Mobility of Sources and Listeners in IP Multicast-enabled Networks

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***Abstract* — In today's Internet, it can be noticed the increasing demand for group-based multimedia sessions, such as video/audio conferencing, IPTV, push media. Moreover, there is an increasing trend for mobile communications, with large network dynamic events, which require fast resilience to keep, as much as possible, sessions alive over time. In this sense, the bandwidth-constrained data transport scheme of IP multicast allows traffic optimization throughout the network. However, current IP multicast support over mobile communications is not efficient, mainly due to the IP addressing scheme and mobility. If multicast sources mobility is taken into account, then the performance of IP multicast is significantly degraded, due to the requirement for constantly changing the overall multicast tree.**

In this paper we propose a new solution for agent-based multicast in both sources and listeners mobile environments, called Multicast Teleport (MUTE), which considers the existence of anchor points in the network that provide proxy features, assuming the view of multicast data source inside the network, and establishing independence between listeners and sources movements. MUTE was evaluated in NS-2, and the results show that it is able to provide *both* multicast sources and listeners mobility with decreased disruption time and increased network performance.

***Index Terms*— IP Multicast, mobility of source and listeners, agent-based control.**

I. Introduction

Multicast mobility is a generic term, which subsumes a collection of quite distinct functions. The roles of sources and listeners are distinct and asymmetric. Both may individually be mobile. Their interaction is facilitated by a multicast routing protocol, such as Protocol Independent Multicast (PIM) [2], and also a client interaction with the multicast listener discovery protocol (MLD) [3]. Any multicast mobility solution should enable seamless continuity of multicast sessions when moving from one IPv6 subnet to another. It should preserve the multicast nature of packet distribution and approximate optimal routing. The Source Specific Multicast (SSM) [4] distinguishes itself from other multicast approaches by its simplicity, where multicast delivery point is centred on each multicast source, and listener manifests its interests on a certain group and a specific source that it wants to receive (S, G). In this process, all the routing paths are optimized and the multicast delivery tree is not centred on a single point of failure. However, the SSM approach is not mobility-friendly since the multicast delivery tree is centred on the moving source.

Moreover, Mobile IPv6 [12] presents two mechanisms to deal with mobile multicast terminals. Mobility is assured using a remote subscription approach or through bi-directional tunnelling via the Home Agent. However, none of the approaches have been optimized for a large scale deployment. A mobile multicast service should provide a service quality compliant to real-time media distribution. Various efforts have been developed, but, due to mobility requirements complexity, the routing procedures scalability is considered a significant effort [14]. In one hand, when a client performs a handover, it requires the adaptation of the multicast tree branch. An important work has already been developed in this matter and much protocol designs efficiently support such movement [6][7][8][9]. In the other hand, dealing with sources handovers is a more demanding task [1] since it requires the adaptation of the entire delivery tree causing disruption times unacceptable to real-time media distribution.

Therefore, this paper proposes a new agent-based mechanism to support transparent and efficient movement of mobile terminals, both sources and listeners, denoted as Multicast Teleport (MUTE). MUTE supports a hierarchical architecture composed by two agents (Multicast Source Discovery Agent – MSDA, and Multicast Teleport Agents - MTA) and one control protocol (Multicast Discovery Protocol - MDP). MUTE overcomes mobility problems in SSM-enabled networks through separating SSM tree into two sub-trees, enabling the seamless movement of mobile terminals, both multicast sources and listeners. The interaction between MTAs is also performed through multicast to improve the process and the usage of the resources in the core network. Since the SSM tree is not entirely centred in the source, when a terminal moves, the reconstruction of the tree is faster and there is no need to re-establish current multicast connections. MUTE was evaluated in NS-2 [13] and the results show that it is able to provide *both* multicast sources and listeners mobility with decreased disruption time (around 200 msec) and increased network performance (low delays and losses).

The paper is organized as follow. Section II presents multicast mobility main challenges and current research work. Section III presents the MUTE proposal, its elements and

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processes, and section IV depicts the tested scenarios and the obtained results. Finally, section V concludes the paper and introduces topics for further work.

II. RELATED WORK

The efficient integration of mobility and IP multicast is a challenge due to issues of IP address changes: after handover, sessions must be re-established to receive multicast data on the new position. Mobility of multicast receivers is currently possible in existing multicast routing protocols, such as PIM, by means of Mobile IP (MIP) for IPv4 [11] or IPv6 [12] networks. Unfortunately, IP multicast and MIP can place service degradations during session re-establishment in foreign networks, which is not acceptable for real-time multimedia applications.

