

S. Sargento¹, T. Melia², A. Banchs³, I. Soto³, J. Moedeker⁴, L. Marchetti⁵

¹Instituto de Telecomunicações, Aveiro, ²NEC Europe Ltd, Network Laboratories,

³Universidad Carlos III Madrid, ⁴Fraunhofer FOKUS, ⁵Telecom 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.

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, WiMax, UMTS, and DVB, depending on the situation and the traffic requirements, and also through different types of networks, including mobile ad-hoc and moving networks.

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 splitted 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.

The following section describes how each of the mentioned features is addressed in the Daidalos II architecture. Finally, we present the most relevant conclusions in section III.

II. DAIDALOS II ARCHITECTURE

This section gives an overview of the envisioned architecture and its features.

A. Splitting of the Mobility Management

Network operators require the flexibility of managing their networks according to their requirements, technologies, and preferences. To provide this feature for the mobility management, Daidalos II architecture splits the mobility management in global and local domains (see Figure 1). Each of these mobility domains can belong to different operators. A global mobility domain is related with a user home network and provides user subscriptions and mobility across different local domains. Local mobility domains are related with access networks. 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 mobility management in each of the domains is independent of the mobility management solution in other domains.

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.

In the Daidalos II solution the terminals are not directly involved in the local mobility management: they only generate triggers that the local mobility management can use to manage the terminal mobility. We define a framework, based on the IEEE 802.21, to support this signalling and to integrate QoS concepts. IEEE 802.21 provides a standard interface between the network and the terminals in a technology independent way.

Daidalos II mobility management view is in line with the current trends envisioned in the NetLMM IETF Working group [5]. However, many extensions need to be provided to the local mobility protocol. The support of heterogeneous domains, layer 2 domains, MANETs and NEMOs, multihoming, QoS integration support, and identity based mobility management are some of the examples of flaws in the current NetLMM draft.

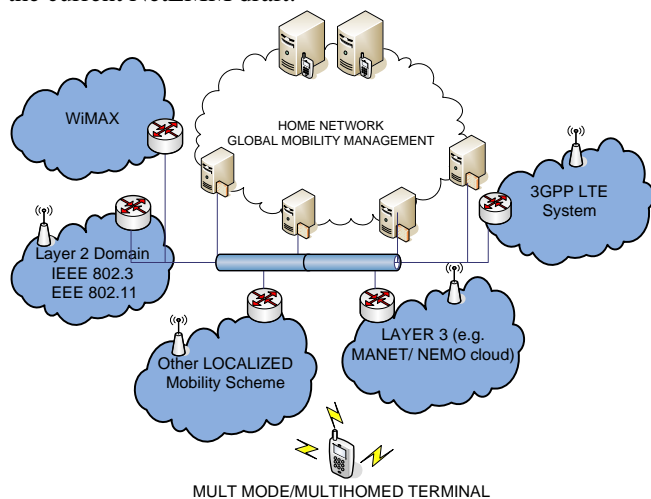


Figure 1 – Daidalos II network architecture

Splitting the mobility management in two domains, and making both mobility management solutions independent brings a lot of flexibility to operators. For example, access operators can manage the mobility of the terminals closer to them, thus more efficiently and with less overhead. Moreover, they do not depend on functions of an external operator to provide their own mobility services. In this sense, the access operator is free to choose any option for local mobility, including layer 2, layer 3 or legacy mobile technologies. Also, while retaining the overall interoperation, network operations can be managed according to access provider's or home operator's preferences giving the opportunity for multiple wireless or wired access technologies. In addition, our architecture also relieves the requirements on the terminal side since it can provide mobility transparently within the local domain to terminals that do not implement any mobility function. To allow easy integration with the terminal side, it is envisioned the specification of a single interface, based on

802.21, abstracting the communication with the local mobility management scheme.

This solution also allows an easier integration of different legacy technologies like 3GPP Long Term Evolution (LTE) and WiMax networks that can be integrated as local mobility domain clouds. 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).

B. Mobile Initiated and Network Initiated handovers

Terminals roaming across different access networks, potentially implementing different wireless/wired access technologies, have 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 neighboring access points/wireless stations, and also because the own resource management in the network side can require the movement of terminals from some access points to others, the network is required to implement intelligent functions to manage information systems as well as mobility, resources, and QoS. 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 will coexist in the same framework, being tightly integrated with the QoS support providing efficient support for handover decisions and resource management.

C. Multihoming

We envision mobile terminals with multiple wireless access technologies that enable the opportunity for multihoming, namely the capability to receive/send data through different paths simultaneously. 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 mobility domain. Terminals can be therefore multihomed without the mobile operator knowing the users' settings.

Since one of the advantages of the local mobility concept is the flexibility that it provides to access operators to manage the mobility of mobile nodes inside their domain without depending on an external operator, it is reasonable to extend this advantage to the multihoming support. Moreover, multihoming can be an excellent way for the access provider to maximize the use of its resources by using the best interface/technology to send/receive traffic to/from the mobile node, according not only to the mobile node's requirements, but also to the general situation of the network. For these reasons, multihoming support at the local mobility domain level is a nice feature for access providers and will be developed in this architecture.

D. Virtual identities and mobility management

One of the Daidalos key aspects is the virtual identity 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 physical device or different physical devices. The bootstrapping of the different virtual identities is strictly connected with the authentication and authorization aspects. From the network perspective, virtual identities behave as different users, with different preferences, for instance, with respect to their preferred provider. This may lead to a mobile terminal having simultaneous connections for different virtual identities, based on the multihoming support described in the previous section.

Virtual Identities impact mobility in the sense that users can move virtual identities without really moving the physical device. 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. Traditional terminal mobility is therefore extended with this new concept. Considering multihoming aspects, virtual identities could then be multihomed 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.

E. Ad-hoc and network mobility

Figure 1 shows local domains composed by MANETs and NEMOs. 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 terms of the legacy nodes, all the address configuration and mobility processes (including route optimization) need to be handled by the mobile router. In terms of

the visiting mobile nodes, we can consider that these nodes will belong to the local domain directly, and then they can be handled considering that NEMO is an extension of the mobility domain, or we can consider that they can belong to a new NEMO, creating a nested local mobility domain.

The envisioned MANETs in Daidalos II are considered as multi-hop networks connected to the core network by means of one or more gateways, announcing specific prefixes within the MANET. 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.

Both in NEMO and MANET we are currently specifying the process for the mobility of mobile nodes between NEMO and infrastructure, and between MANET and infrastructure. We are also working on the specification of the support for multicast services, QoS and security, to enable the seamless movement between any access network envisioned in the project.

F. Broadcast/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.

Both MBMS and DVB networks require special actions to support them in the architecture. MBMS runs its own mobility management scheme. Therefore, it is required to provide the interoperation between MBMS and our architecture, with MBMS acting as local domain, without requiring any further modification.

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.

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 seamless 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.

To make effective use of the "one-to-many" capability of all these broadcast networks, multicast is used. 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 virtual identity support. 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.

G. QoS support

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 main functions provided by the QoS architecture and the corresponding interface 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 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, these extensions were already performed [7])

The QoS architecture contains central elements to control the QoS processes and the communication to other modules, such as mobility and authentication modules, and technology specific modules that convey QoS to the respective technology drivers.

H. Ubiquitous and Pervasiveness

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. CONCLUSION AND FUTURE WORK

This paper presented a mobility architecture able to seamlessly 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.

This paper briefly described the functionalities of this architecture and some ideas on how to achieve them. The final paper will deeply explain the architecture and the mechanisms developed to support all the mentioned functionalities.

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