# MEDIA – An approach to an efficient integration of IPv6 and ATM multicast environments

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**Abstract - This paper presents a new approach to the integration of the promising Internet Protocol version 6 (IPv6) with Asynchronous Transfer Mode (ATM) for multicast networking environments. Multicast technology has been the subject of special interest in recent years in terms of its applicability to present and future networks, especially by the Internet2 group. Nowadays, an increasing number of applications as, for example, distance learning, virtual reality and distributed simulation, need multicasting in order to be scalable, feasible and effective.**

**This paper proposes a new set of unicast and multicast algorithms for IPv6-over-ATM overlay-models that take advantage of inherent properties of IPv6 and ATM not sufficiently explored in existing models. Additionally, the use of ATM multicast addresses is proposed and evaluated. The applicability of the proposed approach is illustrated in a scenario where the provision of Quality of Service (QoS) according to the DiffServ architecture is supported.**

## I. INTRODUCTION

IPv6 was designed to overcome the limitations of the current version of IP – IPv4. One of the main reasons for the introduction of IPv6 was the foreseeable exhaustion of the IPv4 address space, but issues such as QoS support, security, routing and self-configuration also served as motivation.

Although there are several proposals for the deployment of IPv4 over ATM, using overlay models or peer-networking models, few studies address the integration of IPv6 with ATM. Furthermore, proposals concerning multicast systems over these two technologies are practically inexistent.

This paper presents an approach to the mapping of IP multicast addresses and IP flow requirements into ATM addresses, for IPv6-over-ATM multicast environments. Section 2 describes some important IPv4-over-ATM multicast proposals applied to Classical IP [1] environments. In this section the main differences between IPv4 and IPv6-over-ATM networks are presented. The model proposed in this paper is described in section 3. This model is called MEDIA, Mars Extensions Developed for IPv6 over ATM. In section 4 illustrates the application of the proposed model to a DiffServ environment. The support of shortcuts are presented and evaluated in section 5. Conclusions and topics for further work are described in the last section.

## II. IPV6-OVER-ATM NETWORKS

Initially, Classical IP [1] didn't offer multicast support. This was later introduced with the Multicast Address Resolution Server (MARS) solution [2] that aggregates sets of nodes in clusters. MARS offers support for the translation of IP multicast addresses into sets of ATM unicast addresses, as the ATM technology does not provide multicast addresses. When a node wants to send a message to an IP multicast address for which it doesn't know the corresponding ATM unicast addresses, the node must query a MARS server.

In this context, multicasting can be implemented in one of the following ways: through a set of point-to-multipoint connections from all the sender nodes to all the receiving nodes (VC Mesh topology), or through a set of Multicast Servers (MCSs). In the latter case, when a MARS server receives a translation request it sends not the corresponding ATM addresses of the final stations but the address of the corresponding MCS. This process is transparent to sender nodes, which transmit to the address(es) by from the MARS server, whether they are end-system addresses or MCS addresses.

MCSs environments are more efficient and offer a centralised control. Whenever there is a change in a multicast group only the MCS connections need to be updated. On the other hand the use of a MCS can be critical in the presence of delay sensitive traffic.

The main difference between IPv4 and IPv6-over-ATM networks, using overlay models, lies in the fact that IPv6 performs layer 3 to layer 2 unicast address translation, as opposed to IPv4 that delegates this process in other modules like the Address Resolution Protocol (ARP) or ATMARP.

On other hand, IPv6 assumes an underlying network technology that is broadcast and connectionless. Although this is the case when an Ethernet is present, the same is not true for ATM environments.

When a node wishes to send a unicast message and it does not know the corresponding layer-2 address, it broadcasts a

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Neighbour Solicitation (NS) message to all cluster members. The node that identifies its own IP address in the Neighbour Solicitation message replies with a Neighbour Advertisement (NA) message to the sender node, containing its own layer-2 address.

In the case of IPv6 and ATM integration it is necessary to use an IPv6-over-ATM sublayer that captures all broadcast traffic and sends it to the MARS server. The MARS server is, then, responsible for the distribution of the broadcast traffic to all cluster stations [3], [4].