In MIPv6, Remote Subscription (MIP-RS) and Bi-directional Tunnelling (MIP-BT) strategies are introduced as attempts to overcome the problems during handover. The main idea behind MIP-RS consists in using the Context Transfer Protocol (CXTP) [5] to allow the transfer of context between multicast-enabled Access Routers (AR). Each mobile node must re-subscribe to the desired multicast group upon entering a foreign network. Besides providing optimum routing, remote subscription can place excessive processing and signalling overhead to reconstruct the multicast tree, depending on the frequency of handoffs. Moreover, mobile nodes are forced to re-initiate multicast distribution after handover, and rely on multicast dynamics to adapt to network changes. In addition to rigorous service disruption, this scheme leads to mobility-driven changes of source addresses, and thus cannot support session persistence under multicast source mobility. Multicast Scheme for Wireless Networks (MobiCast) [10] and Mobile Multicast with Routing Optimization (MMROP) [8] are examples of current proposals using MIP-RS. MMROP introduces the Mobility Agent (MA) entity to ensure routing efficiency and no packet losses from roaming. MAs are Foreign Agents (FAs) that route missing packets (via tunneling) to neighboring subnets. MobiCast's key extension is the introduction of the Domain Foreign Agent (DFA) which serves many small adjacent wireless cells, and then a hierarchy is introduced, as in Hierarchical Mobile IP approaches.

In MIP-BT approaches, when a mobile multicast source aims to redirect its multicast flow through the home network, it must tunnel the data to its Home Agent (HA). The HA receives the multicast packets from the tunnel and sends out the packets using IP Multicast Routing on behalf of the mobile multicast source. This fundamental multicast solution hides all movement since HAs remain fixed and results in static multicast trees. It may be employed transparently by mobile multicast listeners and sources, at the cost of significant performance degradations due to the overhead on the network and also the delay on the data delivering. The Mobile Multicast (MoM) Protocol [7] is an example of proposals using MIP-BT. MoM's key extension is the use of a Designated Multicast Service Provider (DMSP) in order to solve tunnel convergence problem. A DMSP for a given multicast group is an HA chosen by the visited subnet's FA out of the many HAs that forward packets for the specific group to the visited subnet.

Neither MIP-RS nor MIP-BT related proposals have efficient support to multicast source mobility, because they cannot deploy mobility in a transparent manner. When a source moves between two different ARs, listeners and multicast routers should be able to receive the multicast data coming from the new CoA (nCoA). However, when the IPv6 address changes, the entire SSM multicast tree must be reconstructed to be compliant with the new one. This reconstruction takes place because SSM trees are always centred on the multicast source. Such limitations motivated the design of a new scheme called agent-based solution, which expects to reduce the reconstruction of SSM multicast trees.

In agent-based approaches, static Multicast Agents (MA) typically act as local tunnelling proxies, thus multicast source movement can be deployed transparently (actually, [7][8][10] are also considered agent-based approaches). When a multicast source moves, and gets a new CoA accordingly, the multicast tree only needs to be re-established from the MA to the multicast source. Hence, the multicast tree reconstructing time is reduced, and consequently, the service disruption time. Current agent-based proposals are supported only by MIPv4, and cannot be used in MIPv6 due to the foreign agent (FA) dependency (only available in MIPv4) [11]. As an example, Constraint Tree Migration Scheme (CTMS) [9] is an attempt to design a new global multicast routing protocol, but focused on mobile multicast listeners.

The limitations identified in the related work analysis motivated the design of MUlticast TEleport (MUTE), an agent-based mobility control approach for the efficient support of source and listeners mobile nodes in SSM scenarios.

III. MULTICAST TELEPORT OVERVIEW

The Multicast Teleport (MUTE) proposal aims to provide an efficient mobility control to support movements of ***both*** multicast source and listener nodes in SSM environments. Fig. 1 shows the hierarchical architecture of MUTE, which is supported by two types of active agents, Multicast Source Discovery Agent (MSDA) and Multicast Teleport Agents (MTA). Moreover, the Multicast Discovery Protocol (MDP) is designed to handle Mobile Terminal (MT) events, namely multicast source node subscription and multicast listener discovery. MTs use the MDP to interact with Multicast Routers (MR) to transmit/receive multicast streams, as well as to move to a different AR.

A. Multicast Source Discovery Agent

The MSDA is located in the core network, being the knowledge point in MUTE approach. MSDA stores information about: multicast groups; source addresses; source access router addresses; and the MTA addresses corresponding to the domain where source is located. Thus, when a node aims to be the source of a certain multicast flow, MSDA must be triggered firstly.

