Mobility Issues in OverDRiVE[1] Mobile Networks

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ABSTRACT

Mobile networks are subject to current research. OverDRiVE [1][2] investigates possible enhancements for vehicular environments, in particular for people sharing private cars and using public transport. This paper discusses a vehicular scenario in which vehicles (e.g. cars, trains) are seen as moving IPv6 networks which use several access systems to provide Internet (IPv6) connectivity to the vehicle itself and the deployed devices within (IVAN). Focus is placed on the approach for advanced scenarios, such as nested mobile networks, multi-access and mobility within large vehicles.

I. INTRODUCTION

Vehicular communication is expected to grow rapidly in the next years [3]. While sitting and having idle time people want to use mobile multimedia services. Passenger cars and especially larger vehicles like buses or trains may have several users who could naturally form a local area network within the vehicle, an intra-vehicular area network (IVAN). The IVAN makes the case of a mobile network, which raises interesting new technical challenges:

- The mobile router should provide transparency of its (topological) mobility to its residing nodes; that is, its residing nodes should not perceive that the mobile router changes its point of attachment to the backbone network infrastructure.
- A mobile network may itself be one leaf IP-subnet or a tree of IP-subnets (nested mobility), with a mobile router serving to maintain its network connectivity with the backbone network infrastructure.
- The mobile router may support access to different types of access systems, hence enlarging its scope of mobility. In this case, the mobile router will need to support handover between different access systems.
- A mobile network may itself be a hybrid network, allowing its residing nodes to use various access interfaces.
- A mobile network should also appear as part of the backbone network infrastructure, supporting mobile nodes moving (topologically) into and out of the network.

Moreover, authentication, authorization and accounting (AAA) needs to be performed by the mobile terminals in the moving vehicles with regard to the used AAA mechanisms in the infrastructure. The AAA is not in the scope of this paper; it is discussed in [4].

The objective of the OverDRiVE project is to enable and demonstrate the delivery of spectrum efficient multi- and unicast services to vehicles. The project OverDRiVE aims at UMTS (Universal Mobile Telecommunication System) enhancements and co-ordination of existing radio networks into a hybrid network to ensure spectrum efficient provision of mobile multimedia services. An IPv6 based architecture enables interworking of cellular and broadcast networks in a common frequency range with dynamic spectrum allocation (DSA). OverDRiVE issues are:

(1) develop a vehicular router, that supports roaming into the IVAN,
(2) enable mobile multicast by UMTS enhancements and multiradio multicast group management, and
(3) improve spectrum efficiency by system coexistence in one frequency band and DSA.

This paper discusses the mobility issues in OverDRiVE mobile networks and is organized as follows. In section II we introduce the basic mobility scenarios of the project, in section III we give a short overview how network mobility is solved in OverDRiVE. Section IV deals with nested mobility and how it could be solved. Section V is about multi-access issues and in section VI we propose a mobility management solution inside the IVAN. In section VII we conclude our work.

II. MOBILITY SCENARIOS

OverDRiVE has defined a set of mobility scenarios that are used as a basis for the design of a mobility and security solution for moving networks. The core scenarios are the following:

- The IVAN moves and connects to several access systems
- Mobile Hosts (MH) move into or out of an IVAN
- MHs move inside an IVAN

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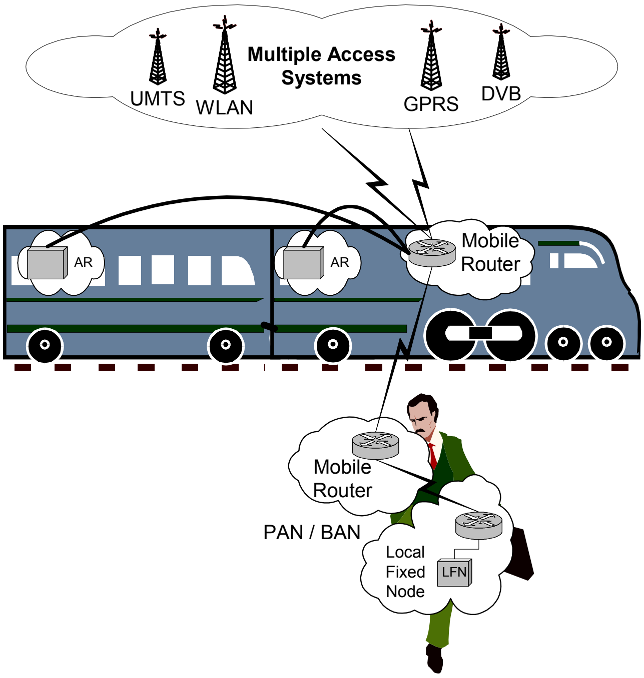