## III. MEDIA – MARS EXTENSIONS DEVELOPED FOR IPV6 OVER ATM

The approach presented in this paper, called MEDIA, is being developed in the context of a project with the same name whose objective is to study and evaluate new MARS modules for IPv6-over-ATM networks. For this, an IPv6-over-ATM platform was developed [5] along with an IPv6-over-ATM simulator called SIANET [6]. Both the platform and the simulator were used to study and validate the approach presented in this section.

The MEDIA model extends the basic MARS model, overcoming some of its limitations and allowing for some of the mechanisms and abilities of other IPv4 multicast over ATM solutions (see section 2), for IPv6-over-ATM environments. The proposed model can be applied when multicast groups are composed of different subgroups with different properties, with the ability to support shortcuts in unicast and multicast communications, and multipoint-to-multipoint connections using a Differentiated Services (DiffServ) model.

### A. The MEDIA approach

Some ISPs offer different service levels to their clients. Clients with similar requirements are grouped in a given subgroup, that supports a given service level. According to the MEDIA approach, the IPv6 Flow Label Field or the IPv6 Traffic Class Octet (TCO) can be used to transport the values that indicate the subgroup service level and its properties in the multicast communication. These values are transported in a new TLV of the MARS_JOIN message sent by a node requiring to be added to a multicast group with specific properties. In addition, a MARS server uses IP multicast addresses and the set of transported parameters to find out the multicast address of the specific MCS of a given subgroup, according to a mapping function whose general form is

MCS multicast address = f ( IP multicast_address , Parameter 1 , ... , Parameter N)

Thus, address resolution becomes not only a function of IP multicast addresses, but also a function of service level parameters. In general, the set of parameters conveys information about the required QoS level. After address resolution, the node is added as a leaf to the corresponding MCS, that is, to the MCS that supports the required service level.

On the other hand, when a node wants to send a multicast message it must query its MARS server to find out the corresponding MCSs, that is, the MCSs that correspond to all multicast subgroups. On reception of a multicast message, each MCS must, then, adapt the message properties to the service level of its receivers.

As can be easily understood, this model has a large potential in heterogeneous ATM networks, where different sub-networks present different capabilities. Additionally, this model can be used for load sharing among several MCSs.

### B. Use of ATM multicast addresses

MEDIA is a centralised approach, as only one MARS server needs to translate IP multicast addresses based on the set of subgroup parameters. To overcome the limitations presented in VENUS [7], where MARS servers are shown to be network nodes susceptible to congestion, MEDIA explores the use of ATM group addresses in multicast environments.

ATM group addresses have been introduced in UNIv4.0 but only to anycast systems. In the MEDIA project we are studying the necessary PNNI extensions [8] to support ATM multicast addresses. If supported, a single multicast address can be used by a MARS server to identify a group of MCSs or a group of hosts. Additionally, the use of ATM multicast addresses reduces not only the number of MARS_MULTI messages sent by a MARS server when a multicast group has a large number of members, but also the length of MARS_MULTI messages.

If group membership changes are managed by PNNI, MARS servers are no longer potential congestion points, as their traffic volume is considerably reduced. According to this proposal, a MARS server presents a functionality that is similar to the ATM Address Resolution Protocol server functionality in unicast environments: each IP multicast address is converted into one ATM multicast address.

Reference [9] proposes, as item for further study, the use of an hashing mechanism to convert each IP multicast address into a layer 2 multicast address. Nevertheless, in addition to being difficult to mathematically develop hashing functions, they do not support dynamic groups and they are limited to the configuration process.

In the MEDIA proposal, PNNI is responsible for the management, establishment and removal of VCCs between multicast group members. In ATM addresses, AFI field values from A0 to F5 identify anycast addresses. In the MEDIA model these addresses must be further divided into anycast and multicast addresses.

In each ATM switch, the Routing Information Base must be complemented with an additional table - the Multicast Conversion Table. This table is used to convert ATM multicast addresses into the set of ATM unicast addresses. These unicast addresses identify the final stations in the same peer-group and, additionally, other peer-groups with multicast members. In the latter case, the peer-group hierarchy is used, as each source needs only to know the path to the border nodes. As in unicast environments, each border node is responsible for the establishment of point-to-multipoint VCCs in its peer-group and the development of the new Designated Transit Lists (DTLs) (Figure 1).