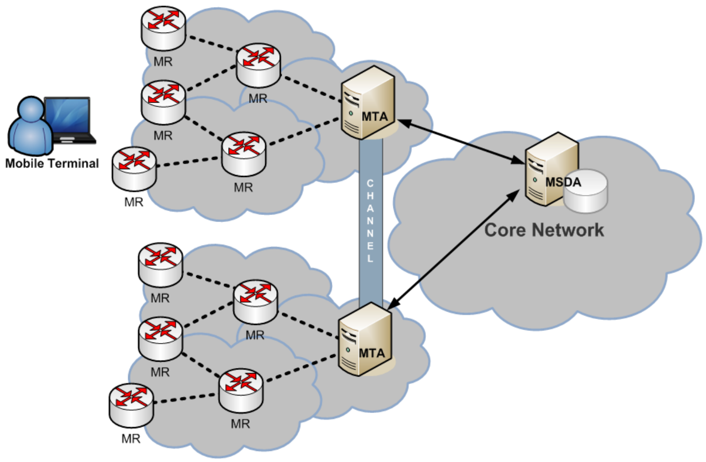

Fig. 1. Hierarchical MUTE architecture in SSM-enabled networks.

B. Multicast Teleport Agent

The MTA is responsible to control the mobility of multicast sources, being an anchor point that provides proxy features, assuming the view of multicast data source inside the network. Hence, the SSM tree is not centred only on one point, overcoming thus issues of resilience operations in multicast scenarios based on Rendezvous Point (RP), which easily places unsustainable data transport delays. MTA receives the multicast data from the source node and teleports it to others interested MTAs through a multicast channel on the core network. On each domain with interested multicast listeners, the correspondent MTA will be seen as the source for that stream, teleporting the packets to the listeners on its domain accordingly. The multicast channel between MTAs is dynamically assigned by the MSDA during the source registration process. Each source has a correspondent multicast channel on the core network used to teleport data between MTAs. The usage of multicast channels, instead of multiple unicast flows between different MTAs, guarantees the efficient use of core network resources and simplifies data teleport process.

An important benefit of MTA is that it allows multicast source moving freely without changing the multicast trees of listeners, by dividing the main SSM tree in two sub-trees. When a source aims to move, only the multicast tree between the correspondent MTA and the multicast source must be reconstructed. Moreover, the impact of moving sources in multicast scenarios is reduced, and the efficient usage of network resources in terms of bandwidth is increased.

C. Multicast Discovery Protocol (MDP)

The MDP is used in MUTE approach to coordinate MTs, MSDAs and MTAs behaviour. MDP extends MLDv2 with mobility support functionalities to allow MTs subscribing/discovering multicast nodes on access networks. MDP implements messages for the following functionalities:

- **Multicast Source Registration (SR):** used by a source for registration on the MSDA during the start-up process. SR message must also be used to make registration in a new position and perform handover;
- **Multicast Source Registration Acknowledge (SR Ack):** used by MSDA to confirm multicast source registration process;
- **Multicast Listener Request (LR):** used by multicast listeners to start receiving multicast content from a local MTA;
- **Multicast Listener Request Acknowledge (LR Ack):** used by MTAs to confirm content delivery start;
- **Multicast Listener HO (LHO):** used by listeners for handover, by means of remote subscription mechanisms;
- **Multicast Listener HO Acknowledge (LHOA):** used by MTAs after succeeding handover process.

Fig. 2 shows the operations deployed during the source registration process, which is invoked by sending a SR message to its neighbour multicast AR.

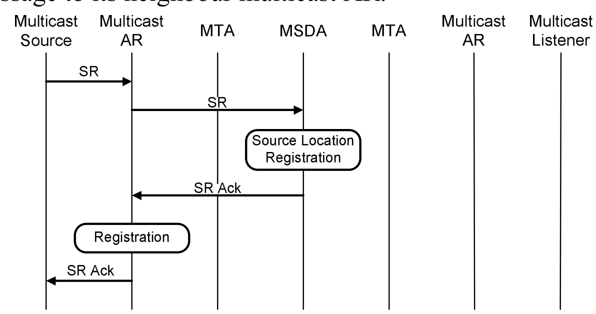

Fig. 2. Source registration Process

SR carries information about the multicast interests and eventually which Quality of Service (QoS) should be provided for the corresponding multicast session. The Multicast AR forwards the SR message to the MSDA to register the current multicast source location. After receiving SR message, MSDA is able to locate the multicast source on the network and know which MTA is responsible for it. As a result, MSDA sends an SR Ack message to the multicast AR which, in turn, forwards the message to the multicast source. Upon receiving the message, the multicast source successfully completes the registration, and is ready to start streaming.

