controlled-Load Service (CLS) and the ATM Forum UNI specification versions 3.0, 3.1 and 4.0. In short, it considers ATM versus IP (IntServ) and proposes a service and a parameter mapping. Concerning the former:

- Guaranteed Service → CBR or rtVBR;
- Controlled Load → nrtVBR or ABR;
- Best Effort → UBR or ABR.

The service mapping reported is only a possible example but it clarifies one of the operations the Relay Layer(s) box should perform.

A. Layered Architecture

After defining a methodology to guarantee the QoS, it is also important to specify a proper layered structure from the protocol viewpoint (the "to be specified" blocks in Fig. 4), if the QoS-PRN approach is chosen. If QoS-RNs are used the architecture is much simpler and it is depicted in Fig. 5 for the ATM-IP interface. The choice of the protocol interfaces should be strictly dependent of the QoS architecture and functionalities. Anyway, some possible alternative solutions are: SDH/ATM (Fig. 6), Ethernet/IP (Fig. 7), MPLS (Fig. 8).

It is important to say that all the solutions have the same dignity from the technical point of view. A stack that helps map the QoS and that depends on the QoS and traffic parameters may simplify the implementation and the service provision.

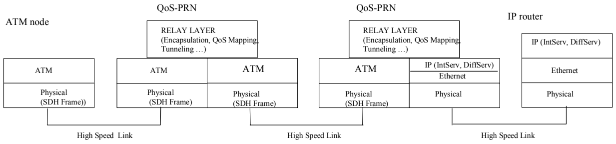

Fig. 6. Layered Architecture: SDH/ATM.

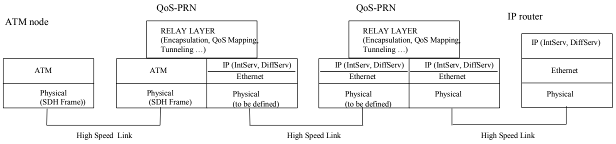

Fig. 7. Layered Architecture: Ethernet/IP.

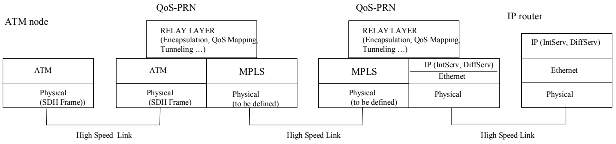

Fig. 8. Layered Architecture: MPLS.

B. Packet versus Cell

One of the topical problem at the QoS-RN (PRN) is the effect of the basic information unit length over the bandwidth requirements of a connection (or a traffic flow) [16, 17]. Taking the environment shown in Fig. 1 as reference, information is, on the ATM side, encapsulated in cells of 53 bytes, and on the IP side, in packets of variable length. It has a strong impact on the bandwidth requirements to keep the same level of QoS while traversing the Relay Nodes. The topic is extremely complex even because it heavily depends on the traffic models used but it is fundamental for a proper design of the Relay Nodes. The following section contains some results about the mentioned topic concerning the interaction ATM-IP. No further distinction between QoS-RN and QoS-PRN will be made in the following.

IV. SIMULATION RESULTS

The performance analysis has been dedicated, in this work, to show the different bandwidth requirements when the QoS-RN between an ATM and an IP network is traversed. In more detail, we analyze the equivalent bandwidth (which is the bandwidth required to provide a flow with a specified level of quality [18]) shift at the QoS-RN due to the change in the information units (cell vs packet). In our case, several connections are multiplexed in one flow, and the flow is routed across the ATM and the IP network. We consider a metric as Service Level Agreement (SLA) that guarantees to the users a protection over the loss of information inside each subnetwork. Such protection is expressed in Bit Loss Probability (BLP). The problem is how to maintain the same SLA taking into account the change in the support technology (IP - ATM). Each user's application level generates an on-off source whose parameters are: Peak bandwidth: 1.0 Mbit/s; Mean Burst Duration: 1.0 s; Mean Silence Duration: 5.0 s. Two different on-off models have been used in this work to describe a connection. The first one follows the MMDP (Markov Modulated Deterministic Process) [19] and the second one uses a Pareto model ([19, 20, 21]. Both of them alternates on and off periods and generate cells (or packets) at a deterministic rate during the on period. The difference between them stands in the methodology to generate the length of the on and off period. MMDP uses an exponential distribution; Pareto model uses a Pareto distribution.

The traffic encapsulation is performed in a simple way. The traffic generated during the on period (the burst) is directly encapsulated in cells of 53 bytes, concerning ATM, and in packets of 1500 bytes, concerning IP, having Ethernet in mind. The study ignores, for now, the header's overhead. The IP portion is supposed to work with packets of homogeneous fixed length, as often performed in the literature for QoS-oriented traffic. Further studies will consider also the variability of the packet lengths.

