Comparison of Three Approaches Towards Mobile Multicast[1]

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ABSTRACT

This paper describes three mobile multicast proposals from the perspective of the OverDRiVE IST project. OverDRiVE aims at enabling the delivery of spectrum efficient multi- and unicast services to vehicles. The examined approaches are the state-of-the-art of IPv6 mobile multicast, namely bi-directional tunnelling, remote subscription and multicast agent. The paper also features a comparison of these approaches, based on the requirements defined by the project.

I. INTRODUCTION

There is a consensus that the main drive behind mobile network revenues will shift from voice traffic to data and other multimedia services. Thus, the public mobile network operators are looking to efficient ways of service distribution. An important part of these services will be related to group and cluster communications, like videoconferencing, tele-working or location-based information broadcasting. The multicast connections are a natural solution to optimise the resources in such cases. Currently the available multicast protocols are designed for fixed networks. The mobility-related issues are targeted by the Mobile IP solution of the IETF. However, Mobile IP is designed for unicast.

In OverDRiVE, a multi-access system is designed that delivers uni- and multicast services in an optimised manner to vehicular networks. Among other elements, there is a need for a mobile multicast protocol to enable a mobile node to take part in IPv6 multicast sessions irrespective of its current point of attachment. The goal of this paper is to analyse and compare the candidate mobile multicast proposals from the perspective of this project. Based on this objective we first develop, in section II, a requirement list towards the mobile multicast solutions. The three following sections present the three techniques suitable to enable mobile IPv6 networks with multicast capabilities; namely Bi-directional Tunnelling (BT), Remote Subscription (RS), and Multicast Agent (MA). Finally, section VI makes a comparison of all these solutions based on the requirements enlisted in section II.

II. MOBILE MULTICAST REQUIREMENTS

In this section we define the requirements to be fulfilled by the mobile multicast protocol deployed in the OverDRiVE architecture. We consider that these requirements are general enough to characterize any multi-access network based on Mobile IPv6.

First, it should enable mobility of multicast sources as well as multicast receivers. Especially, it should enable *seamless* continuity of multicast sessions when moving from one IPv6 subnet to another; so that the perceived impact of the handover on the applications is minimized. With that respect, the session should not incur any additional packet loss or latency due to the handover process. Second, it should enable per-flow handover for multicast traffic. This feature relates to the capability of a multi-mode terminal to receive several multicast sessions through various network interfaces simultaneously, and move each of these multicast sessions from one interface to another independently from other unicast or multicast sessions run by the terminal. An IPv6 mobile multicast protocol should also preserve the multicast nature of an IPv6 multicast session all along the path from the source to the receiver, in order to optimise the use of network resources. Similarly, it should enable routing of multicast packets along the optimal path in the topology from the source to the receiver. Finally it should minimize changes to existing protocols.

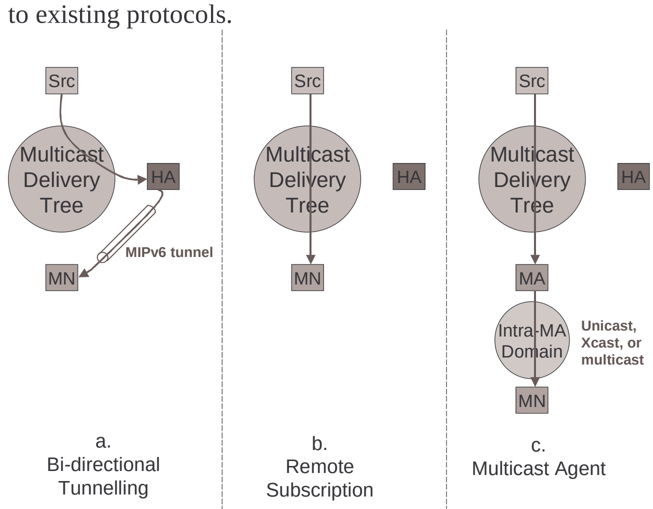

Figure 1: Three Approaches towards Mobile Multicast.