When a multicast listener aims to receive from a certain group, it sends a Listener Request message (LR) (Fig. 3). The message is forwarded to the MTA that will use a Source Location Request message (SLQ), asking the MSDA for information about the current location of the source. The MSDA informs the MTA of the source's domain (with an MTA Notification – MTA Not) to start the PIM-Join process to the source in order to receive the multicast data. The MSDA retrieves information about the current MTA of the source via a Source Location Response message (SLP). Therefore, the MTA of the listener is able to join the agreed teleported channel on the core network. Then, the MTA sends a Listener Request Acknowledge message (LR Ack) to the AR notifying it about the success of the operation. The multicast AR starts the PIM-Join process to the MTA in order to receive the multicast data. The listener, after the reception of the LR Ack message, starts receiving the desired stream.

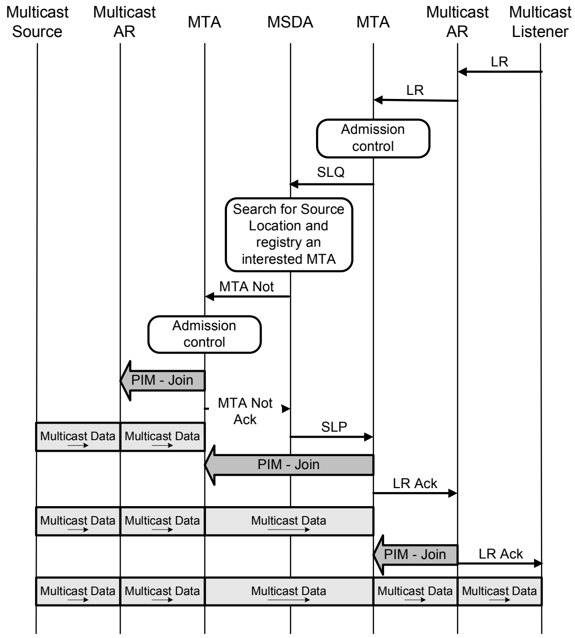

Fig. 3. Multicast Listener Request (LR) Process

When a multicast source aims to move between two different Multicast ARs inside the same MTA domain, it performs an Intra-MTA domain handover (Fig. 4). When the source arrives at the new AR, it sends a SR message. Then the AR forwards the message to the MSDA to continue the registration process. Since the registration of the source is already present on MSDA's Data Base, it refreshes the information with source's current network location and, then, sends a MTA Notification message (MTA Not) to the MTA informing it about the new location of the multicast source. The MTA starts the PIM-Join process to the multicast source's new location. Finally, the MSDA informs the source, with a SR Ack message, that the handover was successfully accomplished. Once the multicast tree between the MTA and the new multicast AR is completed, the MTA starts receiving the multicast content from the source. Notice that the multicast source needs to unregister from the previous AR (SuR message).

When a multicast source aims to move between two different Multicast ARs located in two different MTA domains, it performs an Inter-MTA domain handover (Fig. 5). As in intra-MTA handover, the source sends a SR message in order to request its new registration. The Multicast AR handles the packet and forwards it to the MSDA. Since the registration of the source on the new AR was already started, the MSDA knows that the source aims to realize a handover. After refreshing the new location of the source, the MSDA sends a MTA Notification (Not) to the new MTA which, in turn, starts the PIM-Join process to the multicast source in its domain. Then, the MSDA sends a MTA Not to the old MTA informing to leave the source and, finally, informs the source that the handover process was successfully concluded. Simultaneously, the MSDA advises all MTAs that have interested listeners for that multicast stream that these MTAs should join the new multicast teleport channel in order to receive the data coming from the new MTA. This way, listeners continue the multicast reception without the need of any operation and without changing the multicast tree.

