Mobility Across Multiple Technologies —the Daidalos Approach

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The paper describes a network architecture, studied within the Daidalos EU project, which supports seamless communication mobility across multiple technologies at the IP layer. The architecture implements an approach to heterogeneity management in which supporting functions are distributed among the end-devices and the network infrastructure. It supports both mobile- and network-initiated handovers, managed in a technology-independent way. The architecture incorporates a cross-layer design of supporting functions, resulting in enhanced reliability and good performance. A high degree of security is achieved with a combination of security protocols that govern terminal bootstrapping, user registration in the network and handover process.

The solution is generic. It is being tested in different network environments of single-hop radio access networks (802.11, 802.16, TD-CDMA) and broadcast networks (DVB-T). It will also be tested soon in multi-hop *ad-hoc* (802.11e) and in moving networks (NEMO).

KEYWORDS: mobility, security, pervasiveness, all-IP networks, systems beyond 3G

1. Introduction

Mobility has become a central issue in today's telecommunications. Vendors are designing and implementing solutions and position their products on the market. Telecom operators are integrating systems that would eventually go beyond 3G. Services are being created for business, education and every-day life. Rapid technological and social changes facilitate adoption of new, increasingly sophisticated services by mobile users. The demand for unrestricted capabilities and convenient use makes the communications environment complex, sometimes confusing and difficult to manage, both for the users and the network operators. Further development of new technologies and addition of new ones in 'systems beyond 3G' (B3G) calls for re-thinking of the approach to deployment of a user-centered, manageable communications infrastructure.

The Daidalos Integrated Project [1] was founded within the strategic objective of the 6th Framework Research and Development Program of the European Commission¹⁾. The goal of the "Mobile & Wireless Systems Beyond 3G" program, and the project itself, was to evaluate the existing solutions as well as design and prototype new ones that will implement a vision of users "optimally connected anywhere and anytime". The Daidalos project has been developing a communications infrastructure in which mobile users can access network services with heterogeneous access technologies. The infrastructure provides a diverse range of personalized services seamlessly supported by underlying technologies at different system levels [2–4]. In technical terms, the project develops and demonstrates an open "all-IPv6"-based architecture, which involves:

- design and prototyping of the components for efficient distribution of services beyond 3G,
- integration of diverse network technologies to provide pervasive and user-centered access to these services,
- development of a coherent signaling system for communications, services and system management in such networks,
- building a pervasive environment for service auto-configuration and composition according to user preferences and the communications context.

Currently, the work is conducted in Daidalos II²⁾ with the objective to demonstrate the results of the work and to extend the solutions through research and integration in a Pan-European test-bed.

2. General Architecture

The architecture of the system consists of the following three major layers: the mobility layer, the system-services layer and the pervasive services layer. The mobility-layer incorporates multiple link-layer technologies and abstraction functions that serve as a uniform interface to services offered by the underlying heterogeneous technology. IP mobility is based on IPv6 with multiple extensions. Proactive and reactive handoff management and mobility optimizations including Fast Handover (FHO) and detection of network attachment via link-layer monitoring and triggers [5] related to current work of IETF have been designed and incorporated. Reliability and performance have been the main criteria in the design process.

At the system-services level, the control and management infrastructure is implemented based on current developments of standardization bodies (IETF, ETSI) and results from previous IST projects, such as Moby Dick, Tequila, Brain, Mind, Euro6IX, Youngster, etc. [6]. An integrated signaling framework covers service management, quality of service assurance, mobility, security, and A4C (Auditing, Authentication, Authorization, Accounting, Charging). The management infrastructure provides management with SNMP (Simple Network Management Protocol) and where appropriate with COPS (Common Open Policy Service Protocol) and includes the policy-based management and SLS/SLA (Service Level Specification/Service Level Agreement) concepts.

The pervasive services layer provides service discovery and composition of a user environment through autoconfiguration and content adaptation.

The following key concepts are considered as guidelines in the design and development process:

- MARQS (Mobility Management, A4C—AAA, Auditing and Charging, Resource Management, QoS and Security), which is an essential requirement of next generation networks. This will support end-to-end services.
- Virtual Identity (VID): This concept decouples a user from a device, enabling a new level of flexibility while maintaining support for privacy and personalization for network access, services and content.
- Ubiquitous and Seamless Pervasiveness (USP): pervasiveness will allow adaptation to a changing context, movement in accordance with a user profile.
- Seamless integration of broadcast at two important levels: technology, such as DVB-S/T-H, and services, such TV, carousels and datacast.

