Continuous Connectivity in Ambient Networks

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***Abstract*—A key question for mobile communications is how to integrate different communication standards and radio access technologies. Ambient Networks augment existing networks with an Ambient Control Space (ACS), which provides control entities for collaboration between different networking technologies and across network boundaries. The ACS functionality includes, among others, functions for managing multiple radio access technologies, a mobility framework for coordinating different mobility procedures and media adaptation functions. In this paper we describe, how these different control functions are integrated and interact, in order to provide continuous connectivity to a user when passing through the coverage areas of different access technologies and operators.**

***Index Terms*—Ambient Networks, cooperative networking, inter-system handover**

I. INTRODUCTION

ONE of the largest challenges in communications today is to cope with the large number of heterogeneous communication technologies. The European research project Ambient Networks [1] is developing solutions that allow to integrate different networking technologies and also enable cooperation across network boundaries in a dynamic way. Ambient Networks (AN) comprise a new set of control functions, the so-called Ambient Control Space (ACS). For the collaboration between two different networks, these two networks *compose* by negotiating dynamically between the Ambient Control Space functions of the individual networks which networking technologies are used and the type of cooperation they want to achieve. For that purpose, also end user devices are considered as a separate AN, no matter if they consist of multiple devices in a personal area network or a single integrated terminal. This emphasizes the role of the end user, he becomes involved in the network cooperation process, he can compose with multiple networks in parallel, thereby opening up the space for new types of business relationships compared to today. Within the Ambient Networks project different aspects of control sharing have been investigated. The scope ranges from network management and security procedures, over new ways of context management, a new mobility management framework and multi-radio access, to media adaptation by the introduction of media ports in an overlay network structure [2]. Within this paper, we will describe how some of these different aspects play together in a typical every-day scenario. For that we have developed a use case following a story line for which we have investigated the involved functional entities of the ACS and how they interact. The use case is called "continuous connectivity", and its focus lies on the areas of multi-radio access and the mobility management framework. However, also the areas of media adaptation and context management are involved. A description of the complete story line is beyond the scope of this paper and for more information the reader is referred to [2]. In this paper we will introduce the key functional entities of the ACS, and pick out some examples within the use case for which we present the interaction of the different functions.

The paper is structured as follows. In Section II we present the Ambient Networks functions to support multi-radio access. Section III describes the mobility management framework, followed by an overview of multimedia delivery using MediaPorts in Section IV. In Section V we present the use case, starting with the story line and the system architecture. Afterwards we describe two different scenes in the story line in which the radio access technology is dynamically changed during the communication session. The difference between the two scenes is, that in one case both radio access technologies are integrated into a common network, whereas in the other case they are provided by different operators. Section IV summarises the paper.

This paper describes work undertaken within the Ambient Networks project which is part of the EU's IST program. In total 41 organizations from Europe, Canada, Australia and Japan are involved in this Integrated Project, which will run from 2004-2007. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the Ambient Networks Project. The authors would like to thank all members of the Ambient Networks project, who have all contributed to the development of the concept presented in this paper.

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II. AMBIENT MULTI-RADIO ACCESS

As depicted in Figure 1 Ambient Networks contain two new functional entities that enable efficient management of multiple radio access technologies: Multi-Radio Resource Management (MRRM) and Generic Link Layer (GLL) [3][4].