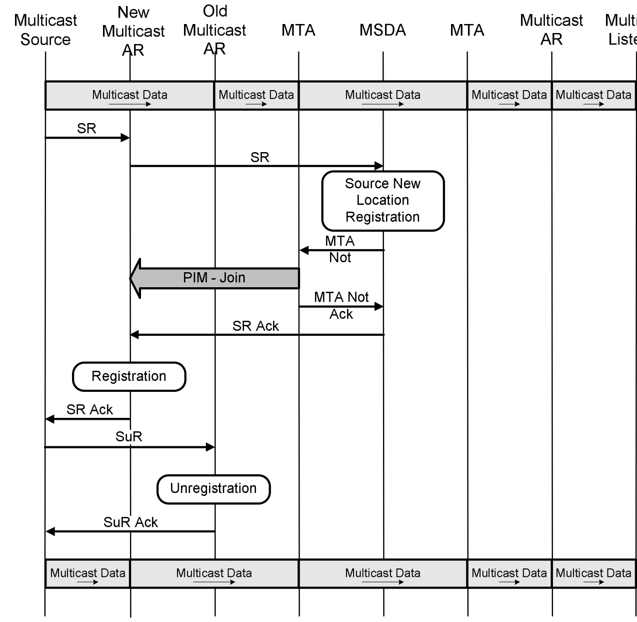

Fig. 4. Multicast Source Intra MTA Domain Handover Process

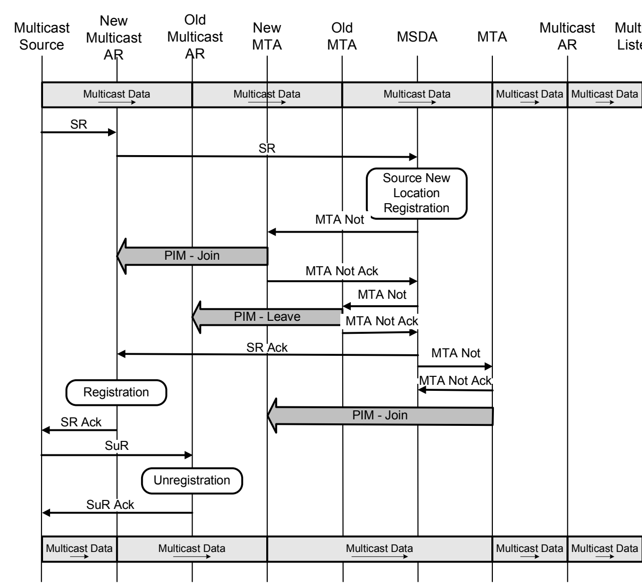

Fig.5. Multicast Source Inter MTA Domain Handover Process

When a multicast listener aims to perform an Intra-MTA domain handover, i.e., move between different Multicast ARs in the same MTA domain, a Listener Handover message (LHO) is sent before start moving, to inform the AR to which it would like to move (Fig. 6). When the current AR receives the handover request message, it realizes that the desired multicast AR belongs to the same MTA domain and forwards the message to the new listener's desired AR. The LHO message carries the listener's multicast context: when the new AR receives that information, it joins the multicast group according to the listener's interest. After that process, the new AR sends a LHO Ack message back to the current AR, which then notifies the terminal that it can perform the handover. If the old AR has no more interested Listeners for that group, a PIM-Leave message is sent to stop receiving the corresponding data stream. Upon receiving the LHO Ack message, the handover is triggered and the listener arrives at its new AR with the multicast tree already rebuilt.

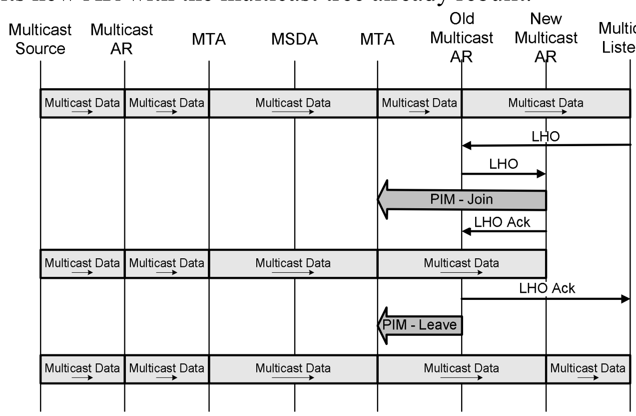

Fig. 6. Multicast Listener Intra MTA Domain Handover Process

When a listener aims to move between two different multicast ARs in different MTAs (Fig. 7), the current AR realizes than the new indicated AR does not belong to its MTA domain and sends the LHO message to the corresponding MTA, requesting to lead the process. Upon receiving the message, the MTA forwards it to the MTA corresponding to the new AR. This one, in turn, after authorizing the new mobile terminal in its domain, informs the MSDA about its interest in receiving the stream from the desired group. When the registration is completed, the new MTA joins the teleport channel on the core network to start receiving the data stream. At the same time, it forwards the LHO message to the new AR, informing that a handover will be performed and that it should join the corresponding multicast group according to the listener's context indicated in the LHO message. At this time, the multicast data is already received by the new multicast AR, since it already joined the group extending the corresponding multicast tree.

IV. Architecture Evaluation

The MUTE solution was implemented and evaluated using Network Simulator (NS-2) [13]. Five different tests were performed in order to assess and demonstrate the efficiency of the proposed solution, considering different numbers of (1) sources and (2) listeners, different values of (3) multicast traffic rate, (4) multicast data packets size and (5) handover frequency. To evaluate the performance of MUTE, we tested a network with six MTA domains and fifteen ARs fairly distributed. Sources and listeners are randomly located, randomly assigned as sources or listeners for the multicast traffic, randomly select the AR to connect, and randomly change their location on performing handover. This scenario is used to cover all possibilities of handovers of sources and listeners at random time instants and location. Fig. 8 shows the network topology used.