The QoS metric is the BLP (the threshold is set to $5 \cdot 10^{-4}$, in the results) and it can be expressed in terms of the ATM Cell Loss Probability (CLP) and IP Packet Loss Probability (PLP) respectively:

$$BLP = \frac{bits\_lost}{bits\_arrived} = \frac{ATMCell\_lost \cdot 53 \cdot 8}{ATMCell\_arrived \cdot 53 \cdot 8} = CLP$$

$$BLP = \frac{bits\_lost}{bits\_arrived} = \frac{IPPacket\_lost \cdot 1500 \cdot 8}{IPPacket\_arrived \cdot 1500 \cdot 8} = PLP$$

On the basis of the formulas reported above, it is clear that the requirement, in terms of CLP and PLP, is exactly the same to get a fixed BLP. The aim is to evaluate which is the bandwidth that should be given to the IP flow and to the ATM flow to get the result. The bandwidth needed, as clear from the following, is different and the already mentioned bandwidth shift needed to keep the same BLP traversing the border between the two networks (QoS-RN) has to be considered within the QoS mapping operation. The bandwidth requirements (the "equivalent bandwidth") is computed by simulation with the following hypothesis: the modeled on-off traffic enters a buffer of fixed length. The buffer dimension is set as 80*1500 bytes, both for IP and for ATM side. The bandwidth required is the minimum service capacity the buffer needs to guarantee a BLP less than the threshold. We have developed a C++ simulator that models the aggregation of homogeneous on-off sources and evaluates the buffer loss probability. For all the results presented, the width of the confidence interval is less then 1% of the estimated loss probability for the 99% of the cases.

In Fig. 9, the bandwidth necessary to maintain a $BLP \le 5 \cdot 10^{-4}$ in both the IP and the ATM portions is shown when the on and the off period duration is exponentially distributed (MMDP). The number of ingoing connections is varied. IP encapsulation requires more bandwidth independently of the number of connections. A measure of the bandwidth shift required in this situation is shown in Fig. 10, where the bandwidth difference is reported.

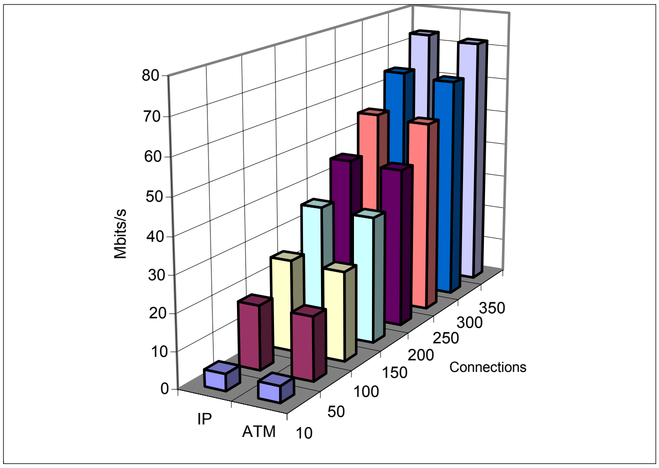

Fig. 9. Equivalent Bandwidth, IP and ATM, MMDP.

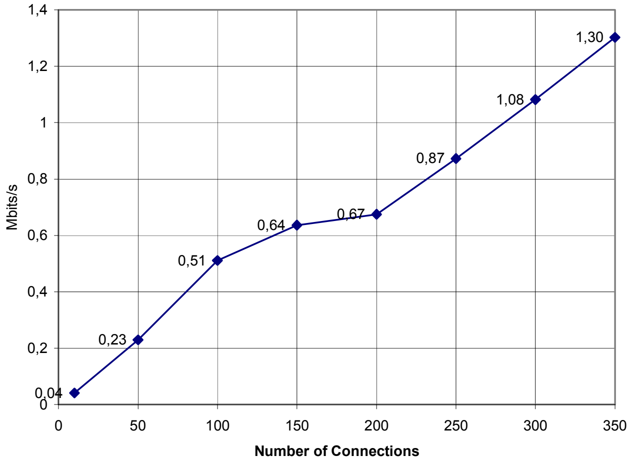

Fig. 10. Required bandwidth increase, IP and ATM, MMDP.

The bandwidth shift has to be taken into account within the QoS-RN. For example, if a new connection requires to be added to the flow that is currently composed by 349 connections, a request of additional 1.302 Mbits/s of bandwidth should be performed at the IP side with respect of the ATM side (last point on the right in Fig. 10).

