Advanced Network Handover Mechanism in Ambient Networks

Tiziana Toniatti[1], Francesco Meago[1], Alberto Pericciolì[1], Shintaro Uno[2], Eranga Perera[3], Roksana Boreli[3]

[1] Siemens - Italy, {Francesco.Meago, Alberto.Perricciolì, Tiziana.Toniatti@siemens.com}
[2] Motorola - Japan, c22898@motorola.com
[3] National ICT Australia, {eranga.perera, Roksana.Boreli@nicta.com.au}

www.ambient-networks.org

***Abstract*— In heterogeneous networks such as new multi-domain and multi-technology mobile networks, handover requests could be driven by several needs, such as cost reduction criteria, network resource optimization, service related requirements, etc. Thus, handover could become a critical issue if not done in an optimized way. The main objective is therefore to define concepts and functions with the aim to realize handovers characterized by new multi-dimensions (multi-domain mobile networks, multi-technologies, multi-services, multi-devices, any-cast, etc). Furthermore it is necessary to be able to support novel requirements that have emerged due to the proliferation of mobile communication services. This paper attempts to address the above challenges pertaining to handovers in the context of the Ambient Networking architecture. This work has been performed within the framework of the Ambient Networks project, belonging to the IST 6th Programme.**

Key words: Ambient Networks, handover management, mobility management, beyond-3G, heterogeneous networks.

1. INTRODUCTION

The Ambient Networks (AN) project [1] is developing a particular networking vision for Beyond-3G based on the *cooperation of heterogeneous networks* (Ambient Networks, ANs) characterised by different access technologies and user/operator domains. In line with this, the AN approach for Beyond-3G is clearly based on *convergence*, i.e. to harmonise usage of all access technologies and networks.

From an organisational perspective, the Ambient Networks project is an IST project of the 6th framework. The project is running in its first phase (2004-2005), which goal is primarily around concept development and evaluation, therefore the nature of this paper. The whole project spans over 6 years: future phases include system specification and implementation.

A basic *paradigm* of the AN project states that “everything is a network”. In other words, the project aims to define a new networking vision for today’s heterogeneous world where the elementary networking element is an “Ambient Network” (AN). This vision is based on the basic concept of *dynamic composition*, where a number of ANs can compose into joint ANs through establishment of inter-network agreements. A main goal for the project is therefore to define the properties and functions of such basic networking elements, to define their inter-relations and interfaces.

From the perspective of *communication capabilities*, the project aims to support multi-hop, multi-access, multi-operator, multi-domain and multicast/broadcast operations. This is later referred to as “a multi-dimensional environment” in which ANs operate.

In terms of *supported scenarios*, Ambient Networks should open towards a wide range of use cases including local access providers, PANs, peer-to-peer, moving networks, sensor networks and competitive scenarios with cost-based access selection.

As shown in Figure 1, the AN architecture introduces an *Ambient Control Space* (ACS) as a control stratum that realises the described Ambient Networks vision. A number of interfaces are also defined: the ANI between ACSs, the ASI towards the user applications and the ARI towards the underlaying network resources (Ambient Connectivity) [2].

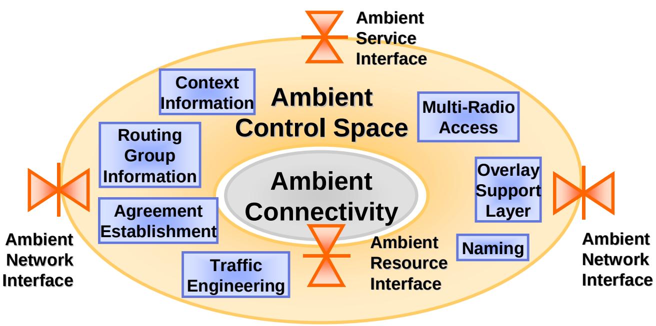

Figure 1: Ambient Control Space

However, given the conceptual focus of the first phase of the project, it should be remarked how the ACS architecture allows for *different implementation options* regarding how this networking realm should be realised: e.g. the ACS could be constructed above existing GGSNs of GSM/UMTS, as well it could be built within new generation multi-RAT resource controllers such as RNCs/BSCs, as well as a unified solution allowing for all these options could be the most desirable one.

The AN multi-dimensional environment poses a number of challenges on mobility management and handover (HO), which are integral parts and functions of the Ambient Networks architecture and ACS. An advanced mobility management was highlighted as one of the challenges with strong impact on future AN solutions [3].