Currently, NS-2 is not able to simultaneously run wireless and multicast. To solve this issue, dynamic links between MTs and their ARs were used to emulate a wireless network. We used and *error model* to emulate wireless characteristics, in particular packets losses and delays due to collisions, similarly to what happens in wireless scenarios.

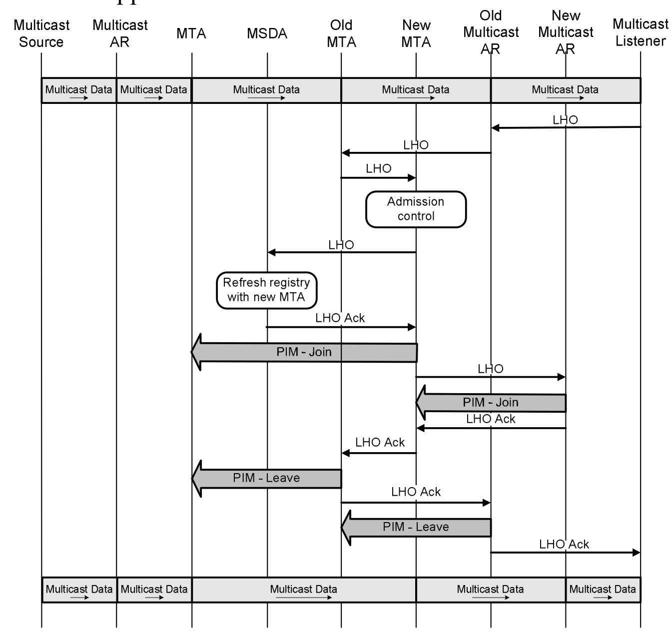

Fig. 7. Multicast Listener Inter MTA Domain Handover Process

The next sub-sections show in more detail the handover performance in the described scenarios. All results consider the mean of 10 simulation runs with 95% confidence interval.

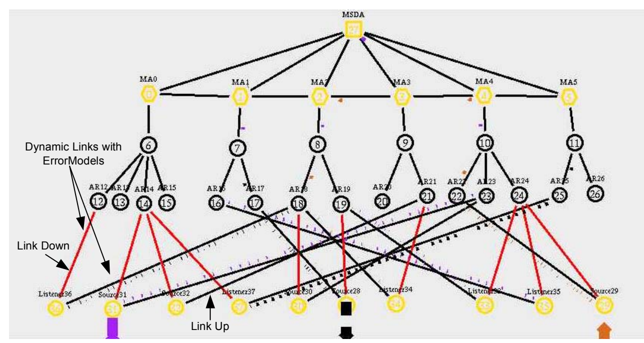

Fig. 8. Evaluated Scenario

A. *Test 1: Influence of Sources' Number*

This test considers a network with five listeners randomly distributed along the network. Each source starts sending data packets when one listener, the first one, requests the corresponding group. Traffic from all sources has the same characteristics: CBR applications with a bit rate of 448 kbps and packets with 210 bytes.

The time needed to accomplish SR and LR processes depends on the number of sources. Both processes need between 60 msec, with one source and five listeners, and almost 1s, with ten sources and five listeners.

Attending to the listeners handover process, it is necessary more than 75 msec to perform the operation. As can be seen in Fig. 9 and Fig. 10, the disruption time is never larger than 180 msec and 535 msec, in sources and listeners handover, respectively. When the number of sources increases, and consequently the number of flows in the network increases, the probability that collisions occur in the emulated wireless domain is larger, and therefore more packets are dropped, delays increase and the offered bandwidth is smaller, which leads to the observed behaviour.

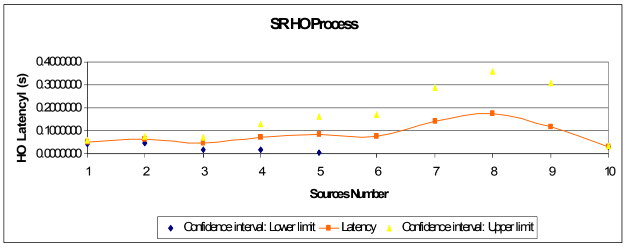

Fig. 9. Sources Handover Latency while increasing number of sources

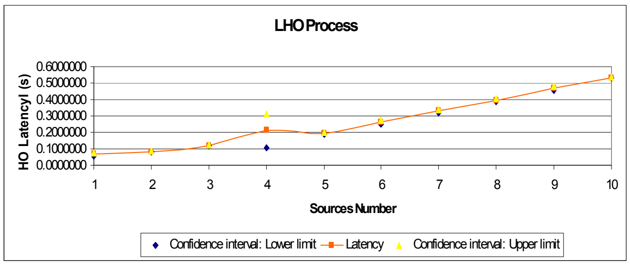

Fig. 10. Listeners Handover Latency while increasing number of sources

The Overhead caused by the MDP protocol is presented in Fig. 11. With the increase on the number of sources, more processes occur, and the number of control messages increases. However, the increment in the number of sources implies more data packets in the network and, consequently, the overhead remains practically unchanged and around 0.5%.

