MARS EXTENSIONS FOR IPV6 OVER ATM NETWORKS

Jorge Sá Silva[1], Sérgio Duarte[2], Nuno Veiga[3], and Fernando Boavida[4]
Universidade de Coimbra,
Departamento de Engenharia Informática
Polo II - Pinhal de Marrocos, P-3030 Coimbra
PORTUGAL
Tel.: +351 239 790000 Fax.: +351 239 701266 e-mail: sasilva@dei.uc.pt

ABSTRACT

The rapid growth and increasing bandwidth has made it possible to use the Internet for multimedia applications ranging from telephony to conferencing, and broadcast applications.
This paper describes the Mars Extensions Development for IPv6 over ATM (MEDIA) project developed at Coimbra University. In this context, it is presented a new approach to IPv6 over ATM networks, using overlay models.

1. INTRODUCTION

The IPv6, as the new Internet protocol, was developed to overcome the current IP (IPv4) limitations. As a fact, the main IPv6 improvements are the address extension – to resolve the address exhaustion occurred in the IPv4 address space, the routing improvement, the self-configuration, the multicasting, the Quality of Service (QoS) support and the security.
The ATM is a powerful connection-oriented technology that has been elected by some organisations as the transfer mode of choice for the Broadband Integrated Services Digital Network. The ATM supports different types of services in an integrated manner with bandwidth flexibility.
Currently, there is a lack of investigation in the IPv6 and ATM integration. There are lots of IP over ATM models, some using peer-models others using overlay models, but few take advantage of the IPv6 properties and the ATM innovations.
The next section resumes the main IP over ATM models, giving special relevance to Classical IP (CLIP) environments. The importance of the multicast system in the present society is also described, and it is presented the adopted IP multicast over ATM solution to the CLIP model. This multicast model has also been elected as a fundamental element of the IPv6 over ATM networks, as described in section 3.
Section 4 describes the MEDIA project and it platforms – the testbed and the simulator. The new proposed solution is also described in this section.
Section 5 presents some evaluation studies. The conclusions and topics for further work are presented in section 6. As it will be describe later, it is necessary to foment new studies, industry and scientific knowledge exchanges as this integration is in an initial phase.

2. IP OVER ATM

The IP over ATM proposes can be divided in two models: the peer-model and the overlay model. The first model uses the IP addresses in the IP and ATM networks, offering the routing methods to all the systems presented.
The overlay model differentiates the IP and ATM using their two types of addresses. As there is no direct address relation it is necessary the presence of an address translation protocol.
But the IP and ATM integration is not resumed only to the address translation. As a fact, there are other properties of capital importance. The QoS has been deserved a special attention by the scientific and industrial community. The security and authentication are also very important, and the Internet Engineering Task

[1] Communications Group - Trás-os-Montes and Alto Douro University
[2] Guarda Polytechnic Institute
[3] ESTG – Leiria Polytechnic Institute
[4] Computer Department – Coimbra University

Force and the ATM Forum are given them very attention.

The LAN Emulation (LANE) protocol [1] is an overlay-model that delivers network layer packets over the ATM network. The main LANE function is to translate MAC addresses into ATM addresses.

The LANE supports the use of different Emulated LANs (ELANs). This simplifies the management process and the configuration tasks. On the other hand the inter-ELAN communication must be done using routers.

While the LANE technology implements the MAC sublayer, in the CLIP [2] emulates the link layer. The CLIP is simpler than LANE as in this last protocol it is necessary 2 address translation processes: IP to MAC and MAC to ATM. On the other hand, the CLIP technology does not offer any mechanism as the broadcast LANE service (BUS) to send the information while the connection to the final node is being set-up, resulting in the latency increase of the first information blocks. Another CLIP restriction is due to the establishment of only one VC between each pair of nodes, using LLC/SNAP encapsulation. With this process it is difficult to take advantage of ATM QoS properties.

