WIRELESS WORLD

RESEARCH FORUM

## 1 WG or SIG to which this Contribution was submitted:

WG3

## 2 State which of the categories a) – f) given is the section below:

Identifying new research areas

## 3 Title of research item

Mobility through heterogeneous networks in a 4G environment

## 4 Contact details of author/submitter

Susana Sargento

Instituto de Telecomunicações, University of Aveiro

Campus Universitário de Santiago

3810-193 Aveiro

ssargento@det.ua.pt

Phone: +351 234 377900

## 5 Subject area (WG/SIG and subtopic (as of CfC) where appropriate)

WG3 – Co-operative and Ad-Hoc Networks

- Impact of new fixed-network IP architectures on mobile and wireless architectures and vice versa touching on the “limits of IP” and possible ways to overcome them
- Integration and inter-working of different access and core technologies and networks, ranging from 2/3G over WLAN to vehicular or home area networks including migration

## 6 Relevance of the topic to the above subject area

The IST project Daidalos II intends to present its identified research directions for the mobility in heterogeneous environments.

## 7 Preferred presentation form:

Speech – already accepted.

## 8 Camera ready version

See below

# Mobility through Heterogeneous Networks in a 4G Environment

S. Sargento[1], T. Melia[2], A. Banchs[3], I. Soto[3], J. Moedeker[4], L. Marchetti[5]

[1]Instituto de Telecomunicações, Aveiro, [2]NEC Europe Ltd, Network Laboratories, [3]Universidad Carlos III Madrid, [4] Fraunhofer FOKUS, [5]Telecom Italia Lab

*Abstract*—**The increase will of ubiquitous access of the users to the requested services points towards the integration of heterogeneous networks. In this sense, a user shall be able to access its services through different access technologies, such as WLAN, Wimax, UMTS and DVB technologies, from the same or different network operators, and to seamless move between different networks with active communications.**

**In this paper we propose a mobility architecture able to support this users' ubiquitous access and seamless movement, while simultaneously bringing a large flexibility to access network operators. This mobility architecture seamless integrates heterogeneous networks with different technologies, including broadcast ones, with different network types, such as MANETs and NEMOs, and able to interoperate with legacy architectures, such as 3GPP and Wimax.**

*Index Terms*— **Broadcast, heterogeneous, local and global domains, mobility, multihoming, pervasiveness, QoS.**

## I. Introduction

Daidalos II [1] is an EU IST research project that is working to define and validate the network architecture of future mobile operators. A key requirement for these networks is the support of ubiquitous access. With the current evolution of technologies we envision that, to provide this ubiquitous access, users will access to the networks through a heterogeneous landscape of technologies such as WLAN (Wireless Local Area Networks), Wimax, UMTS and MBMS (Multimedia Broadcast/Multicast Services), and DVB (Digital Video Broadcasting), depending on the situation and the traffic requirements; we also envision that this ubiquitous access can be performed through different types of networks, including mobile ad-hoc (MANET) and moving networks (NEMO).

Daidalos II is defining a network architecture to provide ubiquitous access integrating heterogeneous access networks and providing seamless movement among them. The architecture will support also the following features:

- Mobility management is spitted between local and global domains. As such, access network operators will have the flexibility to choose the mobility management inside their networks. The main advantage is that the access provider is free to choose any option for local mobility, including layer 2, layer 3 or legacy mobile technologies.
- It supports handovers with QoS through a common framework for mobility and QoS signalling in heterogeneous technology networks. This common framework is based on the IEEE 802.21 draft standard [2].
- It supports host multihoming - the host owns multiple physical network interfaces and concurrently gets access through them.
- It explores an identity based mobility management solution through the independent and general management of identities - this would enhance from traditional network mobility protocols towards a solution for mobility of identities.
- It integrates MANETs (ad-hoc networks) and NEMOs (mobile networks) in the mobility architecture. This will allow a terminal to roam, not only among infrastructure access networks, but also through NEMOs or MANETs, keeping all the properties of the Daidalos II architecture in QoS support and security.
- It integrates broadcast networks, also considering unidirectional networks without return channel. It also supports QoS in multicast services running through broadcast networks.
- It integrates ubiquitous and pervasiveness concepts for customized services to the users.

This paper presents a network architecture able to support the above mentioned functionalities. We briefly describe the challenges and the directions to specify the pervasive mobility architecture, supporting heterogeneous technologies, including unidirectional broadcast, local and global mobility concept, and different types of networks. We also address the challenges of the proposed architecture when considering host multihoming, virtual identities and integrated QoS support.

This paper is organized as follows. Section II describes the overall architecture and the main functionalities envisioned. Following, section III describes the mobility architecture, including its concepts of local and global domains and media independent handovers. The integration of both NEMO and MANET networks is addressed in section IV, and broadcast networks and multicast services are presented in section VI. The support of QoS in this heterogeneous environment is depicted in section V, and finally, section VI presents the most relevant conclusions.