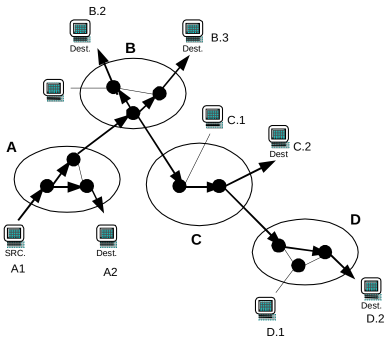

Figure 1 - Establishment of a point-to-multipoint communication

Using the PNNI hierarchy each node only needs to maintain summarised information about multicast members of other peer-groups.

When a station wants to join a multicast group it must use the ILMI protocols. Using a new PTSE (PNNI Topology State Element), the corresponding switch will inform the Peer-Group-Leader which, in turn, will inform other peer members. Similarly to the Internet Group Management Protocol (IGMP), each Peer-Group-Leader will notify the higher logical peer-group if the number of multicast group members changes from 0 to 1 or 1 to 0. Any other transition does not give rise to exterior notifications.

### C. Evaluating the use of PNNI

In order to evaluate the use of PNNI for multicast group management, simple simulation studies were performed. The next simulated scenario consisted of a peer-group comprising a different number of switches in series (Figure 2).

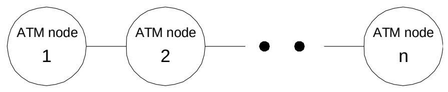

Figure 2 – Network configuration for the simulation

The objective of the simulation was to determine the time needed for the initial stabilization of a given peer-group, as a function of the number of ATM switches, when a new member is added to the group. The results were obtained using a modified version of APRoPS [10]. The mean input time values per packet use in the simulation were the simulator default values, that is:

PNNI Topology State Packet (PTSP) process time - 0.5 seconds
Hello process time - 0.1 seconds
Data Base (DBS) process time - 0.3 seconds
PTSE Request process time - 0.5 seconds

Figure 3 presents the time needed to the initial stabilisation of a peer-group when a new PTSE to support one multicast ATM group is included in a PSTP. When a PSTP can transport several PTSEs we verified in the studies that the additional time needed is minimal. For example, in a 155 Mbps network an extra 8.97x10$^{-6}$ seconds are necessary to process the multicast PTSE.

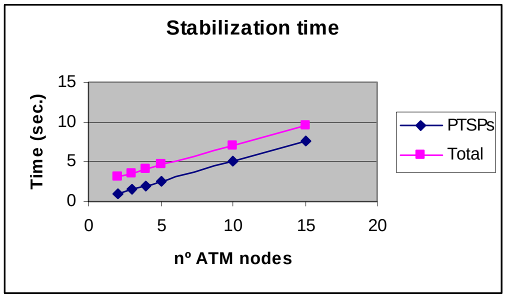

Figure 3 – Stabilization time

Figure 3 compares the time needed to broadcast the PTSPs (to speed up the data base synchronization) and the total time for the system stabilization.

## IV. QUALITY OF SERVICE SUPPORT USING MEDIA – A CASE STUDY

This section illustrates the application of the proposed approach to an IPv6-over-ATM environment that supports various QoS levels, according to a differentiated services paradigm. In this case study, in addition to the IP multicasting address, a single service-level parameter representing a QoS level from a pre-configured set of levels is used for address translation.

The use of different QoS levels in multicast communications depends on the service properties and on the service provider's policy. Some studies propose the use of a standardised set of QoS levels, while others propose the use a dynamic signalling protocol to offer non-static QoS levels. In any case, the QoS granularity derives from a management decision.

The MEDIA model can be applied when an ATM sub-network is part of a Differentiated Services network. The various QoS levels are negotiated with the network operator and must be known by all stations.

Figure 4 presents the scenario under study: a network composed of 3 switches and one multicast group comprising 4 nodes. This scenario, and the corresponding MEDIA procedures, were simulated using the SIANET simulator developed in the scope of the MEDIA project. In the simulations, the network was heavily congested (with a utilisation of roughly 70%) by traffic generated by other nodes not belonging to the multicast group.