In Chapter 2 the state of the art is analyzed in order to clarify the issues of handover. In Chapter 3 the requirements for handover in B-3G AN environments are identified. Chapter 4 provides an overview of the envisaged HO functional model for AN HO management. Chapter 5 describes the concept of "HO Toolbox" as a basic concept for AN HO management, consisting of a set of elementary handover mechanisms (or tools) that are selected to construct the required handover. Finally, chapter 6 describes a HO toolbox implementation aimed to prove the HO Toolbox concept through demonstration and to analyse the practical impact and relation to the overall AN concepts.

2. STATE OF THE ART ON HANDOVER

Access systems have different strategies and concepts to provide the mobility management functions and to maintain the communication service while the mobile device is moving. A detailed analysis of current and emerging mobile communication systems has been carried out considering four main areas of investigation: cellular wide area networks (2G GSM, 3GPP UMTS, CDMA2000), wireless local/short-range networks (IEEE 802.11/15/16/21 families), IETF mobility protocols and relevant results of research projects belonging to the IST programme (e. g.: MIND, overDRIVE).

Handover design criteria are strictly related to the reference communication services (voice, data, streaming, etc.) and to the required quality of service levels, upon which very different requirements apply for interruption time and data loss.

With regards to HO steps such as HO initiation, HO decision and HO supervision, different solutions apply to different technologies (e.g. GSM vs. UMTS) and services (e.g. packet vs. circuit switched), as well as different solutions are possible within one technologies (e.g. as in GSM), as well as different steps may be accomplished by different entities (e.g. user vs. network).

Various mechanisms are implemented in various systems for handover purposes: soft/softer handovers, packet/frame duplication, tunnelling or forwarding, context forwarding, etc.

The goal of our work is to find *suitable mechanisms and concepts* that can encompass the heterogeneity of current solutions, finding the *common denominator* on which to base the mobility management of the ACS.

3. HANDOVER REQUIREMENTS FOR B-3G

This section tries to describe the requirements that the Ambient Networks project envisages for beyond-3G handover based on the very basic project vision of future networks based on heterogeneity and convergence.

In light of this, one may argue whether the following listed functions and requirements are new or not for a given technology. Still, the following represents a (probably not exhaustive) challenging list of handover requirements for B-3G:

- To handover *different mobile entities*: users, devices, networks, applications, flows and sessions.
- To support different *bearer service QoS and modes* (*unicast, multicast, broadcast*).
- To account for *heterogeneous access technologies* and *multi-hop networks*.
- To allow for *different HO types*: e.g. seamless HO, fast HO, smooth HO, best effort HO, hard/soft(er) HO and mobile device/network initiated HO.
- To *prepare* handover through info exchange.
- To support *cross domain* HO (inter-RAT, address, provider, administrative, security, etc.).
- To account for advanced characteristics such as *Multi-homing* and *Advanced location services*.
- To allow *usage of specific mechanisms* and characteristics of a certain technology (e.g., softer handover, pre-reservation of resources, IPv4/IPv6).
- To consider *user and operator HO policies* capable of handling conflicts.
- To include a comprehensive *security framework*.
- To allow *efficient usage of resources* (e.g., low cost path/rerouting, signalling load, e.g., aggregate HO).

4. HANDOVER FUNCTIONAL MODEL

The goal of this section is to present a HO functional model that is generic enough to support the wide range of HO requirements, in order to devise those steps through which the HO process will need to proceed in the selected B-3G AN environment.

Mobility management includes several functions: "reachability" management, HO management, etc.

Our focus is on the *HO process*, for which Figure 2 models a number of HO steps described through a group of related HO functions:

- *Trigger Collection and Pre-computation*: The process of deciding whether or not to perform a handover starts by collecting, classifying and precomputing the different triggering events that could lead to a handover.
- *Handover Decision & Tool Selection*: The HO decision is made on the basis of available information and also based on possible negotiations between the involved entities.