The Next Hop Resolution Protocol (NHRP) [3] was developed to bypass the restrictions of inter-domain communications. Earlier, when a node wanted to send some information to a node from a different domain, but with possible ATM direct connections, it was always necessary to use one or more routers, resulting unnecessary overheads. NHRP is not a routing protocol, it is a protocol that uses routing processes in an Non Broadcast Multiple Access address translation.

The ATM Forum developed the MultiPrococol over ATM (MPOA) [4] to overcome the limitations of IP over ATM protocols, to use the ATM QoS, and to integrate ATM with others protocols than IP. The MPOA uses the LANE technology in intra-domain environments, and uses some extensions of NHRP to establish shortcuts between nodes belonging to different LISs.

The Integrated-PNNI [5] was developed to take advantage of the QoS routing from PNNI.

There are some private protocols that offer the ATM QoS to the IP. The common idea is to take advantage from the ATM efficiency and speed, and from the IP simplicity.

The IETF has elected the CLIP models, having a perspective of IP. On the other hand the ATM Forum chooses the MPOA, thinking in the ATM technology. Later the Multi-Protocol Label Switching (MPLS) Working Group began a standard development to integrate IP Switching [6], the Tag Switching [7], the Cell Switched Router technology [8] and the ARIS [9] from IBM.

The multicast technology has deserved a special interest by Interne2 [10] in present and future networks. The number of applications that use multicast systems is increasing, including distance learning, videoconference or distribute simulation.

The correct choose of a multicast environment saves bandwidth and resources. There are application examples, as virtual reality, where it is imperative the use of a restrict policy in resource management. The use of multiple point-by-point connections in a multicast system is not efficient and it is not applicable in medium or large networks: it would be necessary that all stations have a large database actualised and consistent. The traffic volume in the network would increase because of the presence of JOIN and LEAVE messages.

As proposed in the Internet2 recommendation [10] the multicast services must support:

- ten of thousands one-to-many communications,
- low delay services in many-to-many hundreds communications,
- a robust connection admission control in traffic volume and in the security mechanisms.

Although the broadcast services have already an active presence, the need for more efficient multicast protocols is a constant. It is important to study new solutions to solve the increasing number of acknowledgements (ACK) resulted of the growth of the Internet.

The QoS protocols began to be studied. It was necessary to base the routing decisions in an increasing number of metrics, and always to make possible dynamic alterations of the paths whenever the network modified its QoS parameters.

The CLIP did not support natively the multicast technology. Later, multicast support was introduced in the Multicast Address Resolution Server (MARS) [11]. This protocol aggregates the network nodes in clusters.

The MARS allows address resolution between the IP multicast address and the corresponding set of unicast ATM addresses. The MARS keeps a point-multipoint VC (ClusterControlVC) for all the cluster members, to make possible the asynchronous notification of the change of the group elements. When one specific node intends to be part of a multicast group it is necessary to initiate a register process with MARS server. Then all previous nodes have to be informed of

such to proceed themselves to the establishment of the necessary VCs.
There are two possibilities in the implementation of the multicast system: through a set of point-to-multipoint VCs from the source to the destination nodes (VC Mesh), or through the use of multicast servers (MCS). While in the first solution the sender establishes a direct point-multipoint VC, in the second solution the sender sends the information for a server, which makes the distribution for all the nodes.
For a MCS solution, each server establishes one point-to-point (bi-directional) VC with MARS server. This VC makes possible the transmission of control messages. The MARS adds the MCS to the point-multipoint that it keeps with the all the MCSs (ServerControlVC). This VC allows the MARS server to send general messages to all the present MCSs.
As ATMA Adaptation Layer 5 (AAL5) does not to support interleave from different sources, the MCS must be responsible from the reassemble of the cells.
The resource efficiency in MCS systems is higher, and it makes possible a centralised control. Whenever an alteration in the elements of the multicast group occurs only the MCS servers will have to update the VCs, in contrast of the VC Mesh structures where it is necessary actualise all the VCs from all the source nodes.
One MCS does not only support a high number of members. On the other hand, the VC Mesh offers direct connections, and prevents the AAL5 cells reassembly.
The presence of MCSs increases the susceptible congestion or damages points. Another MCS disadvantage, not present in VC Mesh configuration, is the necessity of the source node to identify and to reject the information received that was sent by proper it. For such, it is necessary to use the field with the emitting address to detect the reflected messages.