Figure 1: Mobility scenario of OverDRiVE

In Figure 1 a combined scenario for several network mobility issues is given. On the one hand the train utilizes mobile routers (MR) to connect to the Internet using different access systems. The user might bring another moving network inside the train network by having a personal or body area network deployed (PAN/BAN). Inside the train users are free to move around and connect to whatever access router (AR) provided to utilize seamless Internet connectivity. The architecture inside the train might not be flat but rather deploy a network of interworking entities to allow for certain optimizations regarding the mobility management protocols.

Looking in detail, three specific application scenarios are described:

- Nested Mobility: One MR is topologically below another MR
- Multi-Access: A MR is capable to maintain more than one Internet connection to allow for optimizations and flow based routing approaches
- Mobility inside the mobile network.

In the following sections approaches and solutions are described in detail for the basic scenarios as well as for nested mobility, multi-access and micro mobility inside the IVAN.

III. NETWORK MOBILITY

Network mobility support is provided by extensions to the Mobile IPv6 protocol. Basically, a mobile router serving an entire moving network will provide Internet connectivity to all hosts and routers inside the mobile network. The Mobile Router (MR) maintains a bi-directional tunnel with its Home Agent (HA), that is placed in the network that administratively owns and controls the mobile network. This tunnel is named MRHA (Mobile Router – Home Agent) tunnel. A mobile network will visit several foreign networks and the MRHA tunnel will be maintained between each foreign network and the home network (inspite changes in Care-of Address, CoA). The mobile router hides all mobility management from the hosts inside the mobile network. Freeing the hosts from the need to change their care-of addresses naturally provides session continuity and universal reachability at a permanent home address.

The MRHA bi-directional tunnel approach offers several benefits when compared to other routing-based approaches designed for network mobility: (1) does not interact with the routing protocols in the foreign domain thus avoiding introducing non scalable updates of a potentially large number of routing tables of core routers, at each change in the attachment point, (2) leverages on the Mobile IPv6 protocol specification and existing implementations, (3) supports mobile hosts as well as mobile networks containing mobile hosts and (4) supports intra- and inter-domain mobility. On the drawbacks side, one could mention the lack of path optimality and the multiple encapsulating tunnels, both exposed by the nested mobility scenarios, described in the next section.

IV. NESTED MOBILITY

Nested mobility describes situations where two mobile networks attach to each other, maintaining only one attachment point to the Internet through the top-level mobile router (TLMR). An example for the nested case could be a bus on a ferry where the ferry's MR provides Internet connection to the bus' MR and IVAN. Several cases can be identified, where both MRs have the same HA, different HAs, "mobile" HAs placed inside a mobile network and so on. Most of the nesting cases are supported by the MRHA tunnel approach but there exist some minor scenarios that expose protocol drawbacks [5].

A large mobile network containing many fixed routers and connecting to the Internet via a unique TLMR is naturally supporting mobility of the hosts that are attached in the mobile network, with the Mobile IPv6 protocol, and by designating the appropriate HAs inside the mobile network ("mobile" home agents). However, when a MH administratively belonging to another domain than the mobile network itself is visiting the mobile network, and when the requirement of universal reachability at its permanent home address is maintained, then this situation exposes several drawbacks of the MRHA approach [5]. Figure 2 depicts a scenario with a mobile network and a mobile host. MR and MH belong to two different administrative domains. Diagram a) is the initial configuration, b) and c) are subsequent movements. This scenario is entirely supported by the MRHA approach, but with performance drawbacks. When solving these drawbacks, the four important advantages of the MRHA approach mentioned in section III should not be traded off. For example, a routing based solution that offers path optimality and encapsulation-free communication inside the mobile network should not imply lack of reachability at a permanent home address or the impossibility to visit foreign domains that might not implement that routing-based approach.

