PERVASIVENESS IN A COMPETITIVE MULTI-OPERATOR ENVIRONMENT: THE DAIDALOS PROJECT

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ABSTRACT

This article briefly describes the EU-funded Daidalos project, which designs and develops a communications infrastructure for next-generation networks to enable personalized, context-aware, composite services to mobile users. The fundamental concepts rely on federation of operators who create a pervasive environment for service provisioning, on integrated mobility, security, virtual identity for users, and resource management. The project validates concepts by means of specification, implementation, and integration in a large research testbed.

THE PERSONAL SIDE

The 6th Framework Programme for Research and Technological Development founded by the European Commission has set as its strategic objective "Mobile and Wireless Systems Beyond 3G" [1]. Within that program the Daidalos Integrated Project [2] is designing a next-generation all-IP based system in which users are always connected using heterogeneous access technologies [3, 4]. The project consortium, a set of 37 partners representing telecom operators, industry, and academia, aims to find a prospective path toward deployment of a communications infrastructure for personalized, context-aware composite service delivery to mobile users. The work, scheduled for 2006–2009, is supposed to provide a framework that addresses evolution of the roles of operators, service providers, and customers in an increasingly dynamic and fragmented business and service environment. This document explains the concepts that drive the project, provides pointers to results achieved so far, and outlines future plans.

DRIVING ASSUMPTIONS ABOUT NEXT-GENERATION NETWORKS

The wireless telecom operators are evolving rapidly in order to adapt to ongoing business, standarization, legislative,and social changes. Although changes have been considerable so far, the following shifts in service provisioning and business interactions are still to come.

Operators will likely have to deploy multiple application-supporting services in the network infrastructure. By doing
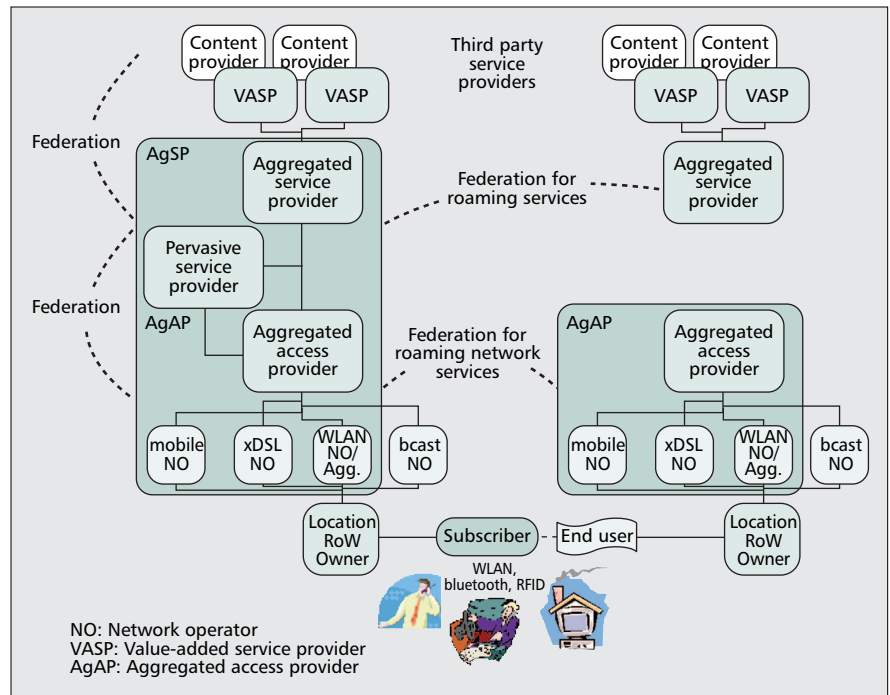
■ Figure 1. *Daidalos business views: federated environments.*

this, telecom operators will position themselves centrally for providing communication facilities to users.

- Services will be created by autonomous service providers and make cost-efficient use of the application support features provided by the operators' infrastructure to add value to the services.
- Services will be discoverable and aggregatable; their use will be accounted for in a converged bill following any suitable charging scheme including pre-paid, post-paid, flat rate, or split charging.
- Incumbent operators will increase availability of services by entering cooperation with other wireless access network providers.
- Users will receive increased levels of control of services and ease of use by means of personalization. Intelligent control will be required to acquire, correlate, and infer user status from context and user profile information, to trigger actions on behalf and in the interest of the user; pervasive and context-aware support infrastructure will create new economic opportunities for the involved parties.

The above presents a considerable shift in the way services are created and offered. The change will allow operators to retain a leading role and users to gain more control over the services they use with the following effects.

Business processes will become more complex and be dynamic in order to allow for short time to market and short life cycles for services. Emerging models with competitors entering cooperation need to be accommodated, such as sharing the enabling infrastructure and delegating roles and functions. Dynamic service composition will be supported by means of standard interfaces.