3. IPV6 OVER ATM

The main difference of the IPv6 address resolution, when compared to IPv4, lies in the fact that IPv6 assumes the layer 3 to layer 2 address translation. In contrast, the IPv4 uses auxiliary protocols in this task.
In IPv6 environments, when a sender node wants to transmit a unicast message to a destination node, and when the layer 2 address is not present in the translation table, the sender node sends a Neighbour Solicitation message carrying the IP destination address. All the stations that receive the NS message must ignore it if the IP address is not it own. If the IP address matches the destination node it must establish a point-to-point VC to the source node, and send a Neighbour Advertisement (NA) message. As the VC is bi-directional the sender can transmit the pending message.
But, probably as the IPv6 was developed assuming an Ethernet behind, IPv6 assumes a connectionless broadcast medium. As the ATM technology does not offer this broadcast medium natively it is necessary to emulate it. The solution, as presented in [12] and [13], is to use an IPv6 over ATM sub-layer that captures all non-unicast messages. The new sub-layer transmits them to the MARS server, which has to distribute them to all cluster members.
Later [14] proposes the use of an IPv6 specific to the ATM technology. But, although this solution could offer better performance results, it was rejected due to it complexity and non-generality.
In multicast communications the process is similar to IPv4 model, described in the section before. Whenever a station needs to send a message to an IP multicast address, it is necessary to transmit a MARS_REQUEST message to the MARS server. The multicast IP address is translated to a set of ATM unicast addresses and they are transported to the sender in MARS_MULTI messages.

4. THE MEDIA PROJECT

The MARS server is responsible for the multicast address translation. However, to enrich the conversion procedures, and to answer to the present and the future requirements, it is proposed that a node ATM when requiring to belong to a multicast group is added as a leaf of a MCS that respect the function presented in equation 1.

$$\text{MCS\_address} = f(\text{IP\_multicast\_address}, \text{Parameter\_1}, \ldots, \text{Parameter\_N}) \quad (1)$$

For multicast communication, the presented solution can be applied when it is necessary the subdivision of the group into sub-groups with different attributes or restrictions
As an application example of the general algorithm we decided to offer QoS to unicast and multicast communications. In this context, using the [15] terminology, it is proposed new functionalities to the Multicast Group Authority. The QoS is developed as a specific

algorithm application. In the MEDIA project we are also studying the adaptation of the algorithm described in another studies as, for example, multicast servers' spatial distribution.
In this paper, we propose the use of an integer value in NS and MARS_JOIN messages indicating a QoS level, according a Differentiated Service model. The different QoS levels must be pre-configured, negotiated with the system administrator, and must be known by all the systems.
In unicast environments the QoS-level integer is transported in the Traffic Classic Octet field. Although it was possible to use the Flow Label Field, taking advantage of it 20 bits, this field is used by NHRP when shortcut establishment is supported. When the NS message arrives at the destination node, it is possible to establish a non best-effort VC, with the QoS properties requested.
When the destination node can not establish the VC with the required QoS parameters it receives an ERR_L_RQFAILED signal. The sender must activate a timer to send another NS message if the NA does not arrive.
In multicast environments the possibility to support different sub-groups in the same multicast group, allows the information to be distributed with different properties. This model presents high utility to offer multicast heterogeneity and loadsharing.
It is necessary the use of a new TLV to inform the MARS server of the QoS level. The IP multicast address is translated to an MCS that offer the requested QoS properties. The proposed solution is based in a MCS set, grouped according different QoS levels.
The MARS server does not manage the admission contracts, the network policy and the shaping.
If there is no available MCS with the request QoS the MARS server can propose a MCS address which offer an approximated QoS level.
The approach presented, in multicast environments, offers a centralised management process as only the MARS server makes the QoS translation from IP level to ATM level.
When it is necessary to renegotiate de QoS level the end station must send a new MARS_JOIN message. The MARS server will react using a similar process.
There are some approaches that propose the use of a standard set of QoS to Differentiated Services model. Others propose the use of a dynamical protocol to offer non-static QoS levels. Although the proposed model is to be used in the first type environments, it can be easily adapted to the second case.