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III. APPROACHES DERIVED FROM BI-DIRECTIONAL TUNNELLING

The bi-directional tunnelling approach described in [1] proposes that a mobile node subscribes to a multicast group through its home network, via its Mobile IPv6 (MIPv6) bi-directional tunnel to its home agent (HA). As shown in Figure 1a, the mobile node tunnels its multicast group membership control packets to its home agent, and the home agent forwards multicast packets down the tunnel to the mobile node. This approach requires the home agent either to be a multicast router or to proxy multicast group membership requests [2] between the mobile node and the multicast router in the home network. A mobile multicast source will directly send its multicast packets towards its home network through the MIPv6 bi-directional tunnel, always using its home address as source address of its packets irrespective of its current location.

The main advantage of the bi-directional tunnelling approach is that it does not require any re-construction of the multicast tree while the mobile node – either multicast source or receiver- is changing its location. It provides true transparency of a node's mobility to the multicast tree. In addition, it will natively leverage on MIPv6 extensions for advanced support such as fast handover with Fast Mobile IPv6 (FMIPv6) [3]. However, the bi-directional tunnelling approach introduces a non-optimal routing of the multicast traffic due to the forwarding of the packets through the home agent. In addition, the home agent represents a single point of failure and introduces scalability issues. The tunnel breaks the multicast nature of the traffic, resulting in non-optimal resources usage. The home agent duplicates the multicast packets for each mobile receiver subscribed to the same group. This *multicast avalanche* problem [5] is even more critical if many of these receivers are located in the same foreign network.

A. Extensions for Seamless Handover

As explained above, seamless handover of multicast traffic can be realised thanks to the FMIPv6 [3] protocol. Although this extension has been designed for unicast traffic, it is applicable since the multicast traffic is conveyed through the unicast MIPv6 tunnel.

B. Extensions for Per-flow Handover

MIPv6 allows a multi-interface mobile node to register only one primary care-of address to its HA, thus aggregating all multicast flows within a single tunnel terminating at MN's primary care-of address. A possible approach for MN to support per-flow handover for multicast traffic is to have multiple home addresses (possibly from different HAs) and maintain a MIPv6 tunnel for each of them terminating at a different local interface (i.e. different primary care-of address). Note that existing proposals (e.g. [4]) defining MIPv6 extensions to support per-flow handover only consider unicast traffic.

C. Extensions for Scalability

The multicast avalanche problem is one major drawback of this approach. [5] addresses this issue and proposes the use of Explicit Multicast (Xcast) on the path between the home agent and the receivers to encapsulate an incoming multicast packet into a single Xcast packet addressed to the list of mobile receivers attached to this home agent. This is known as Multicast-in-Xcast tunnelling. The home agent has to store the home addresses of the mobile nodes subscribed to a given multicast group. Then it will forward multicast packets placing the care-of addresses in the Xcast destination list. Note however that Xcast itself cannot accommodate a large number of receivers.

IV. APPROACHES DERIVED FROM REMOTE SUBSCRIPTION

The Remote Subscription approach [1] proposes that the mobile node joins the multicast group via a local multicast router on the foreign link being visited. For this purpose, the mobile node behaves like any other fixed multicast receiver in the visited network, e.g. sending MLD Report messages to the local multicast router using an IPv6 link-local source address. This is depicted in Figure 1b.

This approach enables optimal routing since the multicast delivery tree will be reconstructed according to the current location of the mobile node. Network resource consumption is also optimised since mobile nodes, in the same foreign link and the same group, will not require duplication of packets. Note that the mobile node is not required to run MIPv6 to maintain its ongoing multicast sessions while moving between IPv6 subnets. Finally, it natively supports per-multicast flow handover. A mobile node equipped with several active network interfaces can join various multicast groups through different interfaces and manage them independently. On the other hand, the re-construction of (a branch of) the multicast tree at each movement of the mobile node may introduce long interruptions of the multicast session. Therefore the remote subscription approach may require new specific extensions for seamless handover. Since this approach is independent of MIPv6, it does not natively benefits from its extensions (e.g. FMIPv6) as the bi-directional tunnelling approach does. Last but not least, the remote subscription approach is not suitable for a mobile Source-Specific Multicast (SSM) source. SSM refers to the ability of a receiver to select the multicast source(s). Mobile source has to use its care-of address as the source address in order to pass the Reverse Path Forwarding (RPF) check at each multicast router. As a consequence, a mobile SSM source should change the source address when moving between IPv6 subnets. This has a major impact on the multicast delivery tree and receivers since the source IPv6 address of multicast packets is also used to identify the multicast source. Since the receivers are not aware of the address change at the source, the SSM source's mobility results in a loss of the multicast session for them.