## II. Daidalos II architecture

The proposed architecture recognizes the current trend in networks to a heterogeneous landscape of access providers. In such environment it is important to give to access providers (e.g. ISP or NAP) the flexibility of managing users mobility inside their own domain without requiring an interaction with the global mobile operator domain. Thus, it is envisioned the splitting of mobility management into different levels: a global level associated with the Mobile Operator network and a local level associated to network access providers (see **¡Error! No se encuentra el origen de la referencia.**). This view is in line with the current trends envisioned in the NetLMM IETF Working group [5], but a number of extensions are proposed, e.g.: support of heterogeneous (multi-technology) local domains, support of multihoming both at global and local domain, support and integration of MANETs and NEMOs clouds. Although, for simplicity, the architecture in Figure 1 restricts a local domain per technology or type of network, we consider that a local domain is an operator network that, eventually, may be heterogeneous and contain several technologies.

The key aspect of this splitting is the association of mobility management at administrative domains. This brings considerable flexibility to access operators allowing each one to choose their preferred methods without being dependent of a particular scheme. The architecture addresses as well the case where the local mobility management domain is implemented either at layer three or at layer two. The splitting further guarantees compatibility with legacy technologies, such as 3GPP or WiMax forum architectures, which may be integrated in the architecture as local mobility domain clouds by means of specific interfaces. Another interesting case that is supported in the proposed architecture is L2 clouds (that manage local mobility using L2 techniques). We are considering IEEE 802 technologies and solutions to improve mobility at L2 (e.g.: IEEE 802.11r for fast transition).

In the global domain, mobility is supported by means of a global mobility protocol – GMP, such as Mobile IPv6 (MIPv6) [3] or Host Identity Protocol (HIP) [4]. Terminal mobility within a local domain is handled via local protocol operations, local mobility protocols (LMP), which are transparent to the core network and independent of the GMP. In this case, when a mobile node moves within a local domain, only the LMP used in that domain operates; when the node moves across domains, only GMP operates.

Terminals roaming across different access networks potentially implementing different wireless/wired access technologies have therefore the possibility to receive/send data from/to different access networks, eventually at the same time. This opens a new variety of business opportunities where users can choose the most suitable technology depending on several parameters such as application requirements, user profiles or network conditions. Considering such complex environments where the terminal might not have the chance to retrieve all the necessary information about neighbouring access points/wireless stations, the network is required to implement intelligent functions to manage information systems as well as mobility, resources and QoS. While these aspects are typically managed in separated ways in standard GSM/3G networks, beyond 3G platforms assume the IPv6 layer as a common convergence layer to handle both data plane and control plane. Thus, mobility, resource management and QoS cannot be regarded anymore as independent issues. The proposed architecture considers the IEEE 802.21 [2] framework as the "glue" to provide the required functionalities and associated signalling methods both in the network and in the terminal side. Thus, while traditional host based mobility will be maintained, more intelligent systems for network decision and network handover trigger are being investigated and developed.

Mobile terminal and network initiated handovers still survive in the same framework being tightly integrated with the QoS support providing, therefore, efficient support for handover decisions and resource management.

Mobile terminals equipped with multiple wireless access technologies enable the opportunity for multihoming, namely the capability to receive/send data through different paths at the same time. The control plane of such technology can be implemented at global level where the mobile operator owns the functionalities for multiple bindings or locally keeping this transparent outside the local domain. Terminals can be therefore multihomed without the mobile operator knowing users' settings.