The use of different MCSs offers distinct QoS levels in the same multicast connection and reduce the computational process in each server. Nevertheless, it is necessary that each destination station receive the broadcast information from only one MCS (figure 1).

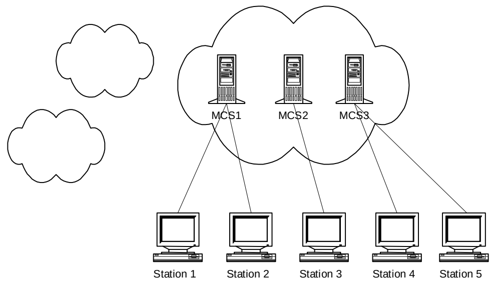

Figure 1 – MCS exclusivity

As it is necessary to guaranty that each destination receives all the multicast information even if it has a different QoS level, each source node sends the information to all the MCSs from the multicast group (figure 2).

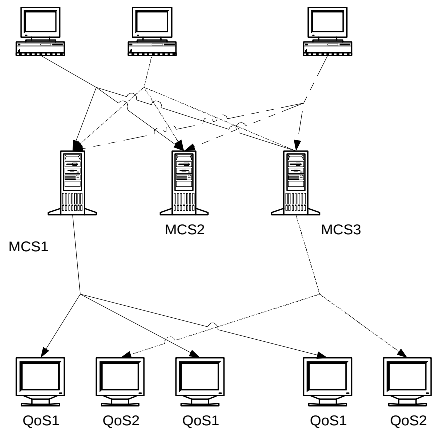

Figure 2 – Sending multicast information

When a node needs to send a multicast message, and it does not know the corresponding set of ATM unicast addresses, it will send a MARS_REQUEST message to the MARS server, which will answer with all the MCS addresses for that multicast group.
The MCSs adapt the information received from the sources to them point-to-multipoint connections.
To use VC Mesh topologies at the same time of MCSs systems it is necessary a solution based in different approaches as presented in [16].

In the MEDIA project we developed a real testbed and a simulator. 2 ATM switches and 6 hosts running FreeBSD compose the testbed (figure 3). We developed the MARS client and MARS server modules, the MCS module and the IPv6 over ATM sublayer.

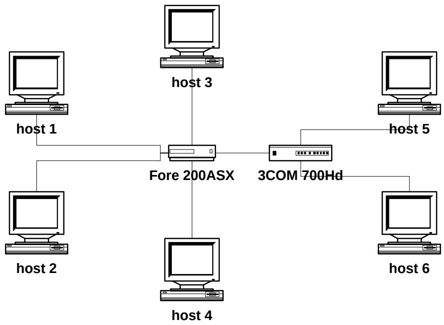

Figure 3 - MEDIA testbed

The simulator – Sianet (figure 4), is a C++ discrete event-driven simulator.

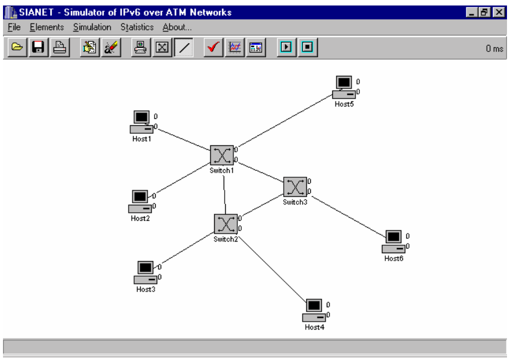

Figure 4 – Sianet main window

It has 3 modules: the engine that implements all the IPv6 over ATM signalling described, the graphical interface, and the PNNI routing module.
Although the 2 platforms were used to study the proposed solutions, each complements the other. Also, the testbed was used to validate the simulator and to obtain time-overhead values to the simulator events.