3. Selected Research Areas

3.1 Mobility subsystem

The key innovations regarding mobility subsystem include the following functions:

- separation of a user from a device (from the mobile terminal) at the conceptual level,
- independence of a specific network access technology while offering continuous reachability of a user,
- flexibility in Layer 3 (L3) handovers which are initiated and managed by the terminal or by the network,
- selection of the preferred network based on various input data related to status of the network interfaces in multimode terminals, network discovery functions as well as operator policy and user profiles,
- unified support for quality of service and security in different access technologies through an abstraction layer.

The enhancements account for information on user's rights and preferences available in the user profiles stored in the A4C subsystem, exploit network-discovery and autoconfiguration functions embedded in the mobile terminal as well as pre-authentication of users for handovers. Some of the work completed so far has been reported in conference and journal papers, such as [7, 8].

In network-initiated handover (NIHO) [9, 10], the decisions to hand(-)over originate in the network. The scenario for handover is a two stage process. Handover preparation is realized with Forced Handover (ForeHand) and Candidate Access Router Discovery protocols that are used to determine networking conditions and convey the status to a handover decision module. The handover execution is realized with a combination of the Fast Handover protocol [11–13] and the context-transfer protocol (CT). Seamlessness of the handover is considerably improved with transfer of the mobility and security context of a mobile terminal between the old- and new-Access Routers (AR). Duplication and merging (D&M) of data packets is carried on while the handover is *en course* to reduce packet loss. Robustness of the handover is further improved with mechanisms for detection of network attachment and accelerations such as *Fast Neighbor Advertisement* in the new network.

NIHO, for mobility reasons, is triggered by the network upon degradation of the quality of the radio signal received by the serving access point (AP). For shared media environments, like wireless LAN (WLAN) the reference scenario is presented in Fig. 1.

NIHO, for performance reasons, is triggered by the decision module (QoS Broker residing in the network) upon detecting that a certain part of the network is congested. The handover targets are selected so that the overall performance of a region is maintained and the user profile is accounted for. Region-based design of handover management improves scalability and performance and is in line with current trends to support mobility via localized mobility management [14]. In NIHO, the handover preparation phase is managed primarily by the Forced Handover protocol (ForeHand) [15]. Its primary role is to create and maintain the image of the current network state, and to provide indications on prospective targets for a handover: a pair of access point (AP) and access router (AR) (Fig. 2).

The Measurement Modules (MM) located in the APs collect signal-strength measurements of Mobile Terminals within their coverage areas and convey filtered results to Aggregation Modules (AM) residing at ARs side for processing and aggregation. The results are presented to a decision component (QoS Broker) that determines the handover target. By measuring the signal strength received from a given mobile terminal (MT) at both the serving and neighbouring APs, it is possible to select prospective candidate APs and their associated ARs that are able to provide a better service parameters to the mobile terminal [15].

Mobility and security subsystems provide common functions for different networking environments studied in the

Fig. 1. Mobility management in the radio access network.

Fig. 2. Forced Handover subsystem (ForeHand) for network initiated handover (NIHO).

project, which extend beyond the single-hop radio access networks into multi-hop *ad-hoc*, broadcast, and moving networks (Fig. 3). These particular network environments add an additional complexity to the mobility management plane. Therefore, the work on related problems is in progress now.

3.2 Security, Authentication, Authorization, Accounting, Auditing and Charging subsystem

Authentication, Authorization, Accounting, Auditing and Charging (A4C) services constitute the core part of the network infrastructure. The most important functions include:

- secure bootstrapping of terminals,

Fig. 3. Heterogeneous network environment of Daidalos.

- single sign-on user authentication and authorization for network access,
- accounting and charging for resource usage with non-repudiation monitoring,
- support for seamless handover,
- security, privacy, anonymity via the virtual identity concept (VID).

In order to access resources in an operator network a user has to be authenticated and authorized. Diameter-based A4C servers are supplemented by A4C agents in mobile terminals and access routers. In the Daidalos approach the QoS subsystem is a policy enforcement point (PEP) for the A4C subsystem.

3.3 QoS and resource management

Providing end-to-end differentiation of the quality of service in a mobile network environment is a challenge. The main tasks covered by the Daidalos project in this respect include:

- end-to-end resource reservation and signaling with support for mobility,
- integration of link-layer specific QoS mechanisms with network layer QoS mechanisms,
- intra- and inter-domain network resource management and monitoring,

For scalability reasons, support for QoS in the core-part of the network is based on the DiffServ model. In the access-part of the network, per-flow reservations are used for fine control of the scarce radio resources. Information on resource requests for individual flows are managed by the Advanced Router Managers (ARMs) which act as attendants of the QoS Brokers. The attendants reside in the access routers (ARs) and perform admission control of flows originated by a user (or destined to) on a per-traffic-class and per-user profile basis. Aggregated traffic flows are managed directly by the QoS Brokers. A combination of per-flow management and per PHB-aggregate traffic management helps to maintain scalability of the QoS management framework by combining core resource management with access network signaling.