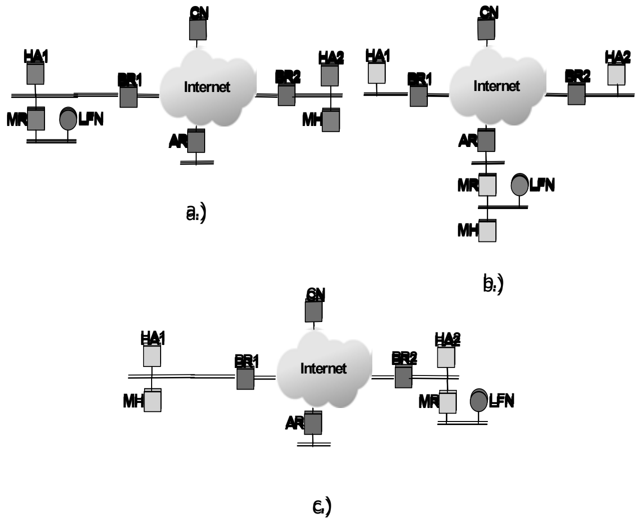

Figure 2: Mobility of an External Host within an IVAN

There exist several approaches to solve the path optimality and excessive tunneling problems with routing protocols: (1) MANET gateways connect a highly dynamic infrastructure-less set of mobile hosts to the Internet, as [6][7][8][9], (2) local-mobility (or micro-mobility) management protocols use a Mobile IPv6 kind of routing protocols to manage mobility of a host with new fixed entities in a foreign network [10][11], (3) OSPF (Open SPF, shortest-path-first) extensions allow for entire moving islands of fixed networks to interact with the OSPF routing protocol running in the fixed domain [12]. The (1) approach does not offer inter-domain mobility, the (2) approach creates a new set of Mobile IPv6-like messages and introduces MAPs as single points of failure while the (3) approach will not interact with other domains that do not run OSPF, thus eliminating the inter-domain handover benefit. Multi-access considers the case when the MR has several egress interfaces or when there are several TLMRs.

V. MULTI-ACCESS

Future wireless communication systems will be characterized by an integration of different access technologies, such as, for example mobile (GSM, IMT-2000), broadcast (DAB, DVB-T) and wireless access (WLAN). All these digital access networks are capable to transport IP, but have been designed for specific services. In a multi-access scenario the user could select the best access system to carry his multimedia traffic.

Multi-access is the capability to connect a terminal to several network attachment points of different technologies simultaneously for obtaining access to the same application services. In addition each access system may provide further different application services. There can be simultaneous connections to different access systems, or connections to only one access system at a time. In a multi-access scenario the mobile network nodes can have multiple IP interfaces: they are multi-homed.

Work on multi-homing has been guided by the objective to introduce redundancy, in particular to connect a site to more than one Internet service provider (ISP), thus eliminating the ISP as a single point of failure. Besides introducing redundancy multi-homing can be used to increase the bandwidth or to balance the load in the network. For moving networks the critical link is the radio link. Multi-homing of mobile network can be employed to introduce redundancy by multiple radio links. A multi-homed node can have different mobility roles depending on the interface. It might be a fixed node on the fixed interface, which is always attached to the same network, and a mobile node on the mobile interface, which changes its point of attachment. In the following the multi-homing of sites and the multi-homing of MR is distinguished:

Site multi-homing: In this case the focus is on the network side. Figure 3a shows a multi-homed network. However, if the home network of a moving network is multi-homed, this is invisible to the MR, since all traffic to and from the MR is tunneled between the HA and MR. Hence site multi-homing is here not considered further.

MR multi-homing: In this case the moving network is multi-homed. One or several mobile routers could provide multi-homing. In the following only one MR is assumed. Figure 3b shows a multi-homed moving network, where the MR is connected to different home networks. In this case the MR can select the appropriate home network. However the MRHA bi-directional tunneling “hides” the access system. If the home network supports different access systems, the MR could not select the best access system.

Figure 3c shows a multi-homed moving network, where the MR is connected to one home network, but over different access systems. The MR acquires a CoA at the different access systems. The MR sets up a bi-directional MRHA tunnel over each access system. To select the most suitable path, the MR must be provided with enough information for making the policy decision on the interfaces to be used. An example could be to use always the link with the highest bandwidth or lowest delay. Moreover, the selection might be guided by application specific criteria.