Service customization and personalization needs to be shared by the network infrastructure providers, service providers, and users, so privacy at all system layers, cross-layer, and interdomain will receive new dimensions.

By embracing these aspects, Daidalos bridges a gap between technology and business, follows foreseeable customer demands, and opens business opportunities that intersect network development, service provisioning, and

business planning. These aspects are explained in more detail below.

### INNOVATIONS AND THEIR IMPACT

A VIEW OF BUSINESS PROCESSES

The next-generation network should be perceived as a composite of autonomous domains that intersect to cooperate based on dynamic service level agreements. The project addresses interoperator federations between similar operators (horizontal) and different types of operators (vertical). Horizontal federations develop between access network providers, between service providers, or between pervasive operators. Vertical federations are established between mixed combinations of wireless access network providers, operators, or service providers, as well as pervasive service providers. Fragmented environments with different arrangements for incumbent operators are also considered. Figure 1 partially reflects the complexity of fragmented environments.

THE FEDERATION MODEL

Business scenarios incorporate roles of operators, wireless access network providers, service providers, content providers, and identity providers, which may be the same or separate entities. New business cases result from various arrangements between these entities (Fig. 1). The project considers the relations that develop between both traditional operators, which aggregate most of the roles of service and access network providers, and micro-operators, which support only selected functions and rely on other service providers and operators for other functions (e.g., identity management or charging). The concept of federation is considered central to the flexibility of such business scenarios. A federation assumes scoped trust relationships and function delegation between domains.

A VIEW OF SERVICES

Traditional network architectures do not attempt to infer user needs from a user's environmental context. In the Daidalos system, services are assumed to be adaptable to network conditions and reconfigurable. Bringing the user into focus encompasses user-controlled service customization and automated service adaptation. The project integrates mechanisms for service personalization and context awareness. This is one step further than the IP multimedia subsystem (IMS), which currently only considers rich presence and basic per-
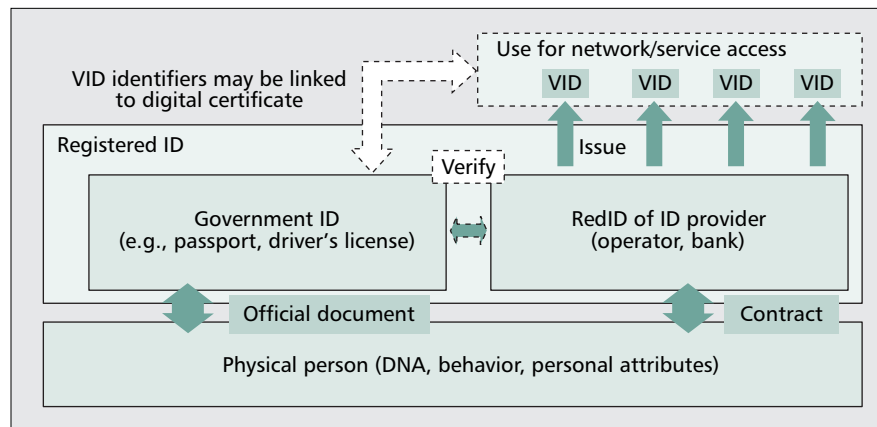
■ Figure 2. *Virtual identities for a user in Daidalos.*

sonalization. A subsystem called the service provisioning platform (SPP) incorporates a modular and extensible toolbox for fragmented models and federations, and allows different entities from different domains to interact.

A VIEW OF USER PRIVACY

Security spans a range of issues, from including mutual authentication for network attachment for users, combined authentication for network and service access in federated and non-federated models, to key management for reauthentication under mobility.

The identity management functionality, based on virtual identities (VIDs), offers privacy by means of anonymity and unlinkability of user activity. VIDs are different instances (or views) that the system has of a user that disallow user identification by other users and service providers during network and service access (Fig. 2). The identity provider is introduced for user information management across different system elements.

VID-based mobility allows physical persons to be decoupled from mobile terminals, and represents user-related attributes such as a profile, personalization, credentials, and user context in the system. A single physical person under a single contract can associate several VIDs to the subscription. VIDs are traceable for legal reasons, but remain anonymous and unlinkable for other users or entities.

LEVERAGING MOBILITY

Separation of the local and global mobility management domains paves the way to better support for federations. Mobility has been further enhanced by inclusion of both terminal and network initiated handovers. Key innovations include decoupling of a user from a mobile terminal at the sys-

tem level through the VID; increased independence of network access technology by means of a generic abstraction layer; and selection of the preferred network attachment based on inputs provided by network discovery functions, network interfaces, user preferences, current networking context, and operator policies in different access technologies and domains. In such a structured mobile environment, Daidalos integrates negotiation and management of network resources for legacy and multimedia services in the local mobility domain. The paradigm allows quality of service control for both single-hop and multihop radio access networks, and for moving networks.