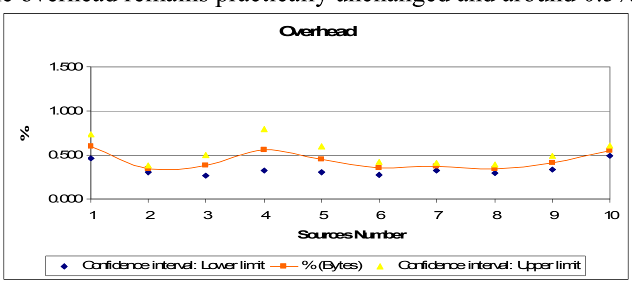

Fig. 11. Overhead while increasing number of sources

In terms of the network performance, delay, packet loss and jitter, it is significantly affected with the increasing number of sources. Again, the increase of the traffic generates more collisions in the wireless domain, and consequently, losses and delays increase, and jitter is affected, as can be seen in Figs. 12-14.

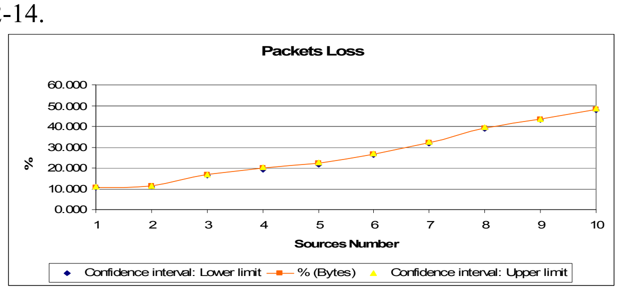

Fig. 12. Packets loss while increasing number of sources

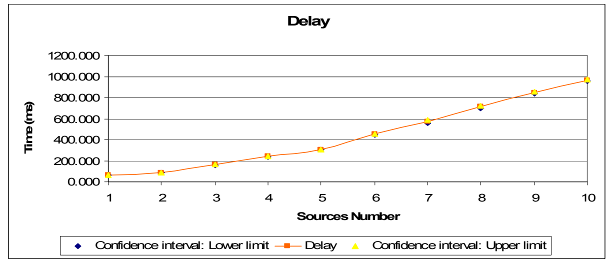

Fig. 13. Delay while increasing number of sources

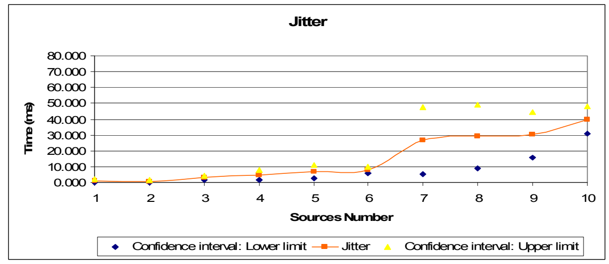

Fig. 14. Jitter while increasing number of sources

B. Test 2: Influence of Listeners' Number

In this test the number of sources remains the same and the number of listeners is incremented: the number of delivery trees depends on the number of listeners. Sources are always ready to send traffic after they complete their registration process, but they only start sending when a listener requests the corresponding multicast group.

In this test, registration and handovers, both of sources and listeners, take similarly the same time to be completed when compared to test 1. As an example, we show in Fig. 15 the latency of the sources handover. Taking into account these two tests, we conclude that the time required for such processes is essentially affected by the number of terminals, irrespective of whether sources or listeners: this number affects the wireless domain behaviour in terms of collisions and delays.

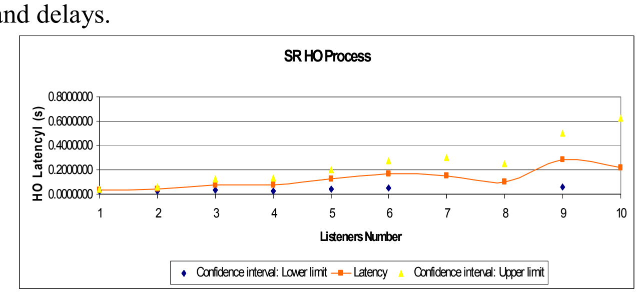

Fig. 15. Sources Handover Latency while increasing number of listeners

C. Tests 3 and 4: Influence of Multicast Traffic Rate and Packets Size

In the third test, the performance of the network was measured increasing the traffic rate. In this test, the time that a source and listener need to accomplish the registration process is not influenced by traffic rate. Moreover, when a source or listener moves, the time needed for such operation is not affected by traffic rate. The handover latency related to these processes is around 95 msec for sources and 190 msec for listeners.