5. SOME RESULTS

In the context of the MEDIA project, we made some studies to evaluate the proposed solutions. This section presents 2 of these studies, the first compares the original ND process [12], [13] with the algorithm presented in this paper, and in the second study we analyse the proposed multicast algorithm.

The following elementary time-overhead values (table 1) were used for the simulation. These values were measured in the MEDIA testbed.

Table 1 – Mean time overhead values

Overhead	Time (µs)
IPv6 layer: downwards direction	30
IPv6 layer: upwards direction	4
IPv6 layer: address table look up	0.6
IPv6 over ATM sublayer: unicast downwards direction	0.5
IPv6 over ATM sublayer: multicast downwards direction	384
IPv6 over ATM sublayer: upwards direction	0.5
CLIP layer: downwards direction	3
CLIP layer: upwards direction	2.2
MARS Server: processing of MARS_REQUEST	189
MARS Client: processing of MARS_MULTI	154
MARS Server: broadcasting of NS messages	120
MCS: broadcast messages	120
ATM layer: downwards direction	50
ATM layer: upwards direction	50

The values obtained for each study were the result of the average of the values obtained in 10 simulation runs. The relative accuracy (for this number of simulations and for a confidence interval of 95 percent) varied between 1 and 4 percent. That is, it can be affirmed with 95 percent certainty that the real time average differs from the measured average in any given simulation run by a maximum of 1-4 percent.
The next table presents some studies used to quantify the worst possible overhead of the proposed solution in relation to the original ND process. When compared to the original process, the proposed algorithm should need some extra time to translate the IPv6 QoS requirements into QoS characteristics (more precisely, non best-effort VCs that correspond to the required QoS level) at the ATM layer.
The sender transmits 200 bytes of information in an overload network with a different number of switches.

Table 2 – Unicast transmission

Intermed. switches	Time (μs)		
	original process	**proposed process**	**overhead**
1	20867	21447	580
2	41096	41688	592
3	61325	61929	604
4	81553	82170	617
5	101782	102412	630
10	202926	203618	692
20	405213	406030	817

As presented, the proposed algorithm does not increase significantly the time consumed. Also, it offers the possibility to use non best-effort connections that respect the present and future service requirements.
As the message length increases, the relative overhead (that is, the ration overhead / message length) decreases, due to the fact that the introduced overhead affects only the establishment phase and is practically constant.
Table 3 present similar studies but to multicast environments. It compares a VC Mesh proposal, the standard MCS and our algorithm using different length information blocks.

Table 3 – Multicast transmission varying the number of switches

Length (bytes)	Time (μs)		
	VC Mesh	**MCS**	**MEDIA**
100	122082	82551	83465
200	122088	82557	83474
300	122094	82563	83480
400	122100	82569	83486
500	122106	82575	83492
1000	122136	82605	83522
2000	122199	82668	83585
3000	122262	82731	83648
4000	122325	82794	83711
5000	122388	82857	83774

As this and other studies prove, the overhead is minimal.

6. CONCLUSIONS

This paper presented a new method for unicast and multicast communications in IPv6 over ATM networks. We described the work done in the context of the MEDIA project: it platforms and it main innovations.
Currently, we are developing a new Sianet version, based in LAN Emulation. In the future, we plan to build a MultiProtocol over ATM version.
We are also studying the use of multicast ATM addresses. As a fact, ATM group addresses has been proposed in UNIv4 but only to the anycast environments. Although it is necessary some PNNI modifications, the use of one-to-one IP multicast address and ATM address is very powerful. As some studies described, it also reduces the use of MARS_MULTI messages.

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