A. Extensions for Seamless Handover

A possible approach for seamless handover of multicast receivers, suggested in [2], is to combine both bi-directional tunnelling and remote subscription approaches to benefit from the advantages of both. The key idea is to deliver multicast traffic via the MIPv6 tunnel to the mobile node while its remote subscription is taking place. As soon as the remote subscription has completed, the mobile node should ask its home agent to stop the forwarding of multicast packets through the MIPv6 tunnel. A new MLD message called *Multicast Listener Hold* (MLD Hold) is proposed for this purpose. Upon reception of this message, the home agent must however maintain the subscription to the multicast group(s). This approach reduces the handover delay down to the MIPv6 registration latency. Further improvement may be achieved if combined with FMIPv6 to seamlessly handover multicast traffic from the home agent, especially if the mobile node is able to re-establish the forwarding from the home agent prior to the handover. The obvious limitation of this approach is the inefficient use of network resources due to the maintenance of two branches per mobile node in the multicast tree. In addition, both home and visited networks should be located within the scope of the multicast group for this approach to work.

The idea of tunnelling received multicast traffic to the new location of the mobile node during the remote subscription duration is further extended in [6]. In order to minimize the network overload, this approach suggests relocating the forwarding tunnel entry point from the home agent to the local multicast router the mobile node was attached to prior to the handover. A temporary tunnel is set-up from the old multicast router to the new one through which multicast traffic is forwarded while the remote subscription initiated at the new multicast router is taking place. However, in [6], the establishment of the tunnel is triggered by the mobile node's MIPv6 registration to its home agent; which introduces significant latency in the multicast handover process. An alternate tunnel management is thus required for faster handover support.

B. Extensions for Mobile SSM Sources

The problem of mobile SSM sources is due to the double interpretation made of the IPv6 source address carried in the packets. On one hand this address must change at each move of the source to pass RPF check, while it should not change since used as source identifier by the receivers. Three families of solutions can be envisaged.

The first approach consists in hiding the mobility of the source to the multicast tree and receivers. The mobile source will always use its home address as source address of the multicast packets it sends, but will tunnel these packets up to a point in the network topology wherefrom the RPF check of the multicast routers in the delivery tree will match. This tunnel termination point can be the mobile node's home agent. In this case, the encapsulation could be initiated either by the mobile node itself (MIPv6 tunnel) or by the local router (*hybrid approach* from [7]). While applicable for any multicast routing protocols, the limitation is of course the non-optimal routing and the need for a dedicated tunnel management for the hybrid approach. In the particular case of shared tree routing protocols (e.g. PIM-SM), the tunnel termination point could be the root of the multicast tree (e.g. PIM-SM Rendezvous Point) while the tunnel entry point would be the local designated multicast router [7]. This is possible since the RPF check in the shared tree is carried on the root's address, and not on the source's address. In the particular case of PIM-SM, this tunnel is natively supported thanks to the PIM-REGISTER message. However, specific extensions must be developed to deactivate creation of source specific branches at the root and receivers. A dedicated bit in the PIM-REGISTER message, as well as a new message from the root to the receivers, can be used for this purpose.

A second approach, suggested in [7], is to extend the multicast routing protocol to support an arbitrary RPF point, possibly different from the source address of the multicast packet. Such RPF redirection capability helps in minimizing the handover delay since only a sub-branch of the multicast tree, between the cross-over router and the new location of the source, needs to be created. However it requires significant extensions to all existing multicast routing protocols.

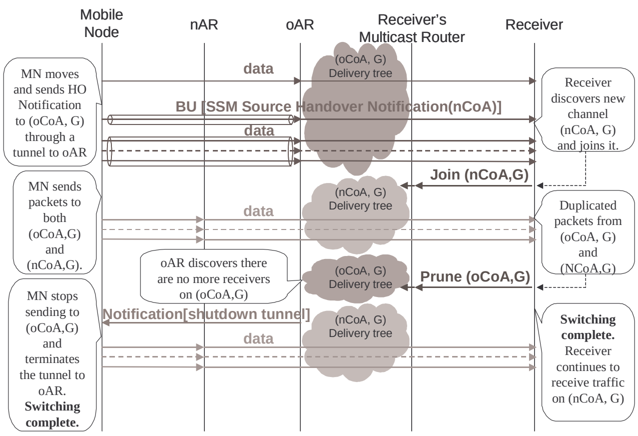

Figure 2: SSM Source Handover Notification.