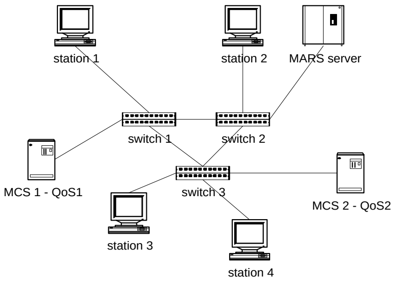

Figure 4 – Case study scenario

In this scenario, different MCSs offer different QoS levels to the same multicast group. The Traffic Class Octet IPv6 field is used to indicate the layer 3 QoS level in the multicast communication. The MARS server translates the layer 3 QoS to the layer 2 QoS and answers any address mapping request with the multicast address of an MCS server capable of providing the required QoS level. If, for a given request, there is no MCS that offers the desired service level, the MARS server produces the address of an MCS that approximates the required QoS.

In this context, QoS renegotiation is straightforward. When a station needs to change the provided QoS level all it has to do is to send a new MARS_JOIN message to the MARS server, which will reply with the address of a new MCS that provides the desired service level.

Using SIANET, several simulation studies were carried out to evaluate the behaviour of this scenario and the impact of the new MARS modules in terms of overhead. 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 actual time average differs from the measured average in any given simulation run by a maximum of 1-4 percent.

As an example, Table 1 compares the time needed to send various amounts of information with two different levels of QoS requirements to the multicast group of Figure 4. The graph shows the required time for three different approaches: VC-Mesh, standard MCSs and MEDIA.

Table 1 – Comparison of VC-Mesh, MCS and MEDIA approaches, in the scenario of Figure 4

| Bytes | Time(μs) | | |
|---|---|---|---|
| | VC-Mesh | MCS original | MEDIA |
| 100 | 122082 | 82551 | 83563 |
| 200 | 122088 | 82557 | 83569 |
| 300 | 122094 | 82563 | 83575 |
| 400 | 122100 | 82569 | 83581 |
| 500 | 122106 | 82575 | 83587 |
| 1000 | 122136 | 82605 | 83617 |
| 2000 | 122199 | 82668 | 83680 |
| 3000 | 122262 | 82731 | 83743 |
| 4000 | 122325 | 82794 | 83806 |
| 5000 | 122388 | 82857 | 83860 |

As the results present the MCS and the MEDIA systems offer reduced time overheads when compared to VC Mesh. The MCS and the MEDIA present the VCCs pre-established, so it is only necessary to establish a new VCC from the source station to the server.

As can be seen in the table, the overhead imposed by the MARS extensions is constant and almost negligible. This can easily be understood, as the MEDIA approach affects the establishment phase only and has no consequences, in terms of overhead, during the data transfer phase.

## V. SHORTCUTS EVALUATION

The MEDIA model cannot be evaluated using only the data transfer time results measured in one Logical Subnet (LIS). Although it is important to evaluate if the new proposed algorithms need significant time overheads when compared with the similar MCS model, on the other hand it is necessary to study all the advantages introduced.

The MEDIA model offers the support to establish shortcuts in unicast and multicast connections, when the source station and the destination station are in different LISs.

In the MEDIA model there is only a MARS server supporting all the LISs, contrasting to the original model where there is a MARS server to each LIS.

In the original model, when a station needs to send a unicast message to a station that belongs to other LIS, it is necessary to respect the establishment phases in each of the sub-networks (figure 5).

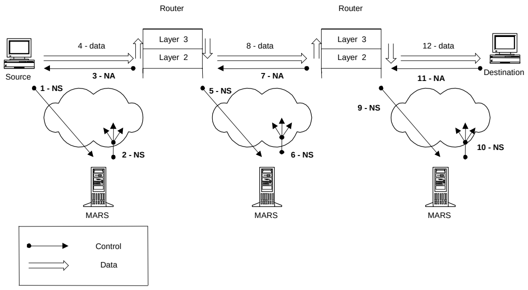

Figure 5 – Original establishment process

The MEDIA model overcomes the Neighbour Discovery process in each LIS, reducing the broadcast of Neighbour Solicitation (NS) messages and offering the direct establishment of the VCC from the source to the destination (figure 6).

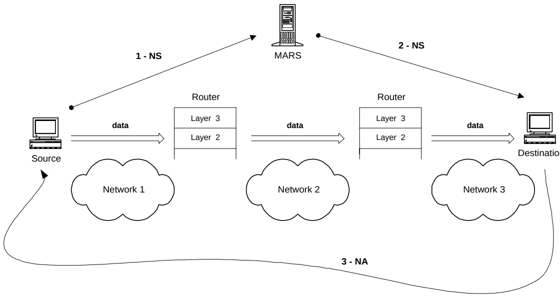

Figure 6 - MEDIA establishment process

The table 2 compares the time needed to send messages of different length in a network composed by 4 LIS (figure 7).