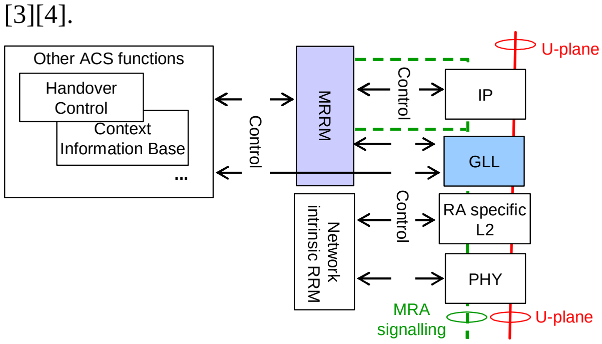

Figure 1: New functional entities MRRM and GLL for multi-radio access

A. *Multi-Radio Resource Management*

The terminal Ambient Network can establish a communication path via different access flows to the fixed infrastructure. MRRM observes and manages these different access flows [6]. A flow consists of a number of consecutive links that provide connectivity between the flow end-points. Locators identify the flow at the end-points. An access flow is a specific form of flow, which provides connectivity in the access domain between two forwarding points (FP). Based on the service requirements of a communication session, MRRM evaluates the available access flows and selects those which are best suited for the data sessions and the network operation. For that it considers the performance of the different radio accesses, the resource costs and resource availability in the radio cells, the terminal behaviour (e.g. its mobility). Within its access selection decision, MRRM is limited to the bounds provided via user and network policies. For access selection, MRRM maintains a number of sets of access flows, as depicted in Figure 2. The *Detected Set* comprises all access flows that are available for the terminal network. The *Candidate Set* exists for every data session and it contains the access flows that are closely monitored by MRRM and can be assigned to the session. The *Active Set* contains the access flow (or access flows) that are currently used by a particular session. The access selection function is part of several MRRM algorithms, like admission control, load management and congestion control.

B. Generic Link Layer

GLL embeds the radio specific transmission methods and protocols and it abstracts radio specific information that it reports to MRRM [5]. For that it continuously observes the performance, the resource usage and the resource costs of the access links. It detects when new access links are established or lost. It also monitors, if the required quality of service of the session is provided by the access link. The GLL filters the observations locally at the link layer and reports them to MRRM whenever significant events occur. GLL also receives link configuration messages from MRRM and can enforce the according link configuration and possible resource allocation.

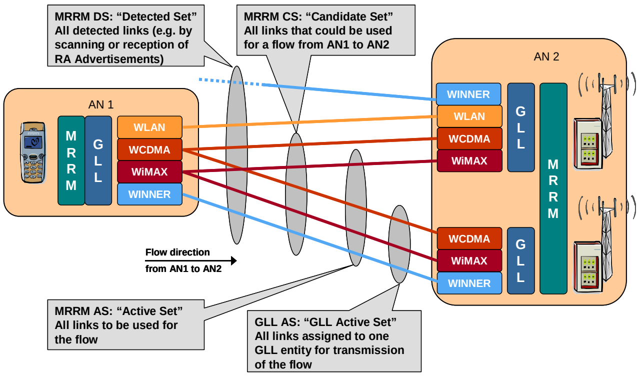

Figure 2: Different sets of access flows used for access selection

III. Ambient Multi-Dimensional Mobility

The mobility related functional entities (FE) in the Ambient Control Space are *Triggering*, *Handover and Locator Management*, *Routing Group Management* and *Rendezvous and Name Resolution* [7]. In the use case presented in this paper, we have the triggering and the handover and locator management functional entities present. Integrating routing group management and rendezvous and name resolution into the system is left for further study.

The mobility related functional entities make use of the Context Information Base (CIB). Within the CIB context information is represented by data objects within a distributed database. The collection of objects within this database represents the Context Information Base. The CIB has two main functionalities: On the one hand it keeps track of context sources, including context registration and naming, context data directory, indexing, context data monitoring and management, etc. And on the other hand it provides efficient collection and distribution of context data to clients through context associations, including context data update and context processing such as aggregation, inference etc., to support higher-level context services.

A. The Triggering FE

The Triggering functional area consists of functions such as: collecting and identifying events from various sources, filtering and classifying of those events, calculating triggering event correlations and making the triggers available for any other function in the ACS, such as handover decision or routing group management [7]. The triggering functions are likely to be distributed in the system. For example, the collection and filtering of link layer specific triggers may be located in the different GLL entities, while more filtering may be performed in MRRM, which may forward certain triggers to the CIB for storing them to be used by other functions which may not have as strict real-time requirements.

As some triggers may be received independently of each other, it might happen that different types of movements are detected simultaneously, e.g. the mobile entity may move between access technologies and address spaces at the same time. This leads to the assumption, that the mobility events can be seen to take place in multiple orthogonal dimensions. Seven of those mobility dimensions have been identified, namely *physical location*, *access technology*, *address space*, *security domain*, *provider domain*, *device properties* and *time*. Figure 4 depicts four mobility dimensions. Following this, any mobile entity has a location in the "mobility space" which can be described by coordinates in these seven different dimensions, and the mobility management mechanisms can be seen as updating these coordinates [7]. In the use case presented in this paper, we study two of these dimensions: the access technology and the provider domain.