A third idea, proposed in [8], is to enable receivers to distinguish between the source's identity (i.e. home address) and location (i.e. care-of address). While the former is always used to identify the source of the session, the later indicates the SSM channel (i.e. multicast delivery tree) the receivers should join to receive traffic from the source. Session announcement protocols must be extended to indicate both the home address and the care-of address of the source, and announcements must be updated with the new care-of address each time the source moves. Similarly, a new *SSM Source Handover Notification* sub-option for MIPv6 Binding Update is defined. As depicted in Figure 2, it is used to inform receivers about the new channel (i.e. new care-of address) to join to pursue the session. Seamless handover is achieved thanks to bicasting of traffic onto the old and new channels. Although this scheme implies a reconstruction of the whole multicast tree and duplication of multicast traffic at each move of the source, it provides optimal routing and can be used with any multicast routing protocols without any changes. The ability of the mobile node to anticipate its new care-of address prior to the handover, e.g. thanks to FMIPv6, can further reduce the handover delay.

V. MULTICAST AGENT BASED APPROACH

BT hides the mobility of a mobile node (MN) from the multicast delivery tree, however the unicast tunnelling approach results in inefficient use of network resource. RS is ideal in terms of utilization of network resources, but the mobility of MN may cause significant overhead. This has been confirmed by various simulation studies such as [9]. Agent-based approach presents as a compromise between RS and BT. As shown in Figure 1c, the multicast agent joins the multicast session on behalf of MN in foreign network, it then forwards the traffic to attached MNs. RBMoM [10] introduces a number of MAs, which advertise their services range information (number of hops from MA to MN) in foreign networks. MN has to register to one MA, which is located within the pre-defined range. MA serves the attached MNs within its services range. MN will handover to another MA when it is out of the range. This scheme optimises the multicast routing path through selecting the closest MA, it still uses unicast tunnel to forward traffic from MA to MN. Mobicast [11] is designed for a campus network with small wireless cells located in several subnets. Wireless cells are grouped together and served by a domain MA. When MN joins a session, the MA forwards multicast traffic to the serving cell and all of the possible neighbour cells by using another unique multicast address. Only the serving cell is allowed to forward the multicast traffic to the MN. Thus MN only needs to send request to the local cell when it handovers to a neighbour cell. This approach preserves the multicast nature all the way to the MN; it requires that all of the cells serve as a multicast proxy. [12] is an enhancement to RS approach in order to reduce handover latency. MA acts as proxy located in each subnet. MN sends pre-registration request to the MA in target subnet before handover. When MN handovers to the new subnet, the multicast session is already available. This MIP independent scheme eliminates the handover delay due to IP group management protocol, however the handover delay still could be unacceptable if the core of the multicast tree is far away.

None of aforementioned schemes fulfil the requirements of mobile multicast in IPv6 network as described in section II of this paper. [13] discusses the agent-based architecture in IPv6 network. This proposal mainly includes three components: multicast agent discovery, intra-MA packet delivery, and handover mechanism. Agent-based architecture introduces two level of MAs, a number of domain MAs (DMA) located in core network, and one local MA (LMA) located in each subnet. On behalf of MN, LMA needs to decide to either join the particular session using RS approach or forward the join request to a proper DMA, depending on network topology and session propriety. A dedicated agent discovery protocol is required to perform this task. If DMA joins the session on behalf of attached LMAs, DMA could decide to use unicast tunnel, intra-MA multicast or Multicast-in-Xcast tunnel to forward multicast packets to LMAs. The intra-MA multicast is the most scalable delivery method. In this method, attached LMAs needs to join a unique intra-MA multicast session, DMA changes the address field of the original multicast packet and sends it to this intra-MA session. When LMA receives the packet, it replaces the address field with the original multicast address. Moreover, DMA should be able to switch between different delivery methods depending on session popularity.

The main advantage of the agent-based approach is that it preserves the multicast nature of multicast sessions by using layered multicast delivery tree, and the routing path is near optimised since DMA is located at local network. In addition, it allows to limit the handover delay within a given DMA region since LMAs only need to join a local multicast tree. The main limitation is that this scheme requires dedicated session management protocols and may involve modifications to existing protocols.