Consider now a situation equivalent to the previous one, but with Pareto distributed on-off periods. As it is known in the literature (i.e. [19, 21]), a self-similar traffic has impact in the buffer overflow probability and the bandwidth needs are different from the exponential case. The difference between the two models for the case treated can be seen in Fig. 11, where the difference between the bandwidth required by using a Pareto model and an exponential model is reported both for IP and ATM traffic. The behavior is similar for both ATM and IP: up to a threshold (about 200 connections for IP and 250 for ATM, in our case), Pareto model requires less bandwidth than the exponential case. The behavior changes the trend when the load increases. Anyway, it is important to note that the behavior described is more evident for ATM, where the bandwidth requirement reduction between Pareto and MMDP raises up to 0.4 Mbits/s for 150 and 200 connections. It has impact on the increase of bandwidth necessary to pass from ATM to IP (the related graph is reported in Fig. 12, where the results concerning the Pareto model are shown together with the MMDP results taken from Fig. 10 to simplify the comparison).

An example may help understand: let us take 150 connections as a reference and let us suppose that ATM multiplexing requires "X" Mbits/s of bandwidth to provide the fixed service if the model used is MMDP. IP requires "Y=X+0.64" Mbits/s to match the same requirement (Fig. 10, 150 connections). If a Pareto model is used the bandwidth required is "X-0.383" in ATM and "Y-0.054" in IP. The difference between IP and ATM for 150 connections is "(X+0.64)-0.054-(X-0.383)=0.96", as shown in Fig. 12. In conclusions, fixed the quality to be guaranteed, traversing a QoS-RN from ATM to IP implies (in the case studied) an increase in the bandwidth allocated to an aggregated flow. This increase also depends on the traffic model: if a Pareto model is used, the bandwidth increase is larger than the case if a MMDP model is applied.

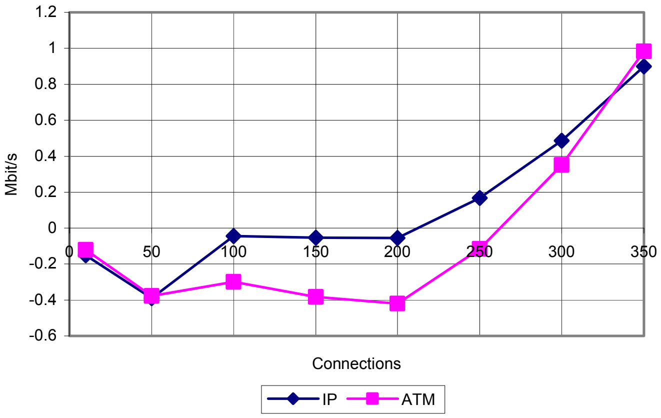

Fig. 11. Difference between the bandwidth required (Pareto-exponential), IP and ATM.

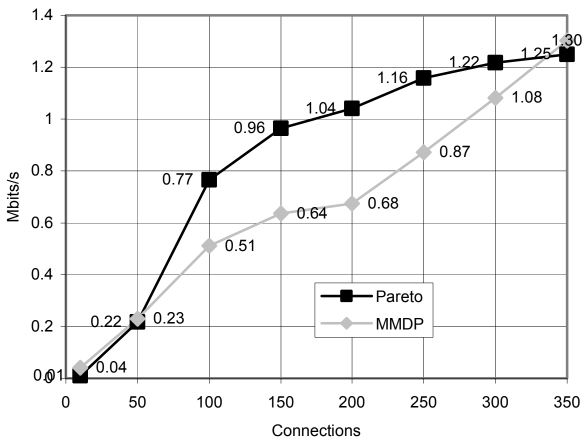

Fig. 12. Required bandwidth increase, IP and ATM, Pareto (and MMDP).

V. CONCLUSIONS

The interconnection of networks implementing different technology to provide QoS implies the study of a QoS mapping. A relevant problem is the different dimension of the basic information unit (IP packet versus ATM cell) and the related bandwidth requirements to provide the same level of quality in terms of QoS parameters (e.g. bit loss probability). The paper defines the employment framework, lists possible QoS parameters and proposes some possible architectures, which introduce special tools to map the quality of service called QoS-RNs (Quality of Service – Relay Nodes). The results, obtained via simulation, concern the impact of the packet length over the bandwidth needed to get a fixed level of quality in terms of bit loss probability. The bandwidth required has been measured both by varying the packet length (with IP packets of 1500 bytes and with ATM cells of 53 bytes) and by using different models to describe the traffic.

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