# Efficient Multicast support within moving IP sub-networks

Dirk v. Hugo, Holger Kahle, Carlos J. Bernardos, María Calderón

*Abstract*— **This contribution describes achievements in more efficient IP-based communication within moving sub-networks as e.g. provided within cars and trains. Especially the non-optimal routing complexity can be considerably improved for both uni- and multicast type of traffic. An approach to improve the performance of multicast forwarding both into and out of a moving network (NEMO) considers traffic origin and vehicular velocity. The actual implementation within the NEMO sub-system of the European integrated project DAIDALOS (Phase 1) and results of tests performed are reported.**

***Index Terms*—Internet, Mobile communication, Multicast, Routing**

## I. Introduction

THERE has been a continuously increasing demand for mobile services which in the future will provide enhanced data services beside traditional voice communication. Future systems beyond currently operated ones, i.e. beyond 3G (B3G) networks will be mainly based on IP technology, utilize different radio access technologies (cellular, WLAN, etc.), and include several network architectures (infrastructure, multihop ad-hoc, moving networks).

Efficient mobile communication is a key issue for continuous success of next generation services. This includes lossless low-delay handover between service areas and support of advanced services as e.g. multicast. As most challenging mobility issues are related to vehicular environments the completion of IP-layer protocols that enable ubiquitous mobility in IPv4 [1] and IPv6 [2] networks by NEMO (Network Mobility) within the corresponding working group at IETF (Internet Engineering Task Force) has gained much interest. The basic NEMO protocol [3] supports the movement of an IPv6-enabled network moving with respect to the fixed infrastructure thereby changing its point of attachment (access point, AP). Terminals within this sub-network can access services 'on the move' without having to support mobility themselves.

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Mobile networks may be resembled as public or private vehicular networks (e.g. trains and busses or cars), corporate administrative networks, or personal area networks (PANs) where various portable IP devices are interconnected to a mobile terminal with routing capability. Mobile networks (e.g. in vehicles) may also contain visiting mobile networks (e.g. passenger-owned PANs) thus representing a so-called nested scenario. This contribution describes some achievements towards integration of the network mobility problem within the framework of the European project DAIDALOS (Designing Advanced Interfaces for the Delivery and Administration of Location independent Optimised personal Services) [4]. Main issues are provision of an optimized route to minimize delay and overhead and to support ongoing multicast transmissions efficiently.

Following this introduction in chapter II the general problem statement of existing solutions for moving networks and their application within DAIDALOS is described. In chapter III issues of multicast handling within moving networks are discussed and the modular solution designed within DAIDALOS Phase 1 is illustrated. First results achieved with as well a basic as an enhanced version of the implemented protocol are given in chapter IV before completion with concluding remarks in chapter V.

## II. Mobile Networks

A mobile network as shown in Fig. 1 consists of one or more mobile nodes acting as routers (MRs) providing connection to the Internet infrastructure. Nodes within this subnet are called Mobile Network Nodes (MNNs) mainly distinguished as local fixed nodes (LFNs) or visiting mobile nodes (VMNs). Communication with any Correspondent Node (CN) is managed via the MR's Home Agent (HA) residing in the home network whereas physical access is provided by the current serving Access Router (AR) within the visited foreign network.

The AR as attachment point to the infrastructure provides the current address (Care of Address, CoA) of the MR away from home. The MR serves an ingress interface towards its mobile network to address any MNN and a physical egress interface towards the AR in the visited network. Two different logical egress interfaces are distinguished, namely a tunnel interface (towards the HA) and a direct interface (towards the AR) which will be explained below.

The basic solution for IPv6 network mobility (NEMO basic support, [3]) follows the principle of mobile IP [1, 2] where a bi-directional tunnel (BT) between the MR and its HA is set up for transport of all traffic between the mobile network and the destination within the Internet. The MR and HA remove the tunnel header of received packets before forwarding them to destination within the mobile network (MNN) and Internet (CN), respectively.