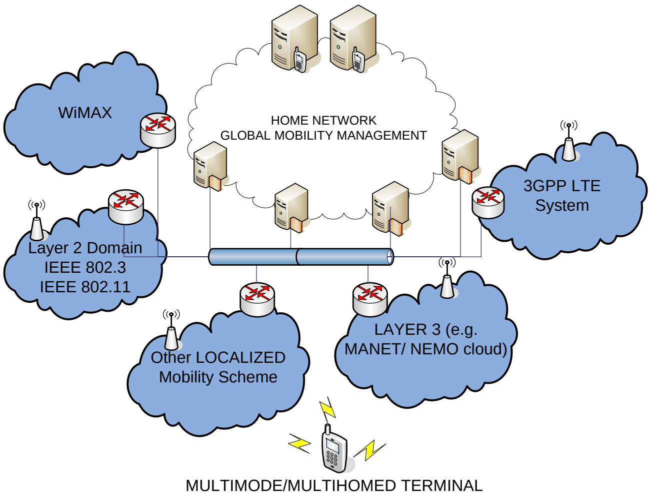


**Figure 1 – Daidalos II network architecture**

One of the Daidalos key aspects is the virtual identity (VID) concept, which provides privacy to the entities utilising it. A user needs/wants to be able to remain anonymous to the service provider and to neighbouring users. Service providers need not know the preferences of any given user and, at the same time, they need sufficient information for charging and accounting. The virtual identity framework provides the possibility to instantiate several virtual users (even being physically only one user) all potentially using the same or different physical devices. From the network perspective, virtual identities behave as different users, with different preferences, for instance, with respect to their preferred provider. The architecture should be designed to avoid the possibility of linking different VIDs, even when used simultaneously by the same user from the same terminal. Virtual Identities impact mobility in the sense that users can move virtual identity without really moving the physical device; this means moving a VID-specific network access session from one interface (access network) to the other. Furthermore, based on their different preferences, each virtual identity may perform handovers independently of the other virtual identities in the same terminal, which yields a novel concept for handovers, no more limited to traditional host mobility. Considering multihoming aspects, virtual identities could then be multihomed, i.e. each VID can have more than one associated network access session on one terminal, introducing the concept of mobility concerning flows. The network and the terminal are therefore required to handle mobility with a different granularity depending on users' profiles and requirements.

In this architecture we consider local domains composed by MANETs and NEMOs, as shown in Figure 1. For both these networks, the concept of local/global mobility has large impact on the mobility between one of these networks and the infrastructure. We consider that NEMO can support the communication of two types of nodes: the legacy nodes that are nodes without any kind of mobility support, and the visiting mobile nodes that are nodes visiting the NEMO. In which case, we have to define how to treat these nodes in the local mobility concept. The envisioned MANETs in Daidalos II are considered as multi-hop networks connected to the core network by means of one or more gateways. Therefore, since access clouds are considered as local mobility domains, the integration of MANET within the overall architecture requires the analysis of the interaction between these networks with the local mobility management protocol. These interactions depend on the number of gateways supported and its location, in the same or different local domains. This has impact on the ad-hoc nodes address configuration and on the mobility management.

The seamless integration of broadcast is also one of the key concepts of Daidalos II project. Namely, we consider the following broadcast technologies: MBMS, Wimax, DVB-H/-T/-S. Both MBMS and DVB networks require special actions to support them in the architecture. MBMS is an enhancement of UMTS to offer point-to-multipoint services which enables this technology to be integrated for multicast services. Therefore we will study how to perform multicast mobility with MBMS. There will be intra-technology handovers as well as handover to or from other network technologies considered, such as from a DVB cell to an MBMS cell. In order to have a seamless integration of the broadcast technologies, we are studying the integration of the UDLR [6] mechanism with IEEE 802.21 to support a unified interface to the upper layers.

For the support of QoS functions in the above framework, the envisioned QoS architecture is independent of the LMP/GMP specifics, and offers a common interface for all cases. The media independent signalling part of the architecture will be based on the 802.21 upcoming standard. Indeed, this standard is an ideal candidate as it aims at providing a media independent interface, which is exactly the objective of the QoS architecture. Note that, for providing all the above functions, some extensions to the standard will need to be designed (in fact, some of these extensions were already performed [7]).

Finally, one of the most relevant tuning parameters to provide mobility decisions is the availability of information from the surrounding context. Ubiquitous and Pervasiveness (USP) are regarded here as a new set of triggers which the architecture can benefit from enabling more customized set of services such as mobility. In this view, terminal mobility and related handover control can receive triggers from network related conditions events as well as from less traditional triggers, such as context information (such as location information, network coverage). This combined with the identity management framework creates a new level of synergies giving novel functionalities to the architecture.

## III. Mobility Architecture

In this section we further explore the requirements to be taken into account for the design of the mobility support. These are:

- R1 - Access Network Operators can implement their own mobility solution (within their domains). The solution must be independent of external Mobility Operators (including home).
- R2 - Minimize complexity in the terminal.
- R3 - Efficient use of wireless resources.
- R4 - Reduce overhead signaling in the network.
- R5 - The solution must be security friendly.
- R6 - Seamless handover support.
- R7 - Multihoming support.
- R8 - Scalability for routing.
- R9 - Minimize network side nodes modifications.
- R10 - Support for heterogeneous networking.
- R11 - The solution must be QoS friendly.

The Daidalos project will address the MIPv6 technology as part of the global mobility domain – GMM (although any other GMP protocol could apply) problem space, and a network based approach as part of the local mobility domain (LMM) problem space (R1). The GMM is tightly integrated with the global identity based mechanism described in the previous section.

The architecture can therefore support multiple LMPs. That is, the terminal should not implement LMP specific functions, but rather implement mechanisms for triggers to be provided to the network (see R2). It is therefore desirable to have a common interface to the access network. We envision the use of IEEE 802.21 for the common interface (extensions here are required to meet Daidalos requirements).