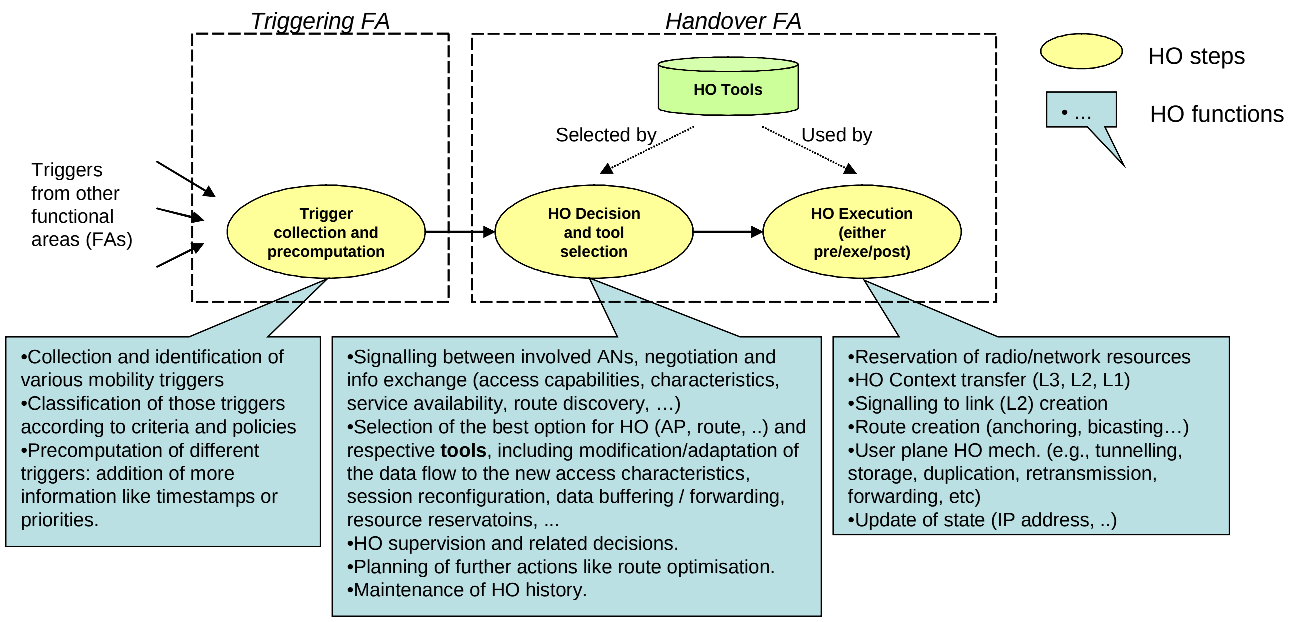

Figure 2: HO model, HO steps and main functions

Signalling between different entities is expected, e.g. for the sake of route discovery, media control and exchange of information such as service requirements, QoS, context, networks information, or user/operator preferences relevant to the HO takes place between different entities. Along with the HO decision a HO tool selection process must be available, i.e. the definition of the mechanisms and the specificities dictating how the handover should be performed.

- *HO execution*: In this step the HO decisions are executed including preparatory actions, main HO execution and post-HO optimisations.

Based on said HO steps, we divide between two functional areas (FAs):

a) *Triggering FA* (TRG_FA), in charge of Trigger Collection and Pre-computation functions,
b) *Handover Management FA* (HO_FA, or HO management), in charge of selecting and executing those mechanisms or commands that are needed for a given *HO process* during its complete *lifecycle*, including HO preparation, initiation, execution, supervision and post-HO optimisations.

5. HO TOOLBOX DESCRIPTION

The purpose of the HO Toolbox is to describe a unified *framework for HO management* in beyond-3G. With this in mind, the following definitions are provided:

- *HO Toolbox:* set of different HO tools.
- *HO tools*: basic HO mechanisms or commands.
- *HO management (HO_FA):* machinery that selects and executes the appropriate HO tools for a given HO need.

In other words, the concept of Handover Toolbox describes a set of elementary handover mechanisms or commands (HO tools) to be used by AN HO management when taking decisions related to handover.

The HO Toolbox allows flexible construction of generic handovers, combining handover characteristics belonging to different HO commands or mechanisms that could classically belong and be inherited from different existing and future systems and handover types. It is clear how such a concept carries in itself a generalization among different technologies that is the most characterizing factor of the AN project.

It is not relevant in this phase whether the HO management is a centralized or distributed function, since both options need to be allowed anyway in different AN scenarios depending on HO needs.

Trying to devise some practical realisations for the HO Toolbox concept, the following alternatives represent a first main subdivision between relevant implementation options:

a) If the HO Toolbox is a *set of elementary HO commands*, the HO_FA is machinery controlling a mobility protocol that transports those HO commands. In this case, the AN project would define new mobility protocols.
b) If the HO Toolbox is a *set of different mobility protocols and extensions*, the HO_FA is a control function that selects the appropriate mobility protocol and extension.