VI. COMPARISON

	BT	RS
Receiver mobility	**Yes**	**Yes**
Source mobility	**Yes**: handover delay is equal to MIPv6 registration delay.	**Yes** with SSM source handover notification: Handover delay is equal to nCoA acquisition duration. *Changes: Session announcement protocols, new MIPv6 Binding Update sub-option.*
Seamless receiver mobility	**Yes** with FMIPv6.	**Almost** with dual subscription: MIPv6 delay. **Yes** with dual subscription plus FMIPv6. *Changes: New MLD Hold message.*
Seamless Source mobility	**Yes** with FMIPv6.	**Yes** with SSM source handover notification. Handover delay can be further reduced if nCoA is anticipated (e.g. thanks to FMIPv6).
Per-flow handover	**Yes**: with several home addresses.	**Yes**
Preserve multicast nature	**Yes** with in-Xcast[2] tunnelling by HA. *Changes: HA to maintain a list of subscriptions for MNs.*	**Yes**
Optimal Routing	**No**	**Yes**

Table 1: BT and RS Approaches against Requirements.

Table 1 attempts to summarize how BT and RS approaches meet capabilities expected from an ideal mobile multicast scheme; when it comes to support any existing multicast routing protocol as specified today. Unless significant support in the network is available (e.g. FMIPv6) and new

[2] Xcast tunnelling cannot be used in conjunction with FMIPv6, unless X2U conversion is performed before, or when, the Xcast packet reaches the access router of MN.

extensions to MIPv6 are standardized (e.g. [5]), the bi-directional tunnelling approach seems quite limited. On the other hand remote subscription natively offers many of the expected capabilities but can hardly support seamless mobility without significant network overload. Actually there is nothing like the best approach that should always be used. The choice really depends on the scenario to be supported taking into account both the capabilities expected and the network architecture. For instance, the basic remote subscription approach may exhibit an acceptable handover delay in a flat network topology where the mobile node always moves between attachment points close one to the others (e.g. between interfaces of the same multicast router).

The multicast agent based approach intends to provide a trade-off between the shortest delivery path (RS strength) and the lowest frequency of multicast tree reconstruction (BT strength). A hierarchical RS-based architecture is introduced for this purpose; where the multicast agent will hide the mobility of a receiver, within a given region, to the main multicast tree. When it comes to compare this approach with RS, the key point to be understood is how the hierarchy helps in the support of seamless handover. The answer depends on the multicast method selected for packet delivery within the intra-MA domain. Two cases should be distinguished: flooding to all LMAs within the domain, or intra-MA multicast tree reconstruction triggered by RS-based mobile node’s mobility. While the first solution obviously eases seamless handover within the intra-MA domain, it highly overloads this part of the network. Depending on the network topology, the second solution will not necessarily provide a faster handover than a basic RS to the main multicast tree since the multicast branches to be re-constructed in both cases may span over the very same routers in the intra-MA region (i.e. same cross-over routers). However, the MA approach provides an easy way to control the upper bound of the handover delay within a given region. It also features a flexible traffic delivery scheme, which may help in optimising usage of network resources in the intra-MA domain. Of course, RS extensions for seamless handover should be reused in the MA context, where the forwarding tunnel entry point (as discussed in section IV.A.) could be the old multicast router or the domain multicast agent itself.

VII. CONCLUSIONS

This paper has presented a comparison of three state-of-the-art mobile multicast proposals from the perspective of the OverDRiVE IST project. Unless significant extensions to Mobile IPv6 are deployed in the network, the Bi-directional Tunnelling approach can hardly meet OverDRiVE requirements. The Remote Subscription approach offers many of the expected capabilities but requires further extensions for seamless handover support with limited network overhead. The Multicast Agent based approach proposes a layered architecture that eases control of handover delay and resource usage in a given region. However, it must be combined with RS extensions to enable seamless handover. Such an integrated support is being specified and evaluated through simulations in OverDRiVE. Similarly, RS-based delivery of multicast traffic to mobile hosts and moving networks is being implemented into a testbed for validation and demonstration by the end of 2003.

The project aims at enabling the delivery of *spectrum efficient* multi- and unicast services to vehicles. To meet this overall objective, the mobile multicast functionality discussed in this paper must be coupled with an advanced multicast group partitioning functionality [14]. Its role is to cluster the members of a multicast group and co-ordinate the traffic distribution in a hierarchical multi-access scenario, according to operator and user needs.

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