One of the main goals of the mobility split is to provide a scalable solution where signaling overhead, both in the network and over the air, is minimized (see R3 and R4). It is desirable to study the optimal (routing) configuration for large scale LMDs (see R8).

It is desirable that an LMD can (potentially) implement different wireless access technologies. We address these LMDs to be heterogeneous. Homogeneous LMDs are supported too (see R10).

It is recommended to maintain the same IP address (Care of Address - CoA) within a single LMD. This feature looks appealing from a security point of view since LMDs can be untrusted. It avoids as well signaling to the home network for location update when performing handover (see R6, R9, R3, R4). By not changing the IP address, location privacy is also provided. It obviously depends on the size of the LMD (see R5).

Seamless (proactive) handover is required. The 802.21 signaling framework will provide this feature (see R6). The IEEE 802.21 (or Media Independent Handover - MIH) technology enables the optimization of handovers between heterogeneous IEEE 802 systems, as well as between 802 and cellular systems. The goal is to provide the means to facilitate and improve the intelligence behind handover procedures, allowing vendors and operators to develop their own strategy and handover policies. Furthermore, IEEE 802.21 is potentially usable in multiple mobility scenarios, both mobile and network initiated, and it is independent of the location of the mobility management entity.

The 802.21 standard specifies the communication model (see Figure 2) with functional entities and associated interfaces where the MIH technology is implemented in the mobile nodes and network side components, both being MIH-enabled. Network side components are classified either as Point of Attachment (PoA), where the mobile node is physically connected to, or as Point of Service (PoS). PoSs provide mobility services as defined in the specification. The transition between PoAs and its optimization is technology specific (e.g. fast BSS transition) in intra-technology handovers. However, in heterogeneous wireless access technologies scenarios, cross layer communication and handover optimizations are required, and are not trivial tasks (due e.g. to the link diversity).

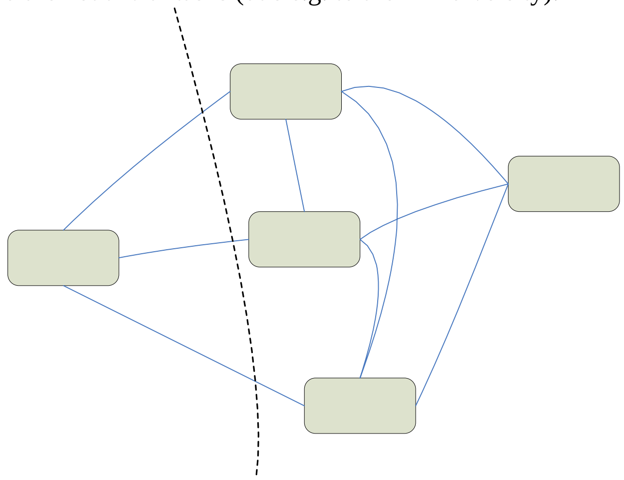


**Figure 2 - IEEE 802.21 reference communication model**

For this purpose, the IEEE 802.21 aims at optimizing the handover procedure between heterogeneous networks by adding a technology independent function (Media Independent Handover Function, MIHF), which improves the communication between different entities, either locally (mobile node) or remotely (network functions). The share of information and the use of common commands and events allow handover algorithms to be sufficiently intelligent to guarantee seamlessness while moving across different PoAs.

MIH defines three main mobility services. The Media Independent Event Service (MIES) provides event classification, event filtering and event reporting, associated to dynamic changes in link characteristics, link status and link quality. The Media Independent Command Service (MICS) enables MIH clients to manage and control link behavior related to handovers and mobility. It also provides the means to mandate actions.

Multihoming at both GMD and LMD should be supported (see R7). Looking at the mobility management architecture, based on a logical separation of local and global mobility management, the following areas have to be considered: handling multihoming in the GMM and in the LMM.

Within LMM two different further possibilities have to be taken into account:

- Homogeneous LMD: this implies that within a local mobility domain only one access technology is deployed; a multihomed mobile terminal is connected to different LMDs (one for each access technology). Multihoming is only managed within the GMD;
- Heterogeneous LMD: a single LMD can deploy different access technologies. A multihomed mobile terminal may be connected to two (or more) different (heterogeneous) access networks belonging to the same LMD. This implies that multihoming can be managed within the LMP. Moreover, it could be the case that some other mobile terminal interfaces could belong to a different LMD; in this case multihoming should again be managed within the GMD through GMP.

Since the mobility is handled using two layers (GMD and/or LMD), multihoming extensions can be applied to GMP, LMP or to both GMP and LMP. In the case multihoming is managed at GMD level, there is no impact on the LMD protocol. The solution for multihoming support is based on MIPv6 extensions. In the case multihoming is managed at LMD level, solutions are related to the LMD protocol considered.