Following for instance alternative a), an example of *HO Toolbox commands* for that alternative is shown Table 1, along with a brief description of their meaning.

Table 1: Examples of HO Toolbox commands

HO Command	Description
Discover new accesses and routes	Trigger new access discovery for HO purposes.
Authentication / De-Authentication	(De)Authenticate a mobile entity (i.e., physical terminal, session, applications, routing groups) to specific ANs or network services.
Authorization / De-Authorization	(De)Authorise a mobile entity to specific ANs or network services.
Register / De-register	(De)Register a mobile entity to specific ANs or network services.
Info exchange	Transfer context info from one AN to another AN.
Book / Release resources	Book (or release) access resources for a certain time and period.
Use security mechanism	Set specific security mechanisms.
Start/end buffering	Start/end buffering of flows in an AN.
Forward/ stop forwarding	Start/end content forwarding from one AN to another AN.
Flush	Discard stored information related to one or more flows.
Reconfigure Session flows	Reconfigure flows within a session.
Change data flow characteristics	Change e.g. data rate, adapt media content, …
Change active routes	Handover from the old to the new transmission routes.
Update Mobility Management context	Update network status and handover history.

6. HO TOOLBOX IMPLEMENTATION

The HO Toolbox implementation could be considered as a *prototype of a new mobility protocol* that demonstrates a number of AN characteristics going beyond traditional mobility concepts.

It uses concepts of both MIPv6 and Fast HO [4], trying to combine their benefits without explicitly using their exact protocol descriptions as available from the IETF and without being based on existing implementations of them. Reasons behind this decision include practical reasons (easier to control our own software) as well as theoretical reasons, since B-3G mobility management is not necessarily based on existing protocols.

MIP typically refers to "reachability" and route optimisation issues, while micro-mobility protocols such as Fast HO refer to local mobility solutions and inter-access router handovers. The Ambient Networks project in its first phase tries instead to look at mobility from a broader viewpoint, even if migration issues from current systems are also considered. We decided therefore to take the broader and more futuristic option not to base ourselves on existing protocol and extensions, but to try to imagine how a new *AN-capable mobility management* would look like.

6.1. Reference scenario

The reference scenario for the implementation is shown in Figure 3. Any 'oval' represents a generic AN, which could be an operator server, an infrastructure relay node, a user terminal and even more. Every line represents a link over a specified technology. AN2 and AN3 are in the same Personal Area Network (PAN).

The following mapping is considered: AN1 is a CN, AN2 is the MN, AN3 the PAR and AN4 the NAR. Flows are established between AN1 and AN2 through AN3, and handed over to a new route passing through AN4.

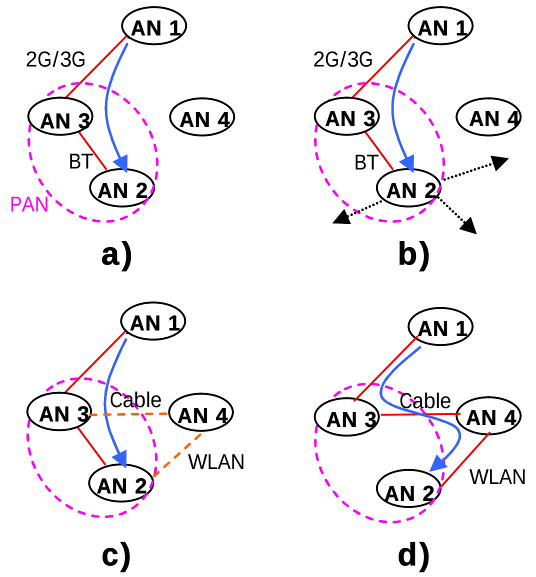

Figure 3: HO reference scenario

6.2. Implemented storyline

Based on the reference scenario, our work consisted of *specifying and implementing* suitable messages and information to exchange between the ANs.

Taking as a reference the four steps of Figure 3,

a) AN3 composes with AN1 in order to be allowed to access AN1 services. AN2 composes with AN3 because it belongs to the same domain and forms a PAN. AN3 composes with AN4 because they are in vicinity. A service is required from AN2 to AN1 through AN3. The service is delivered through AN3 using 2G/3G plus Bluetooth (BT).

b) "Discover new accesses and routes": AN2 requests AN3 to search for alternative routes due to some trigger, therefore initiating a HO process.

c) A better alternative is found through AN4 via cable and WLAN. AN2 triggers a pre-composition at AN4 through AN3, including "Authentication/

Authorisation/ Registration", along with the generation of a valid IP address at AN4. The HO process enters a HO preparation state.

d) "Change active routes": the HO towards the new route is performed for a specific session, therefore executing the handover.