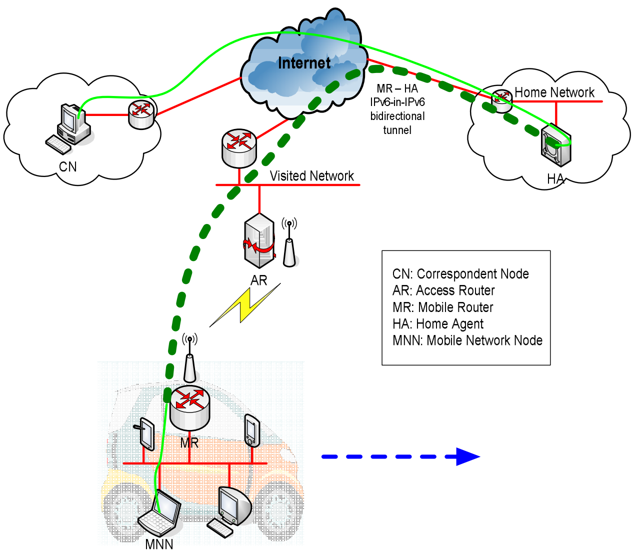


Fig. 1 NEMO network configuration and Basic Support protocol operation

The MR's task is to detect movement of the mobile network by using MIPv6 procedures of listening to Router Advertisements from ARs and sending a registration message (Binding Update) to the HA with a new flag indicating that a router, representing a complete network, is registered instead of a single host. Whereas correct operation has been reported generally a drawback of this solution is the potential inefficient routing via the HA resulting in latency and throughput degradations. The situation deteriorates in case of complex scenarios, e.g. when the CN is represented by another MNN within the mobile network, the MNN is a MIP-enabled VMN, or several mobile networks are combined in a nested configuration, as here concatenated tunnels for each HA have to be set up and released [12].

As these performance problems may be unacceptable for certain applications Route Optimisation (RO) solutions have been proposed, trying to extend the basic solution with the aim of mitigating routing inefficiency. A taxonomy of the solutions proposed so far can be found in [5] together with the MIRON [6] approach of DAIDALOS for unicast flows which deals with the problems of inefficient routing via the HA for single and multiple tunnels present in nested networks. This advantageous protocol allows a quick deployment of the route optimisation support in any IP network because it is transparent to the nodes of the mobile network, which is especially relevant for LFNs (i.e., without specific mobility software) and it allows using the MIPv6 route optimisation support already available at the CNs. Benefits and functionality of this improvement have been shown in theory and practice [7, 8].

Further limitations of standard NEMO protocol arise with multicast traffic received at or originating from a MNN. The MR in the NEMO acts as a multicast router on behalf of all nodes within the moving network. Group membership control and provision of efficient data delivery for Multicast traffic is performed by the MR. However, for real-time multimedia services the delay caused by triangular routing via the HA and by MR-HA tunneling, may be very annoying. Also breech of the multicast nature of the flow due to Multicast-in-Unicast tunnel (multicast avalanche problem), and limited scalability are related to this bi-directional tunnelling (BT) approach. On the other hand the alternative approach of a remote subscription (RS) included in Mobile IPv6 [2] enables direct communication between multicast receivers and multicast sources located within neighboring networks, e.g. the mobile network and the actual access network. During movement of the MR, however, a regular update of part or – in case of a MNN in the NEMO being traffic source – the complete multicast tree is required. As frequent rebuilding of the multicast tree may cause considerable latency increase this approach is only to be applied during standstill or low–speed movement of the sub-net.