An operator has the flexibility to choose any LMP to handle mobility in its own network. Alternatively, a mobile operator may decide to directly use the GMP to support mobility in its own network, and thus, avoid installing any mobility related infrastructure. In this latter case, mobility functions are supported by equipment located in other networks outside the operator's domain.

The LMD solution is based on the IETF NetLMM protocol [5]. Unlike host-based mobility, such as MIPv6, where mobile terminals signal a location change to the network to maintain routing states and to achieve reach ability, the NetLMM approach relocates relevant functionality for mobility management from the mobile terminal to the network. The network learns through standard terminal operation, such as router and neighbor discovery or by means of link-layer support, about a terminal's movement, and coordinates routing state update without any mobility specific support from the terminal. Such an approach allows hierarchical mobility management on one hand, where mobile terminals signal location update to a global mobility anchor only when they change the localized mobility domain; on the other hand, it allows mobility within a localized domain, for terminals without any support for mobility management. NetLMM complements host-based global mobility management by means of introducing local edge domains. In the future, network based approaches may be also used to achieve global mobility.

**¡Error! No se encuentra el origen de la referencia.** shows the entities involved in the localized mobility management. The entities supporting NetLMM functionalities are the Local Mobility Agent (LMA) and the Mobility Access Gateway (MAG). The LMA is a router defining the edge between the NetLMM domain and the core network. If a global mobility scheme is used, it is the boundary between Global and Local Mobility domains. The MAG is the access router for the mobile node. The NetLMM operation is located between the LMA and the MAG.

Finally, the integration of LMDs based on layer two technologies focus on the use of IEEE 802.1D (Learning Bridges). In fact, this traditional Ethernet switching technology is to be used for “routing” IEEE 802 data frames inside the L2 cloud. The choice of this technology considers factors such as the high benefit/cost ration of

Ethernet, integration with 802.11 and 802.16, and legacy considerations.

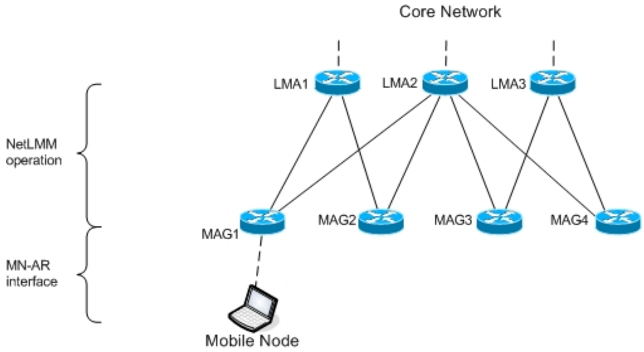


**Figure 3 - NetLMM protocol architecture**

## IV. Ad-Hoc and Network Mobility

The basis for the NEMO support in Daidalos is the NEMO Basic Support protocol [8]. This standard solution has several performance limitations, and for this reason we extend it to provide also route optimization in the traffic between the nodes in the NEMO and other nodes. For providing route optimization we consider that, inside a NEMO we can have two types of nodes: the legacy nodes that are nodes without any kind of mobility support, and the visiting mobile nodes that are mobile nodes visiting the NEMO. In terms of the legacy nodes, all the address configuration and mobility procedures (including route optimization) are handled by the mobile router. The mobile router acts as a proxy for the legacy nodes, detecting flows that can be optimized and generating the appropriate mobility signalling for optimizing those flows. The visiting mobile nodes, on the other hand, can manage their own mobility but they require addresses (CoAs) topologically correct in the infrastructure that the NEMO is visiting. In the proposed solution this is achieved using a PANA functionality that allows telling a node that it must change its IPv6 address and how to get a new one. The mobile router uses this functionality for detecting a visiting node and directs it to configure a topologically correct address in the infrastructure. This is explained in detail in [9].

This route optimization functionality has to be combined with the localized mobility solution, which can be very useful for NEMO, because it avoids the mobility signalling outside the domain in intra-domain handovers (and NEMO solutions can require significant signalling during handovers - signalling corresponding to different nodes inside the NEMO have to be sent). With the localized mobility solution this signalling only takes place in movements between localized mobility domains.

The mobile router will defend all the addresses (CoAs) in the infrastructure, both their own address and the topologically correct addresses that are used by the mobile nodes visiting the NEMO. If the NEMO changes access router inside the localized mobility domain, the LMA will send the traffic to the new access router without any explicit mobility signalling from the mobile router or the visiting mobile nodes inside the NEMO (the corresponding CoAs do not change). When a visiting mobile node moves from the NEMO to an access router in the infrastructure inside the same localized mobility domain the NEMO is visiting, the mobile router will stop defending the address of the visiting mobile node (its CoA) and it can keep using this address as CoA, performing an intra-localized domain handover. The localized mobility protocol will take care of sending the packets addressed to the CoA to the new access router.