6.3. Implementation details and characteristics

Each AN includes a minimal ACS that acts according to our mobility protocol, exchanging messages with the other ACSs. To be noted that this inter-ACS message exchange represents an example of ANI messaging.

In addition, it is possible to run end-user services between different ANs. For realising this, typical applications were used for sending packets to an IP address that we call Home Address (HoA) for simplicity.

Session mobility was realised by using multi-homing: each service/flow is mapped to a single HoA of the same AN, so that we can implement handover and forwarding of a single service/flow independently. Handovers of single sessions may be required directly by the user or by user/network policies, possibly over multiple access network technologies, hops and administrative domains (e.g.: roaming).

The mobility protocol we designed is based on exchange of "AN Negotiation" messages called ANeg, providing a common framework for all ANI messages in our implementation. ANeg messages are built as ICMP messages within respective options.

ANeg messages inherit the characteristics of both RtPrSol and PrRtAdv of Fast HO, therefore they can be both soliciting or advertising messages.

Fast HO messages such as FBU, HI, HAck, FBack, and FNA are largely extended in meaning, while the message itself is translated into an ANeg message in the sense that it carries ANeg options. An "AN-FBU message" includes the HO Toolbox Option indicating whether to continue deliver on the old link, or NAR forwarding, or bicasting. The AN-FNA could then indicate link attachment detection, but also transport a handover command: to switch to the new link, or to stop bicasting on the other link. If we would like to emulate the case of the so called "Predictive Fast HO" of Fast HO, the handover command should be placed already in the FBU message. AN-HI and AN-HAck messages are extended with a Composition Option, in order to allow for pre-composition of the MN to NAR through PAR.

7. CONCLUSIONS

In the scope of the Ambient Networks project, the paper encompasses a wide number of issues and studies around the concept of HO management in B-3G networks characterised by heterogeneity of access technologies and multi-dimensional environments (multi-hop, multi-domain, etc.).

The Ambient Networks project has been presented with its paradigms of "everything is a network", network composition, heterogeneity and convergence, multi-dimensional environments and supported scenarios.

Handover state of the art research has highlighted a number of handover characters in the existing systems and protocols that need to be inherited by B-3G HO management, driving to challenging requirements.

B-3G HO management needs to take care of the *HO process* complete *lifecycle*, including HO initiation, preparation, execution, supervision and optimisations.

The HO Toolbox concept is a unified framework, describing a set of HO tools as the basic HO mechanisms/ commands that the ACS can exploit. HO management is therefore machinery that selects and executes the appropriate HO tools for a given HO need.

HO toolbox implementations may vary as HO tools may consist of basic HO commands within the messages of a mobility protocol, or complete mobility protocols and extensions that may be selected alternatively.

In our implementation we have shown that a way to build Ambient Networks could consist of constructing a new protocol above IP, capable of supporting mobility through an embedded HO Toolbox. The exercise also shows possible messages and information to be carried over ANI between ACSs.

It is important to note how the HO process spans in principle over several functional areas including composition and security.

The Ambient Networks project is currently in a conceptual phase. The work of our implementation could be considered as a first step towards a clean redesign of IP networking, but less drastic alternatives are also possible. Final decisions on the allowed implementations are expected before 2008.

ACKNOWLEDGMENT

This paper describes work undertaken in the context of 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 2004-2005 in its first phase. The views and conclusions contained herein are those of the authors and should not be interpreted as necessarily representing the Ambient Networks Project.

REFERENCES

[1] V. Typpö, J. Eisl, J. Höller, R. Agüero, H. Karl, "Research Challenges in Mobility and Moving Networks: An Ambient Networks View", in: Proc. Workshops on Broadband Satellite Communications and Challenges of Mobility in conjunction with IFIP WCC, Toulouse, France, August 22-27, 2004.

[2] IST project Ambient Networks, www.ambient-networks.org.

[3] H.Flick, E.Helpworth, J.Eisl, S.Uno, "Issues of advanced mobility management in Ambient Network", the 12th WWRF conference, November, 2004.

[4] draft-ietf-mipshop-fast-mipv6-03.txt, "Fast Handovers for Mobile IPv6".