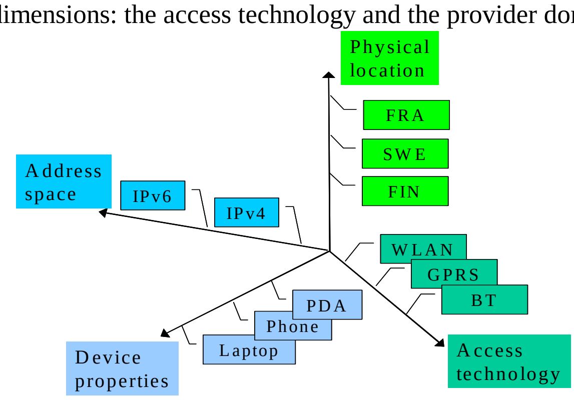

Figure 4: Example of four mobility dimensions

B. Handover and Locator Management

Functions of the Handover and Locator Management entities are the handover decision and the selection of appropriate mechanisms for performing the handover, and the execution of the handover. The handover decision is based on the received triggers and other context information such as system and network status and user preferences, which are stored in the CIB. From the received triggers, it is possible to determine what should be moving and where. As an example, a mobile entity could be moving in a single network, between networks, between different access technologies or even different operator networks; therefore different mobility management mechanisms and protocols are needed to support these mobility events [7].

The *Handover Decision* function is located in the MRRM, and the *Handover Control* (HC) is a separate system component which implements the selection of handover mechanisms and the actual execution of the handover. The Handover Control receives from MRRM a notification of changes of the active set for a session. The HC then translates this into control commands to the respective Forwarding Point (FP) entities. HC may also trigger a context transfer method, e.g. for transferring link layer context between different GLL entities. HC maintains for every access flow the corresponding FP entities, locators/identifiers and handover procedures/protocols.

A *Forwarding Point* (FP) is a routing decision point that maps sessions to access flows. The FPs store the active sets (of flows) for each session. This active set can be changed in the FPs by the HC together with MRRM. The FPs may be in a hierarchy, so that a separate mobility management protocol is run at different levels. In the use case we use IP mobility between WLAN and cellular networks and L2 mobility between different cellular access networks. An *access flow* can be identified by the endpoint locators (e.g. IP addresses), or the "radio bearer identity" as used in 3G.

IV. Ambient Multimedia Delivery Based on MediaPorts

A multimedia delivery architecture that accommodates the future requirements of advanced multimedia services for mobile users is another key contribution of Ambient Networks. Smart multimedia routing and transport (SMART) in this context means the optimisation of media delivery services by taking advantage of network-side media 'processors'. These media 'processors', called *MediaPorts*, provide value-added services, such as pro-active caching, transcoding or media adaptation facilities, flow splitting and synchronisation or special types of routing capabilities. MediaPorts are located at optimal positions on the end-to-end transport path where most appropriate for the improvement of a media service.

A key innovation of the SMART architecture is the concept of *Service-Specific Overlay Networks* (SSONs) [9][10][11]). The central idea is that different 'virtual networks' are deployed in an ad-hoc manner for every media service in order to tailor the network to the distinct requirements of that service (for example, QoS profiles, media formats, cost and fault-tolerance).

The use of SSONs enables the transparent inclusion of *MediaPorts* into the end-to-end communication path(s). Moreover, the use of overlay networks also allows selection of appropriate paths in the underlying network. Depending on the characteristics and requirements of the multimedia service (e.g., QoS, media formats, responsiveness, cost, security, distribution topology), or other factors like user preferences, connectivity and mobility constraints, SSONs can route media streams through different MediaPorts, but also through different access technologies.

In case of a handover to another access network with different link rate, the Ambient media delivery framework will ensure a high as possible service quality of the multimedia service. If, for example, the handover is carried out to an access network with a lower link rate, the MediaPort in the end-to-end path will adapt or transcode the media stream to this lower rate. Although in the case of a handover to a high data rate access network, the inclusion of a MediaPort could improve the overall delivered media quality if a layered source coding scheme is used. Here, some layers are normally blocked in the MediaPort and will only pass in the case of the high data rate access network resulting in an improved media service quality.