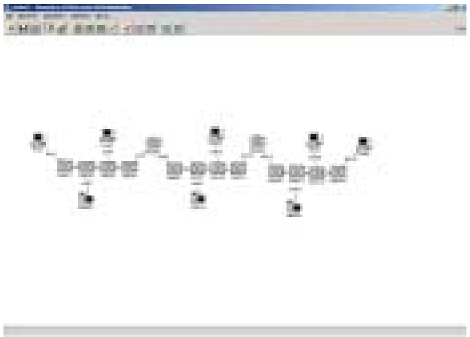

Figure 7 – Network model (using SIANET)

Table 2 – Evaluation of the MEDIA model in multi-LISs environments (unicast)

| Data Lenght (bytes) | Time (µs) | |
|---|---|---|
| | MEDIA | Routers |
| 100 | 283716 | 345501 |
| 200 | 283722 | 345519 |
| 300 | 283728 | 345537 |
| 400 | 283734 | 345555 |
| 500 | 283740 | 345573 |
| 1000 | 283770 | 345663 |
| 2000 | 283833 | 345852 |
| 3000 | 283896 | 346041 |
| 4000 | 283959 | 346230 |
| 5000 | 284022 | 346419 |

The MEDIA model offers the same advantages in multicast communications. As there is only a MARS server, the model also supports shortcuts in multicast environments.

To solve problems of ATM backbone for Internet with Inter-Domain Multicast Routing (IDMR) support over Multicast LIS, the MEDIA uses the algorithm presented in [11]. It uses the “Single Gateway” principle to protect IP routing protocols from being confused by multiple entry/exit points.

The figure 9 presents an example study that compares the original model with the MEDIA model in a network composed by a different number of LISs (figure 8).

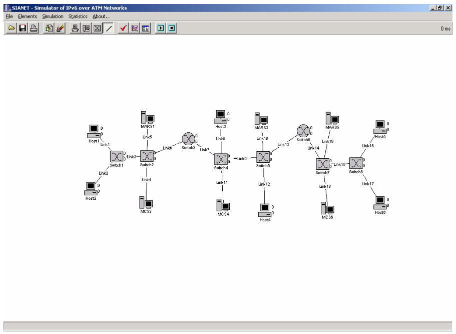

Figure 8 – Network model (using SIANET)

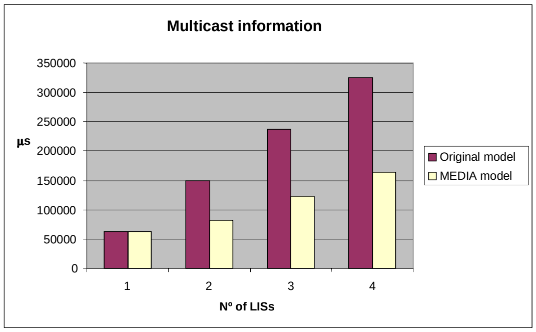

Figure 9 - Evaluation of the MEDIA model in multi-LISs environments (multicast)

As the results present, the MEDIA model offers significant advantages in multi-LIS environments.

## VI. CONCLUSION

This paper presented an approach to the integration of IPv6 and ATM multicasting environments. This approach, named MEDIA, is based on the MARS approach and provides the ability to map IPv6 multicast addresses into ATM addresses in a QoS-aware way. The approach can also provide easy ways to achieve load sharing and QoS re-negotiation, and relies on the use of ATM multicast addresses and on multicast group membership management through PNNI.

The MEDIA model was developed, tested and evaluated using an IPv6-over-ATM platform implemented for this purpose. Additional testing and evaluation was carried out through simulation, using an IPv6-over-ATM simulator developed in the scope of the MEDIA project. The evaluation presented in this paper points to the fact that the proposed model leads to benefits in terms of scalability and QoS support, at the expense of negligible overhead.

Work already under way will explore the use of the proposed approach in conjunction with MPLS scenarios.

## ACKNOWLEDGMENT

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