The support of NEMOs in Daidalos also provides authentication (based on PANA), integration with a authentication, authorization and accounting infrastructure, and QoS. The solutions are extensions of the solution adopted for mobile nodes. In fact, from the point of view of the infrastructure, a NEMO cannot be differentiated from a mobile terminal: the procedures are the same and there is no any new requirement to the infrastructure to support NEMOs.

One of the goals of localized mobility, as defined in [5], is that the terminals run unchanged and local mobility operations are performed by the network equipments. This requires that the access routers inside a local domain detect the attachment of a new node, so that they can trigger movement and inform the LMA. To support this behavior, mobile nodes must run the typical IPv6 network protocols like neighbor discovery. These protocols were designed for one hop scenarios. Inside MANET this has to be carefully evaluated, because a layer 3 network can be composed by multiple links. If we use Optimized Link State routing (OLSR) [10] inside the MANET, a gateway can easily detect a new node attachment: by finding a new address inside the routing messages, the gateway can inform the LMA of the movement of that terminal. With Ad-hoc On demand Distance Vector routing (AODV) [11], mechanisms to locate the nodes are required.

In this architecture we envision scenarios of MANET and infrastructure networks in the same local domain, managed by the same operator. We therefore consider the nodes' mobility between ad-hoc and infrastructure networks. In Figure 4 we depict an example of the network architecture in the local domain.

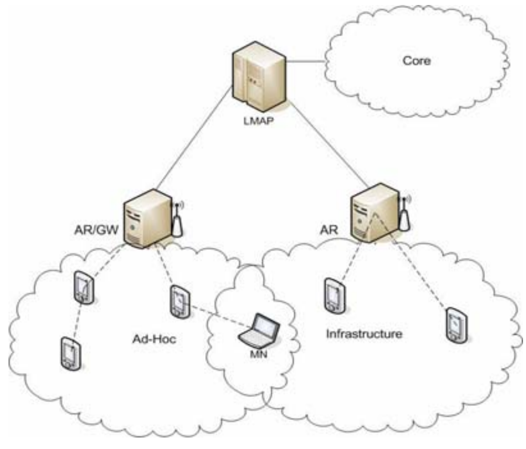


**Figure 4 - MANET and infrastructure in the same local domain**

In the local domain the mobile terminal will have the same IPv6 address whether it is on the infrastructure or it is on the MANET. In this case, the local mobility protocol is based on L2, and thus, the gateway has to translate all the signalling from L2 to L3, so that the routing protocol used inside the MANET can deliver the messages. The main disadvantage of this approach is the overhead placed at the gateway, as well as the enhancements needed to perform such functions.

The concept of multihoming is also applied to MANETs where multiple egress/ingress points (gateways) are considered. We consider both the case of multiple gateways inside the same local domain, or in different local domains. If the gateways all belong to the same local domain, the global mobility protocol is not aware of the multihoming, and it needs to be locally managed. Multihoming at LMA level can be easily handled at layer 3 since a MANET terminal will have several global addresses coherent with the local domain it is connected to. In this case, the mobile node must be aware of the fact that all those addresses belong to the same local domain, and therefore, must register only one of them as CoA with the home agent.

The support of MANETs in Daidalos also provides QoS and security support. Inside the MANET the solutions are specifically built according to the MANET unstable and dynamic characteristics; however, they are integrated with the infrastructure and are not visible to the outside of the MANET.

## V. Broadcast and Multicast

The seamless integration of broadcast is one of the key concepts of Daidalos II project. Namely, we consider the following broadcast technologies: MBMS, Wimax, DVB-H/-T/-S and WLAN.

As previously referred, both MBMS and DVB networks require special actions to support them in the architecture. The integration of DVB networks is a main challenge, since they only support unidirectional transmission. There are several modes of handling this limitation by using a second bidirectional link:

- True unidirectional mode: using the DVB link as a unidirectional link and receive the services broadcasted without being able to react or to control them.
- Virtual bidirectional mode permanently using a second bidirectional link for return traffic. This allows common IP services to be used.
- A composition of these modes: have only unreliable services received via DVB but these services are controlled via a bidirectional link when necessary and possible. This intermediate mode requires quite extensive work on integration.

Figure 5 depicts the support for virtual bidirectional mode on layer two with unidirectional link routing (UDLR) [6].