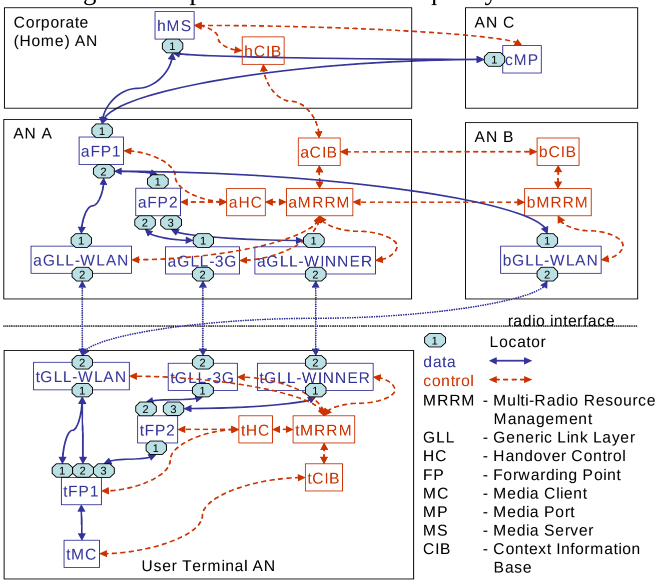

Figure 3: System architecture for the use case

V. Use Case of Continuous Connectivity

A. *Story Line*

We describe the interactions required for continuous connectivity from the perspective of an end user in a typical situation:

Alice travels on a business trip to Brussels. She has been working hard with her presentation material, but during her flight she realises that there are still some open questions that she needs to discuss with a colleague at the home office. Just after arrival at the airport she makes a phone call to her colleague John. They decide to extend the voice call to a multi-media conference, now also including video and shared editing of her presentation material. They continue conferencing during Alice's taxi ride to her hotel, and even upon arrival there. Alice experiences a very smooth voice/video call with shared applications without interruptions although she roams several times between access networks and operators.

The same situation can be described from the perspective of the network operators that are involved in the scenario:

A network operator A has integrated three different radio access technologies into a common network: 3G, WINNER [12] and WLAN. The operator has chosen to deploy each

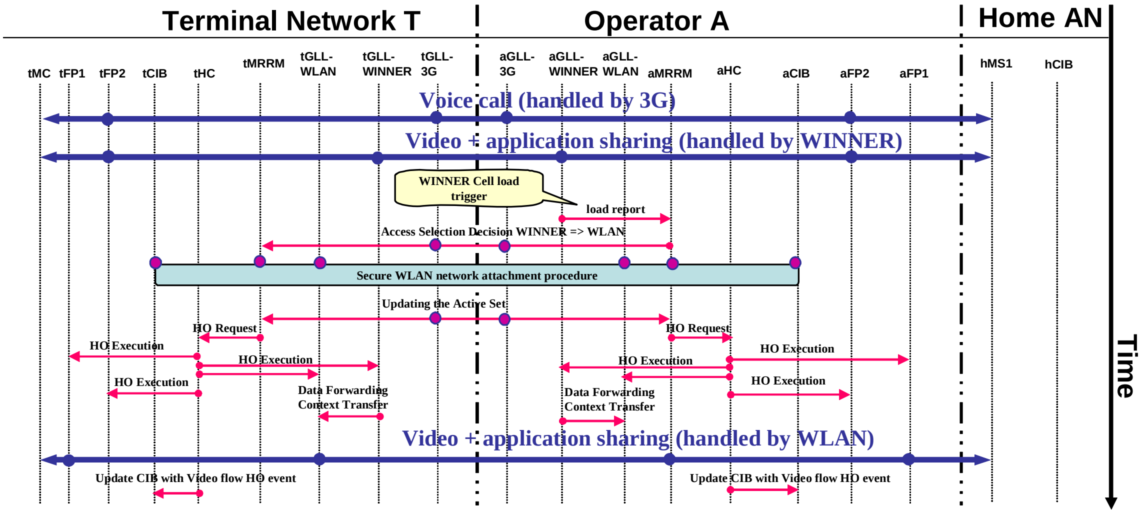

Figure 4: Network controlled handover based on cell load from WINNER to WLAN within the same network

access technology where it fits best. The 3G access is basically available everywhere. WINNER is so far only deployed in areas with rather high traffic demand. The operator has also chosen to deploy WLAN hot-spots at some strategic locations. In Alice's case the operator is offering WLAN access at the airport (in addition to 3G and WINNER). Further, the operator is cooperating with local access providers, which operate own hotspot networks in private areas, like shopping malls, conference centres and hotels. This cooperation is achieved by means of composition of the Ambient Networks of the wide-area operator A and the local operators. While being able to offer a "seamless" experience to Alice, the operator is also able to exploit load sharing between all these access networks (including the ones owned by cooperating operators), taking into account resource availability, QoS requirements, and policies. In the case of Alice, the local WLAN access in the hotel is provided by the hotel operator.