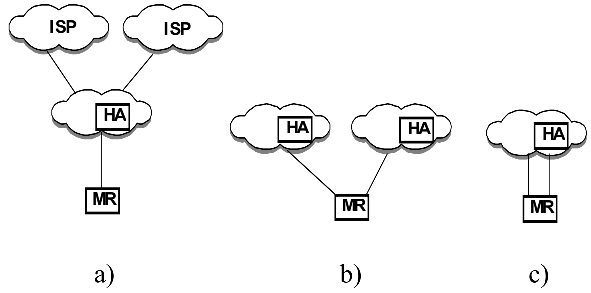

Figure 3: Multi-homing scenarios

Usually, to divert traffic from different services to different interfaces the moving network must use different CoAs when initiating connections. When the moving network changes its point of attachment the MRHA bi-directional tunnel is updated according to the new CoA. In a multi-access scenario the mobile router might hand over active transport connections from one interface to another by using global mobility management, i.e. Mobile IP to update the CoA at the HA. Unfortunately, the new address binding diverts all traffic to the new access system. A solution would be to collocate with the HA a flow router that differentiates the traffic on a per flow basis [13].

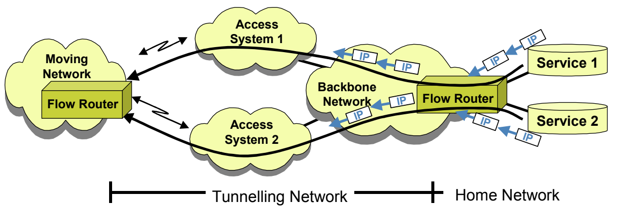

Figure 4: Flow routing for multi-homed mobile networks

Optionally a flow can be identified based on the source/destination address, source/destination port number, transport protocol number quintuple, or based on the IPv6 flow label combined with the source address of the CN.
In a multi-access scenario the HA maintains a binding cache consisting of Home Address – CoAs mappings. In this case of multiple CoA the HA investigates the flow to forward to the corresponding binding. Technically, the flow router employs Hierarchical Mobile IPv6 (HMIPv6) with extensions to allow more elaborate traffic distribution [14]. The mobile router controls the flow routing and informs the flow router in the home network about the flow distribution over the access systems.
In a moving network the Local Fixed Nodes (LFNs) and MHs are not directly aware of the multi-homing, because all traffic is routed to the MR. However, the LFNs and MHs will have application specific demands. Therefore they must register these demands at the MR. Please note that this requires an interworking between the application layer and the network layer.
An approach to distribute the traffic over the appropriate access systems is to collocate a flow router with the MR. The MR distributes the available access system resources according to the demands. The MR implements an optimization procedure to map the flows on the access systems. Vice versa the MR notifies the LFN if the access system capabilities change due to movements. Figure 5 shows the registration procedure.

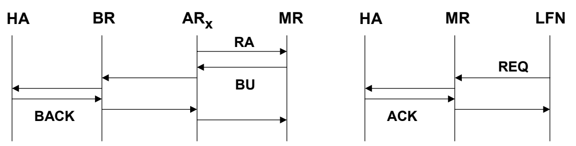

Figure 5: Tunnel set-up and flow routing set-up

The LFN will send the packets to the MR. The MR intercepts the packets and tunnels them over the appropriate interface depending on the flow.