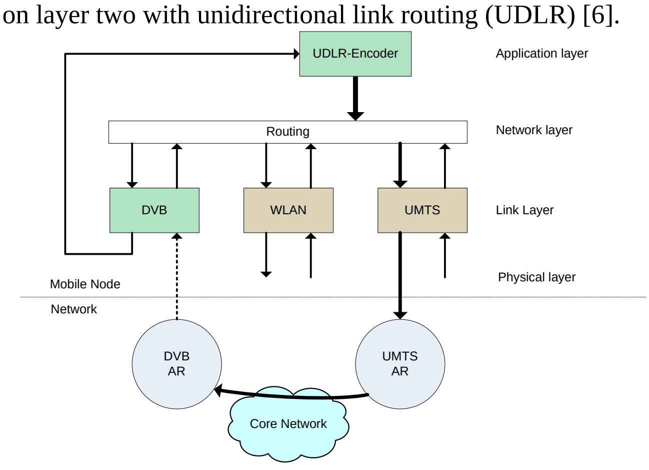


**Figure 5 – Unidirectional link routing and return channel**

For the considered DVB-technologies there will always be just one stationary sending-only node per network and a set of mobile receiving-only nodes (referred to as sender and receivers).

For the used mobility architecture, the virtual bidirectional interface on the receiver side should be usable as any other bidirectional interface, so applications do not have to be changed at all. The integration of UDLR-based support for unidirectional link on the receiver side will have the following implications:

- In order to use the virtual interface for common IP applications, the interface managing entity has to assure that there is a second, bidirectional channel available all the time.
- In order to allow seamless handovers of the return channel when changing the access router, it is necessary to avoid long gaps of connectivity.
- There has to be QoS support for this system.

In order to have a seamless integration of the broadcast technologies, we are studying the integration of the UDLR mechanism with IEEE 802.21 to support a unified interface to the upper layers.

The challenge of unidirectional links support becomes even greater when we consider mobility of both unidirectional and return channel, as well as the QoS and security support. Besides the common QoS and security process, the encapsulated return traffic should be treated in a similar way. Also the support of seamless handover on such links will be studied. The terminal should already know the tunnel endpoint address of the next DVB access router before the handover; otherwise, long gaps of connectivity will be expected.

To make effective use of the “one-to-many” capability of all these broadcast networks, multicast is based on Protocol Independent Multicast – Sparse Mode (PIM-SM) [12] and Multicast Listener Discovery (MLDv2) [13]. The use of multicast in the architecture requires the integration of multicast and the localised mobility management, as well as its integration with authentication and security mechanisms, and support for virtual identities. Since source mobility will also be considered, we will support single source multicast (SSM) besides any source multicast (ASM). To allow seamless forwarding for moving source and efficient routing, PIM-SM will be extended by an indirection mechanism.

For seamless listener handover, there will be a context transfer mechanism used, both for intra- as for inter-domain handovers. Notice that inter-domain handover will require security trusts between domains to perform this transfer.

In our architecture, all virtual identities used on the same device will remain unlinkable concerning multicast subscription as well as multicast transmission. Since multicast routing hides the set of receivers from potential attackers outside of the access network, the actions taken may be restricted to the access network.

To support multicast on unidirectional links with a temporary unavailable return channel, an alternative group membership management system will be provided, which allows subscribing for a certain time in advance. Using this system, there is no need for the listener to provide MLD reports during the specified time frame.

## VI. QoS Support

The envisioned QoS architecture (see Figure 6) is independent of the LMP/GMP specifics, and offers a common interface for all cases. But the QoS management is also split, as described in the following. Each operator owns his administrative domain, consisting of different Access Networks (ANs) with different access technologies within. The communication between an wireless access technology and the wired AN is performed by means of access routers. For each AN there exists one QoS Broker (ANQoSBr), responsible for the management of resources within the AN, which also performs the admission control. At the AN level, QoS management is performed on a per-flow basis. For the coordination of ANs, the Core Network (CN) has its own QoS Broker (CNQoSBr), responsible for the inter-domain QoS provisioning; CNQoSBr manages the MPLS domain that connects (via the core routers) each one of the domain's ANs, and the connections resources allocated to the inter-domain connections. This is performed on a per-aggregate basis.

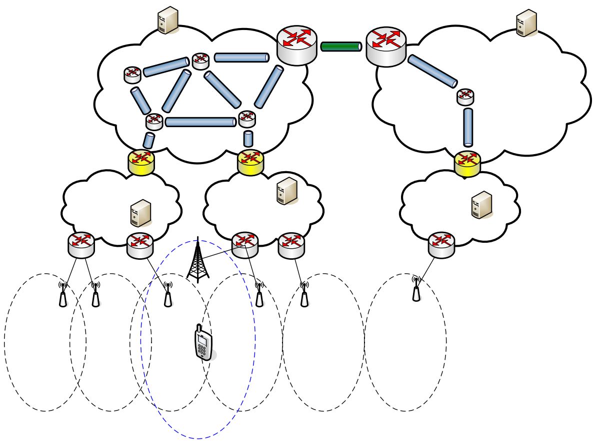

**Figure 6 - QoS architecture model**

The main functions provided by the QoS AN architecture, which is the main focus of this paper, are the following ones:

- Primitives for establishing, releasing and modifying a QoS connection.
- Primitives for maintaining QoS during handovers.
- Primitives for providing QoS related information to other modules, typically for mobility purposes.
- Primitives for handling multihoming and resource management.