B. System Architecture

In total five different Ambient Networks are involved in the use case. The system architecture is depicted in Figure 3, where the lower case prefix identifies the network to which a functional entity belongs. The user terminal AN is Alice's laptop and headset. Her colleague John is connected to the corporate network, here also called home AN. AN A is the mobile network operator, which provides wide-area coverage and has three radio access technologies, 3G, WLAN, and WINNER. AN B is the local WLAN operator of the hotel. Furthermore, we have AN C, which is a network operator that provides a media adaptation service for the session with its MediaPort. The solid lines in Figure 3 indicate the data flow of the session, whereas the dashed lines show the ACS signalling between the AN control entities.

C. Access Selection and Handover Concepts

Within this story line several different types of access selection and handover are performed. The first type of access selection is based on the service requirements. Throughout the scenario, the speech call and ACS control signalling is assigned to the 3G access flow. This decision is motivated by the low required data rate, such that both WINNER and WLAN are not able to provide a better service quality. On the contrary, the wide-area coverage of 3G increases the reliability of maintaining the speech and signalling connection also when moving. For the multimedia session this is different. In this case, the higher data rates of WLAN and WINNER increase the performance for the video connection and for the exchange of files.

Access selection can further be triggered from MRRM located in the terminal network or MRRM located in the access network. The terminal network is mainly responsible for access selection when the radio link performance of the access links varies or the service requirements change. The access network is responsible for re-allocating users in cases of cell overload, in order to balance load between different access technologies also depending on the costs of the resources. In one situation of the use case MRRM access selection is triggered by the change in mobility behaviour when Alice enters the taxi; the increasing number of WLAN handovers cause MRRM to select 3G as an access with wide-area coverage and larger cells compared to WLAN.

D. Handover between different radio access technologies

An example scene of intra-operator handover is depicted in Figure 4. At this point in time Alice is at the airport and has a voice connection established to her colleague which is allocated to the 3G access path. In addition, a multimedia session is established which is assigned to the WINNER access path. The GLL-WINNER entity detects the WINNER cell load passing a critical threshold and reports this to MRRM of operator A. A WLAN access path has already been detected and is included in the Candidate Set of all sessions and becomes now the best access for the multimedia session. A WLAN network attachment procedure is performed and the Active Set for the multimedia session is updated by MRRM signalling between the terminal network and AN A. The MRRM entities send a handover request to the HC entities, which execute the handover by updating all locators and bindings in the forwarding points accordingly. In addition, HC notifies the GLL entities for WINNER and WLAN about the handover, which can perform context transfer and data forwarding to the GLL-WLAN entities. Now the multimedia session is routed via the WLAN access path. The CIB is notified about

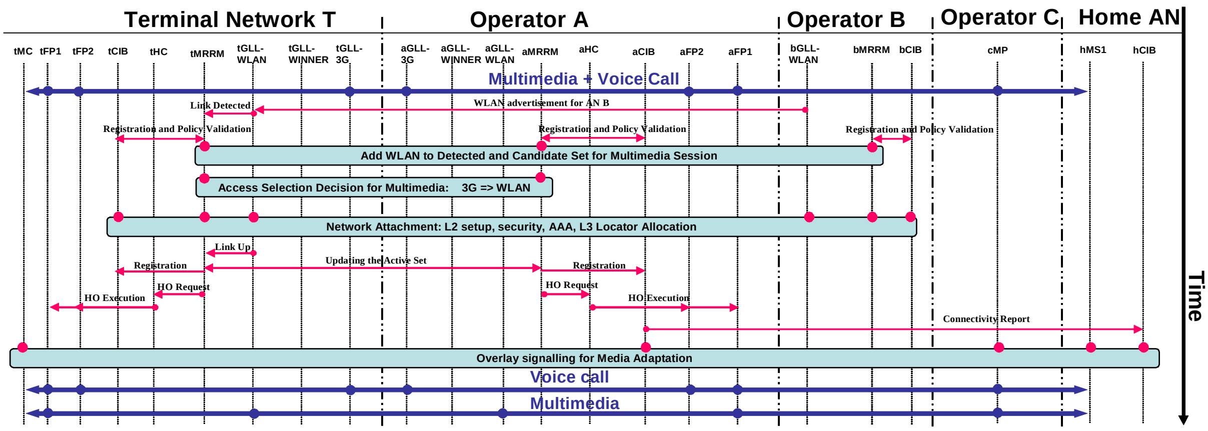

Figure 5: Handover from the operator A (3G) to operator B (WLAN).

the change of the access path.