Test 4 was performed considering the increment of CBR packets size. The other parameters remain the same as in the previous situations. Again, the time needed by a source or listener to accomplish the registration process is not affected by packets size. However, it has influence on the time needed to re-establish connections after the handover. With larger packets, listeners have to wait more time until restarting the delivery of traffic. The reason is that larger packets suffer more delays in the queues of the routers.

D. *Test 5: Influence of handover frequency*

This last test considers the increase of the number of handovers during the same duration of simulation (60 sec). The scenario contains five sources and five listeners. Both the registration and handover processes are not influenced by the handover frequency. However, with more handovers in the same time interval, the probability of having concurrent handovers increases (e.g., the source or the listener handover is aborted because the same terminal - now being listener or source, respectively - decides to perform a new handover before completing the previous one). In such situations, the process is performed according to the last desired movement.

When considering more handovers during the same period of time, the overhead caused by the MDP tends to increase (Fig. 16). Such behaviour is as expected since, in order to perform more handovers, both sources and listeners need to send MDP messages more frequently to perform the process. Taking into account that the number of sources and listeners is constant, traffic packets remain practically unchanged in all scenarios. Thus, the network overhead increases and becomes more perceptible reaching almost 1.5% for 20 handovers.

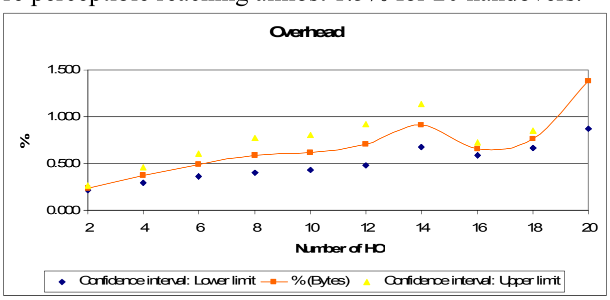

Fig. 16. Overhead while increasing handover frequency

Also, the percentage of packets loss is affected by the number of handovers (Fig. 17), increasing with the handover frequency. This behaviour is expected since, before the reconstruction of the multicast delivery trees due to terminals movement, packets are still routed to the old location.

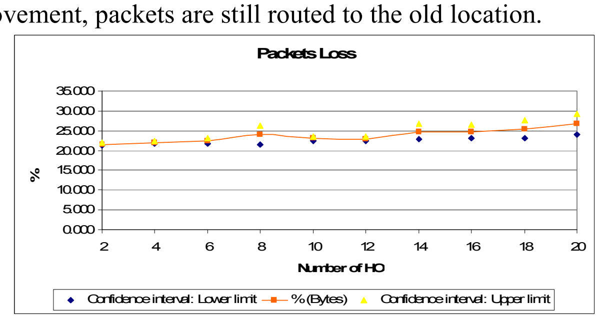

Fig. 17. Packets loss while increasing handover frequency

The delay of the network is not affected with the variation of handover frequency. Values are in all scenarios around 300 msec, which are similar to those presented in similar scenarios and are, essentially, caused by the wireless domain.

V. Conclusions and Future Work

This paper presented a new approach for multicast mobility of *both* multicast sources and listeners considering agent-based solutions, denoted as Multicast Teleport (MUTE). MUTE supports a hierarchical architecture composed by two agents (MTAs, MSDA) and one control protocol (MDP). MUTE overcomes mobility problems in SSM-enabled networks through separating SSM tree into two sub-trees, enabling the seamless movement of mobile terminals, both multicast sources and listeners. The interaction between MTAs is also performed through multicast to improve the process and the usage of the resources in the core network. Since the SSM tree is not entirely centred in the source, when a terminal moves, the reconstruction of the tree is faster and there is no need to re-establish current multicast connections.

This architecture was implemented in NS-2 with different types of scenarios, with both sources and listeners randomly moving, and different tests evaluating the influence of different parameters. The obtained results demonstrate that MUTE efficiently enables full mobility of nodes in SSM environment, abstracting the terminals mobility, with disruption times around 100-200 msec, even for sources mobility.

As future work, we plan to integrate QoS and media independent solutions in this scheme, as well as integrating it in context-aware driven scenarios.

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