The media independent signaling part of the architecture will be based on the IEEE 802.21 upcoming standard. Indeed, this standard is an ideal candidate as it aims at providing a media independent interface, which is exactly the objective of the QoS architecture. IEEE 802.21 enables cooperative handover decision making, by using a media independent information service for network discovery and selection.

The QoS architecture provides interfaces for the communication with other modules, such as mobility and authentication modules, and also defines technology specific modules that convey QoS to the respective technology drivers. A brief overview of the challenges to be tackled by these modules is given in the following:

- For WLAN, which is a connectionless technology, the IEEE 802.11e standard supports differentiated service provisioning based on configurable parameters. These mechanisms need to be complemented with admission control and configuration guidelines. The support for multicast can smoothly be integrated in this technology.
- UMTS is a connection-oriented technology in which mechanisms and procedures for QoS support involve dynamic establishment, modification and release of dedicated radio bearers (for unicast traffic) and MBMS radio bearers (for multicast traffic).
- 802.16 is another connection-oriented technology that it is used as a backhaul technology. The new amendment 802.16e aims at extending this with mobility functions for mobile terminal support.

Unidirectional technologies, as DVB, require the integration of the unidirectional link in the QoS architecture, with a proper management for the asymmetric virtual interface and the QoS integration of the return channel when present.

## VII. Conclusion and Future Work

This paper presented the Daidalos II mobility architecture to seamless integrate heterogeneous networks with different technologies, including broadcast ones, with different network types, such as MANETs and NEMOs, and able to interoperate with legacy architectures, such as 3GPP and Wimax.

The basic idea of the proposed architecture is the splitting of the mobility management in two levels: the local mobility domain and the global mobility domain. The management of the mobility in these two levels is kept completely independent. This independency makes the architecture different from other traditional hierarchical mobility management approaches.

Other important features are considered in the architecture: the innovative notion of "identity based mobility management"; the support of host multihoming with related benefits mainly in terms of resiliency and resource optimization; and the adoption of IEEE 802.21 framework as the "glue" to provide common signaling methods, both in the network and in the terminal side, for mobility, resource management and QoS.

Pervasiveness and context awareness are two other key concepts considered within the architecture, which imply further innovations in the mobility architecture. As an example, in the definition of the handover control it should be taken into account the chance to receive not only triggers from network related conditions / events, but also from less traditional triggers, such as context information.

The foreseen future work aims to evaluate the feasibility and the effective benefits of the architecture both in terms of design, scalability and deployment issues. Simulation work and the set-up of lab trials will be the basis for this evaluation.

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## REFERENCES


[1] The IST Daidalos Poject, http://www.ist-daidalos.org.
[2] The IEEE 802.21 Working Group, http://www.ieee802.org/21.
[3] D. Johnson, C. Perkins, and J. Arkko. Mobility Support in IPv6. RFC 3775 (Proposed Standard), June 2004.
[4] R. Moskowitz. Host Identity Protocol Architecture. Internet Draft (Work in Progress), January 2005).
[5] Giaretta, G., "NetLMM Protocol", draft-giaretta-netlmm-dt-protocol-00, June 2006.
[6] E. Duros, W. Dabbous, H. Izumiyama, N. Fujii, Y. Zhang: A Link-Layer Tunneling Mechanism for Unidirectional Links, , ftp://ftp.ietf.org/rfc/rfc3077.txt.
[7] A.Vidal, T.Melia, and D. Corujo. QoS Considerations in Network Initiated Handovers. Contribution to IEEE 802.21, May 2006.
[8] V. Devarapalli, R. Wakikawa, A. Petrescu, P. Thubert, "Network Mobility (NEMO) Basic Support Protocol," IETF Internet RFC, January 2005.
[9] M. Calderón, C. J. Bernardos, M. Bagnulo, I. Soto, A. de la Oliva, "Design and Experimental Evaluation of a Route Optimisation Solution for NEMO," IEEE Journal on Selected Areas in Communications (J-SAC), issue on Mobile Routers and Network Mobility, Volume 24, Number 9, September 2006.
[10] T. Clausen, P. Jacquet, Optimized Link State Routing Protocol (OLSR), IETF experimental RFC 3626, October 2003.
[11] C. Perkins et al., Ad hoc On-Demand Distance Vector (AODV) Routing, IETF experimental RFC 3561, July 2003.
[12] D. Estrin et al., "Protocol Independent Multicast-Sparse Mode (PIM-SM): Protocol Specification", RFC 2362, June 1998.
[13] R. Vida et al., "Multicast Listener Discovery Version 2 (MLDv2) for IPv6", June 2004.