E. Handover between different network operators

The scene of handover between different operator domains is depicted in Figure 5. During Alice's taxi ride to her hotel all data sessions, for speech as well as multimedia, are transmitted via the 3G access path. Now Alice arrives at her hotel, which provides a WLAN network. The local hotel network operator B is cooperating with the wide area operator A. After attaching to the local WLAN network the ongoing multimedia session is handed over from the wide area operator to WLAN, while the telephony and control signalling remains on the 3G network. The media stream is adapted to the increase in data rate.

First the GLL-WLAN at the terminal receives a WLAN advertisement from the GLL-WLAN at operator B. The advertisement contains the AN B's identifier. The terminal may either have preconfigured information in its CIB that AN A and AN B cooperate, or it may request this information from AN A via the 3G network. AN A may also indicate the availability and appropriate configuration information about AN B to the terminal AN, when it approaches the coverage area of AN B.

Then the GLL-WLAN at the terminal sends a trigger (Link Detected) to the MRRM of the terminal, which then reports the new access to the MRRM at AN A and both include the new access in their detected set.

In both AN A and the user AN, MRRM notifies CIB about the new access and validates the corresponding policies. The new access (WLAN-B) is added to the candidate sets for the speech and multimedia sessions.

The MRRM entities at AN A and at the terminal decide that for the multimedia session the new WLAN access via AN B would be the best suited access. MRRM in the terminal directs the GLL-WLAN to attach to the network AN B. The network attachment includes setting up the L2 security, executing a AAA procedure and receiving a valid locator. All this is done simultaneously. After the network attachment is done, GLL-WLAN in terminal sends a trigger (Link Up) to the MRRM. MRRM notifies the CIB and MRRM at AN A about the new access flow.

MRRM in terminal and MRRM in AN A update the active sets for the Multimedia session and notify the HC in the terminal and AN A respectively to perform the handover. Both HC entities translate the handover commands into handover procedures and the FP1 entities are configured accordingly in both terminal and AN A:

The handover event noted at the CIB in AN A is signalled to the CIB in the Corporate AN where the necessity for media adaptation of the video stream is noticed. Dependent on the new link rate the video stream is either transcoded to another rate or in case of a layered coding scheme additional video layers are added or skipped in the MediaPort of AN C.

VI. CONCLUSION

Within the Ambient Networks project a number of novel approaches have been developed, including a multi-radio access framework, a mobility management framework, a framework for media adaptation based on MediaPorts. Within this paper we have presented a use case of *Continuous Connectivity*, which demonstrates how these different technical concepts can be integrated to enable a user to dynamically change access technologies and roam between different operators.

REFERENCES

[1] Niebert, N., et al., "Ambient Networks – Research for Communication Networks Beyond 3G", Proc. 14th IST Mobile & Wireless Communications Summit, Lyon, France, 27-30 June 2004.

[2] D1-5: AN Framework Architecture. IST–2002-507134-AN/ WP1-D05, 2005. http://www.ambient-networks.org

[3] J. Lundsjö, et al., "A Multi-Radio Access Architecture for Ambient Networking", Proc. 14th IST Mobile & Wireless Communications Summit, Dresden, Germany, 19-23 June 2005.

[4] G.P. Koudouridis, et al., "Feasibility Studies and Architecture for Multi-Radio Access in Ambient Networks", Proc. 15th Wireless World Research Forum Meeting, 8-9 December 2005, Paris, France.

[5] G.P. Koudouridis, et al., "Generic Link Layer Functionality for Multi-Radio Access Networks", Proc. 14th IST Mobile & Wireless Communications Summit, Dresden, Germany, 19-23 June 2005.

[6] P. Magnusson, et al., "Multi-Radio Resource Management for Communication Networks beyond 3G", Proc. VTC Fall, Dallas, USA, Sep. 25-28, 2005.

[7] D4-3: Ambient Networks - Mobility Framework and Mechanisms. IST–2002-507134-AN/WP4/D4.3, 2005.

[8] S. Uno, J. Eisl, R. Agüero, "Study of mobility control functions in Ambient Networks", Proc. ICACT, Phoenix Park, Korea, Feb. 20-22, 2006.

[9] D5-3: SMART – Final Architectural Design. IST–2002-507134-AN/ WP5/D03, 2005. http://www.ambient-networks.org

[10] J. Rey, et al., "SMART: A Media Service Delivery Architecture for Ambient Networks", Proc. 14th IST Mobile & Wireless Communications Summit, Dresden, Germany, 19-23 June 2005.

[11] J. Rey, et al. "Media Aware Overlay Routing in Ambient Networks", Proc. PIMRC, Berlin, Germany, September 11-15, 2005.

[12] WWI WINNER, https://www.ist-winner.org