Interworking of QoS Clients on mobile terminals with Advanced Router Managers in access routers for controlling radio resources in the radio access link is backed up by the Monitoring System and the Policy Based Network Management (PBNM) system. The monitoring subsystem feeds the QoS subsystem with network resource utilization data and consists of Central Monitoring System (CMS) which collects data from Network Monitoring Entities (NME) placed in network nodes. The main goal of the PBNM system is to manage QoS aspects of Service Level Agreements (SLA). More information on the QoS subsystem, including the policy-based management system (PBNMS) can be found in [16, 17].

3.4 Pervasive services subsystem

The Daidalos project envisions that personalized and context-aware access to services and applications will become the driving force and the primary factor differentiating services in future. Today only some applications can interact with a wide range of devices in the environment or to provide the basis for context awareness and extended personalization by means of user-centered configuration and control. Context engines acquire context information from the user environment and feed the information to pervasive applications. The project aims at enhancing the context

engines with generic inference engines capable of maintaining and processing user-defined rules and policies to create decisions based on the context.

3.5 Broadcast, *ad-hoc*, and moving networks

A substantial amount of research is conducted in the area of *ad-hoc* [18], uni-directional broadcast and moving networks environments. Lack of confidence in infrastructure, highly asymmetric or uni-directional links make these environments particularly challenging to the mobility and security subsystems. The research items in such environments include:

- integrated mobility management in broadcast sessions, including issues of vertical handover between different coverage areas, return-channel over UDLR (Uni-Directional Link Routing) and multicast services over broadcast links,
- introduction of personalization elements in broadcast services.

4. Summary and Outlook

Daidalos incorporates a telecom operator-oriented approach. It requires a pragmatic strategy for implementations of elements of the ‘system beyond 3G’. Therefore, the project focuses on research and trial of selected end-to-end services in two scenarios: mobile university and automotive scenario. To this moment, promising results have been achieved in the field of mobility, security, A4C, QoS and system-level services. These have been documented in research publications, workshops [19], events and contributions to standardization bodies. The following lists recaps some of the major findings in the area of design and implementation of subsystems and prototypes:

- a prototype of a network-initiated handover mobility subsystem,
- a prototype of a moving network subsystem with enhanced network mobility (NEMO) functions,
- a prototype of an *ad-hoc* integrated subsystem with QoS differentiation and charging functions,
- partial integration of the ID-token, NVUP (Network View of the User Profile) and SVUP (Service View of the User Profile) concepts in the authentication and authorization (AA) process,
- an enhanced AA process via integration of PANA (Protocol carrying Authentication for Network Access), SAML (Security Assertion Mark-up Language) and the Diameter protocol,
- auditing and SLA management,
- a QoS subsystem with a measurement subsystem integrated with security and A4C.

A test-bed has been setup to validate the results and provide feedback to designers and developers. In order to provide a proof-of-concept three integration sites were set(-)up: in Sophia-Antipolis (France), Aveiro (Portugal) and Stuttgart (Germany), with off-springs to numerous internal pre-integration sites. These integration sites define and execute test cases to verify the solutions and provide feedback as well as technical hints to researchers working on a design.

Further research is needed in the following areas:

- support for several types of mobility at the device interface, user and session level,
- decoupling a user from a device, enabling a new level of flexibility while maintaining tractability of virtual users for accounting and charging purposes,
- support of multihoming and study of security implications,
- localized mobility management schemes,
- support for privacy and anonymity, and interface to the privacy infrastructure—the VID concept,
- ubiquitous and seamless pervasiveness and adaptation to changing contexts or movement,
- context-aware and personalized service discovery and composition,
- integration of broadcast at the technology level (DVB-S/T-H) and services (carousels, datacast).

5. Conclusion

The project is progressing well due to a balanced mix of research, academia and industry partners. Gradually, it is gaining a critical mass to provide input to standardization bodies and committees. The research is relevant to IETF (*e.g.* MOBOPTS, DNA, NETLMM, MANET, AUTOCONF, NEMO), ETSI (TISPAN), IEEE (802.21, 802.16), ITU-T (NGN), 3GPP (AIPN) which are considered to be prospective fora to present our vision of a system beyond 3G.

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Footnotes

- ¹⁾ DAIDALOS, Designing Advanced Interfaces for the Delivery and Administration of Location independent Optimised personal Services IST 2002-IST1 Contract No. 506997, 2003–2006.
- ²⁾ DAIDALOS II, FP6-2004-IS-4, Contract No. 026943, 2006–2009.