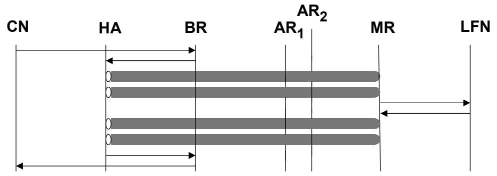

Figure 6: Communication with flow routing

VI. MOBILITY INSIDE THE MOBILE NETWORK

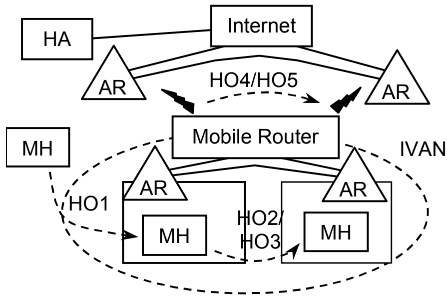

Figure 7: Large vehicle scenario

Figure 7 shows the handover types that can occur in a large vehicle scenario. Outside the IVAN two types of handover can occur, an intra-system (HO4) and an inter-system (HO5) handover. In the case of HO5 and intra-WLAN HO4 handover the MRHA tunnel will be updated from the old AR to the new one. If the HO4 is not an intra-WLAN handover (i.e. UMTS or GPRS) handover, then it will be executed by the corresponding radio system.
The roaming into an IVAN is denoted with HO1 in the figure. During this handover the MRHA tunnel builds up and the MH changes its point of attachment from the AR located in the hotspot to the AR located inside the IVAN.
In the bus and the car scenario if there is only one available radio technology (i.e. 802.11 WLAN) for the communication with the mobile router, there is no need for local mobility management, because inside this kind of vehicles the users do not move from one place to another, and even if they move their terminals can use the same intra-vehicular access router (AR) to stay connected with the mobile router.
In larger vehicles (i.e. train, ship) two types of handovers can occur inside the IVAN. One is an intra-system handover (HO2) between two ARs that support the same radio technology (i.e. 802.11-802.11 handover). The other type of the handover is an inter-system handover (HO3), where the MH not only changes the ARs but the radio technology as well (i.e. 802.11-Bluetooth handover). When the mobile nodes change ARs, these local movements should be hidden from the outside world. One straightforward solution for the mobility management of the nodes inside the mobile network is to use the available layer 2 technology (i.e. 802.11 WLAN) to hide the local movements. However this solution is very simple, it depends on the used layer 2 technology and so it is insufficient when using different radio technologies (i.e. 802.11 WLAN and Bluetooth). In this case the change

between radio technologies needs IP layer involvement. So the usage of IP layer handover is recommended, at least for inter-technology handovers.

Several solutions are available for local mobility management. For example the Hierarchical Mobile IPv6 and a bi-directional tunnel based approach (such as the MRHA tunnel) could manage local movements. Other possible candidates to provide local mobility management are micro mobility proposals such as Cellular IP [10], HAWAII [11] or the Brain Candidate Mobility Protocol (BCMP) [15] that was developed in the IST projects BRAIN [16] and MIND [17].

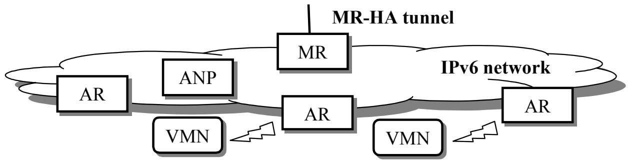

Figure 8: MRHA combined with BCMP

One possible treatment for intra-IVAN mobility could be the MRHA–BCMP combined solution (Figure 8). The mobility of the whole IVAN is managed with the MRHA tunnel [5], while BCMP manages the mobility of the nodes inside the IVAN. Inside the mobile network BCMP anchor points (ANP) are attached to the mobile router. The ANP owns and advertises a pool of IP addresses that it assigns to the visiting mobile nodes. The mobile router is aware of the IP addresses distributed by the ANP. The mobile router forwards packets received via the MRHA tunnel to the ANP and the ANP forwards them using a tunneling mechanism to the appropriate AR. In the other direction, when the VMNs send packets to the IPv6 network of the IVAN, if the destination is outside the IVAN the MR forwards the packet through the MRHA tunnel to the outside world. But if the destination is inside the IVAN, then the ANP receives the packets – because it owns the IP addresses, which are distributed to the VMNs inside the IVAN – and forwards them via the tunneling mechanism to the appropriate AR. In this solution the following features of BCMP could be used: seamless handover, context-transfer and roaming support. The access control could be solved with the OverDRiVE solution [4] or with the MIND User Registration Protocol (MURP).

VII. CONCLUSION

Mobile networks are subject to current research. OverDRiVE investigates possible enhancements for vehicular environments, in particular for people sharing private cars and using public transport. New wireless access technologies (commonly denoted as intra vehicular area networks [IVAN]) may be used as second hop. Thus, passengers can make use of a vehicular router in the vehicle that provides access to high-end multimedia services while sharing a common multi-radio access. This paper described the approach of the OverDRiVE project to provide network mobility. In particular advanced scenarios were discussed including nested mobility, multi-access and intra vehicular mobility. Currently we are integrating an IPv6 based mobile network into a car to evaluate the described approach.

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