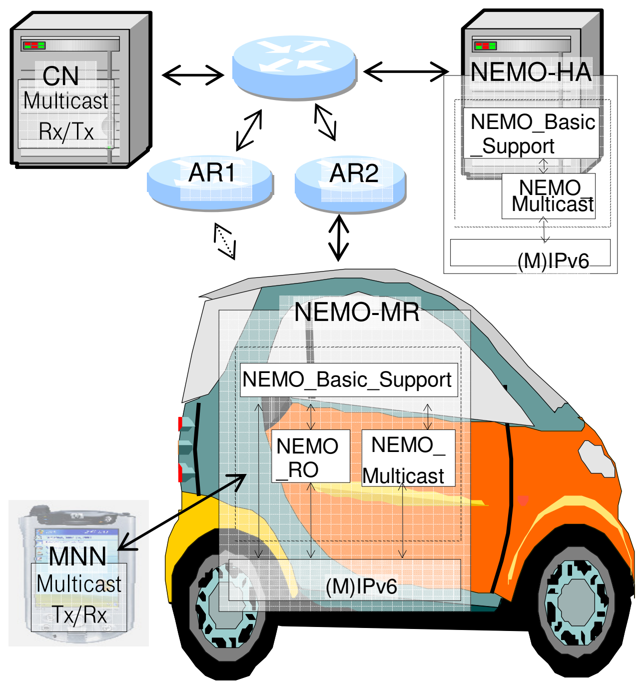


Fig. 2: Extended DAIDALOS NEMO protocol operation and test configuration

## III. Multicast Performance Optimisation and Implementation

In general the basic solution for multicast traffic in mobile networks as proposed by the IETF NEMO WG is to apply the same mechanisms as for unicast traffic based on tunnelling between the MR and the HA. This approach is especially suboptimal in case that source and destination of multicast traffic reside in the same or neighbouring networks (e.g. both moving network and correspondent node are located in the visited foreign network).

DAIDALOS [4] has also achieved a solution for efficient multicast support within NEMO. The set-up of the envisaged scenario with the main protocol modules is shown in Fig. 2

The approach considered in project DAIDALOS consists of combining both methods, BT and RS, depending on the current environment and communication parameters. Upon subscription of a node within the mobile network to a multicast group or transmission of multicast traffic, the MR forwards the request, utilizing the MLDv2 (Multicast Listener Discovery version 2) [9] protocol, or the traffic to the HA. Subsequently the corresponding data traffic or group control messages are forwarded by the HA back to the MR. This proxy functionality of the HA has been described in [10]. In case of reduced mobility of the sub-network detected by means of low handover rate in terms of frequency of CoA changes, the MR initiates routing of multicast traffic via the foreign AR. A protocol implementation within user space based on Linux-2.6 has been achieved and tested. These protocol modules (NEMO_Multicast) together with those for NEMO basic support functionality (NEMO_Basic_Support) and for Route Optimisation (NEMO_RO) have been developed within DAIDALOS. With exception of the latter the software has to be installed on both MR and HA of the NEMO setup as shown in Fig. 2. Here two different ARs denoted by AR1 and AR2 are included in the testbed which will provide mobility in terms of handover within the visited network.

A third hybrid approach aims at introducing local (hierarchical organized) Multicast Agents within the infrastructure. Such a modification allowing for reduction of latency in case of large distance from home network and frequency of multicast tree up-date for fast movement is currently under way for implementation within phase II of the project.

To optimise the overall treatment of multicast traffic the protocol component has the task to identify different multicast streams and flows and to decide on the most appropriate approach according to the current situation. Multiple flows and sessions are controlled and the actually optimal multicast tree is updated.

In the following a description of the NEMO Multicast management module is provided. This module has been developed for and implemented in the MR and in the corresponding HA in the framework of the DAIDALOS project.

The module has to perform the management of the listener-table by means of MLD, the multicast routing function and the decision on the optimised interface for routing the multicast traffic either via BT or RS.

The tasks of the NEMO_Multicast module within NEMO-MR are listed in the following:

- Performing Multicast router tasks for MNNs (LFN, VMN) inside NEMO
- Support of multicast group management protocols and running of a data base
- Forwarding multicast-traffic which is sourced inside NEMO to external listeners (and vice versa)

The specific operations performed by this module comprise the following:

- Addressing different logical interfaces at the egress side of the MR in terms of the bidirectional tunnel to the MR's HA (BT) and the direct access to the visited link as remote subscription (RS), respectively
- Listening to multicast messages (MLD) received from MNNs (ingress) and store data in data base (listening-state table)
- Listening to multicast source traffic received from MNNs (ingress) and store data in cache (replace successfully delivered traffic)
- Generate and send Multicast Listening (MLD) messages (according to the correspondent entry in the listening-state table) to egress interface (AR or tunnel)
- Forward multicast traffic from egress to ingress devices and vice versa (if listed in listening-state table)
- Store Multicast group management messages received via egress in data base (listening-state table)

The NEMO_Multicast module seeks to optimize routing for multicast traffic to and from the mobile network. In this framework characteristic tasks to be performed include:

- Interfacing NEMO_Basic_Support module via Inter Process communication (IPC)
- Monitoring of ongoing multicast sessions and flows within the moving network
- Traffic classification (source/reception, eventually QoS issues, expected session duration, etc.)
- Maintenance of session related optimisation criteria (signalling overhead minimisation, corresponding related user profile conformance, route optimisation principles)
- Decision on final allocation of specific paths
- Consideration of efficient utilisation of the radio resource on the MR-AR link
- Final decision on routing paths based on actually chosen method

The specific operations performed by the module in this context comprise the following:

- Receive message via interface to

NEMO_Basic_Support (new MR CoA) and store value together with time stamp
- Derive movement indication by comparison with preceding values in table
- Decide about logical egress interface to use based on the time the moving network remains in the current foreign network and/or on the approximated moving velocity (i.e. the time until the next change of AR)

As an example a flow chart of exchanged data between NEMO-MR, AR, NEMO-HA, and CN is shown in Fig. 3.

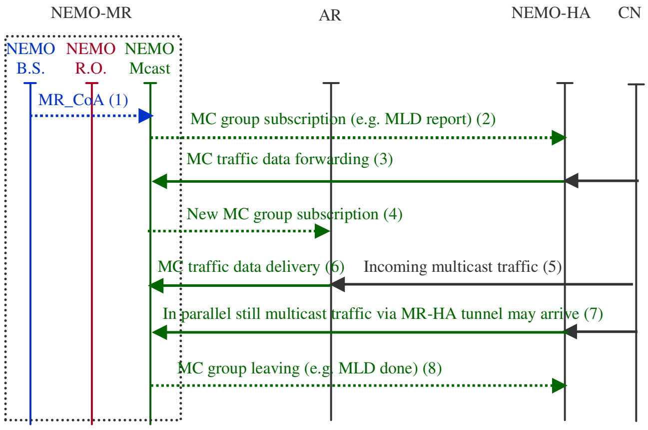


Fig. 3: Message flow example to enable Multicast reception at MR

After subscription of a MNN at the NEMO-MR the following signalling messages (denoted by dotted arrows in the figure) and traffic data (solid arrows) are interchanged between modules and components:

1. NEMO_Basic_Support (B.S.) module informs NEMO_Multicast (Mcast) about current address (CoA)
2. NEMO_Mcast derives movement information (HO frequency)
3. NEMO_Mcast decides for BT approach and forwards multicast group subscription of a MNN within the moving network via NEMO-MR to NEMO-HA and receives incoming traffic via the MR-HA tunnel
4. NEMO_Mcast obtaining no new messages via the interface to NEMO_B.S. derives “no movement” as movement information and decides for new multicast management approach (RS) subsequently sending new group subscription directly to the AR.
5. AR is listening to multicast traffic
6. AR delivers incoming corresponding multicast traffic to MR
7. NEMO_Mcast discards doubled packets still received from NEMO-HA
8. NEMO_MCast at NEMO-MR subsequently cancels subscription via BT approach.

## IV. Test Results

On the test bed described in Fig. 2 a long-term duration test with the two multicast modules in MR and HA has been performed for at least 12 hours. Further tests performed cover the behaviour when the mobile network does a lot of net changes both between the two foreign nets (AR1, AR2) and between foreign and home network (i.e. direct connection to the HA). The period between net changes has been increased from 30 s to 120 s. As a result the expected changeover between the corresponding interfaces could be consistently observed. With the handover rate in the foreign network falling below the installed threshold the egress interface for RS was chosen, a change from home to foreign network results in switch to the tunnel interface for BT approach.

During these tests multicast traffic has been sent from the corresponding node. The local fixed node in the mobile network joined this multicast group to receive the multicast traffic. This has also been tested in reverse direction with LFN as sender and the CN acting as receiver. In this case the BT mode was not altered.

As a test of system performance in case of multicast streaming with variable data rates revealed that for multicast traffic forwarding the router processor load is enhanced from 16.5% to 19.6%, i.e. by about 20 % as compared to unicast traffic forwarding – using 100-Mbit/s network interface cards no limitation in data rate for e.g. video streaming could be observed when the enhanced module performing main operations in kernel space [11] was used.

## V. Conclusion

Within this contribution an approach for more efficient mobile data communication to enable future attractive service provision has been presented. Support for IP-based unicast and multicast traffic to mobile networks irrespective of the access technology is an issue of future mobile systems aimed at within the DAIDALOS project. Optimised routing solutions in the framework of IPv6 network mobility as enabled by IETF protocol NEMO (RFC 3963 [3]) has been developed and implemented within a demonstrator. Main focus here was description of the solution for multicast traffic in mobile networks proposing a decision procedure to optimise the choice between two methods. The approach to increase efficiency relies on characteristics as service parameters, traffic origination, and rate of movement of the mobile networks.

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