UBIQUITOUS AND CONTEXT-AWARE ACCESS TO SERVICES

Ubiquitous access to services is synonymous with universal availability of a service, regardless of network technology, mobile device, service type, or user location. User movement, or other context changes, can trigger service reconfiguration (Fig. 3.).

For this purpose, context engines for collecting and processing relevant information from the network infrastructure and terminal sensors are introduced to feed relevant data to pervasive applications.

SUMMARY

Different validation schemes are applied in the project under a common architecture framework, depending on maturity level. To deal with the complexity of the system, modeling has been used to verify completeness and consistency of design. Selected parts of the design have been represented in a Unified Modeling Language model to ensure proper linkage between subsystems. Detailed models are also avail-

able for some architectural components, a few of which are already modeled down to the message-sequence chart level or state-machine level. Simulations are carried on out to validate selected concepts, such as paging, network-controlled handovers, and interworking moving networks with infrastructure-based networks.

Daidalos is further carrying on prototyping and deployment with a pragmatic strategy of selective implementations of subsystems and components. A few have already been implemented and demonstrated for networking and services pervasiveness aspects [5]. To facilitate deployment, two integration sites were set up with offsprings to numerous pre-integration sites for proof of concept.

The architecture has been presented to the International Telecommunication Union Telecommunication Standardization Sector (ITU-T), European Telecommunications Standards Institute (ETSI) TISPAN, and Third Generation Partnership Project (3GPP), and in groups such as the Wireless World Research Forum (WWRF). Targeted inputs have been provided to the Internet Engineering Task Force (IETF), IEEE, OMA, Liberty Alliance, OSGi, and DVB [2].
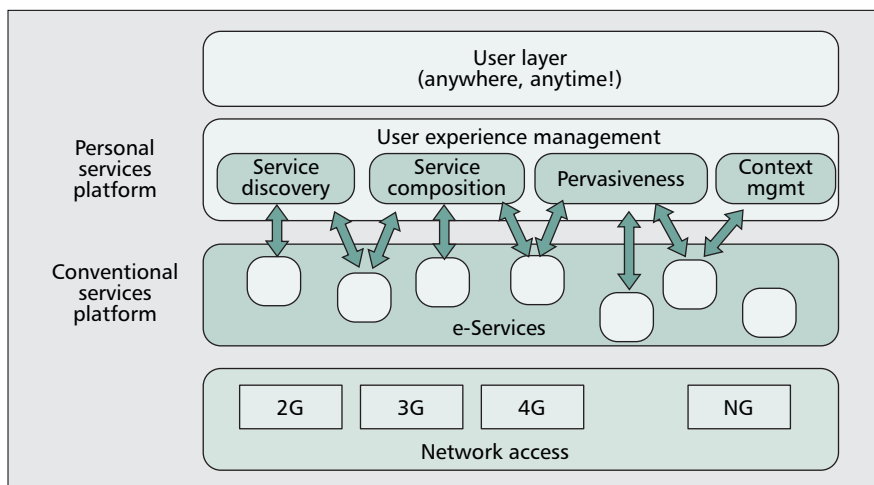
The major impact of the project is in showing progression towards more open and flexible architectures for next-generation wireless systems to enable both competition and cooperation. The architecture ties various parties and allows for their involvement in business chains in systems built beyond 3G.

ACKNOWLEDGMENTS

REFERENCES

[1] http://cordis.europa.eu/ist/so/mobile-wireless/home.html
[2] http://www.ist-daidalos.org/
[3] R. L. Aguiar *et al.*, "Scalable QoS-Aware Mobility for Future Mobile Operators," Special Issue on Scaling the Mobile Internet, *IEEE Commun. Mag.*, pp. 95-102, June 2006.
[4] P. Pacyna, "Advances in Mobility MManagement for the NG Internet," *China Commun.*, June 2006, vol. 3, no. 3, pp. 76-90.
[5] T. Melia *et al.*, "NIHO: Network Initiated Handovers for Next Generation All IP Network," IEEE INFOCOM 2006, poster and standalone demo, 23-29 Apr. 2006, Barcelona, Catalunya, Spain.
[6] http://www.ist-daidalos.org/daten/publications/publications.htm

■ **Figure 3.** *Pervasive vision reflected in the architecture.*

BIOGRAPHIES

RUI L. AGUIAR (ruilaa@det.ua.pt) holds a diploma and a Master's in electronics and telecommunications, and a Ph.D. in electrotechnic from the Universidade de Aveiro, where he is a professor since 2001. He is coordinating a group on heterogeneous networking at Instituto de Telecomunicações, Delhi, and his Master's degree (Dip.-Ing.) research is extensive; he is the chief architect for the Daidalos project. His interests are in high-performance heterogeneous systems and circuits, and he has more than 200 published papers in those areas. Recently, he was the Technical Program Committee Co-Chair for ISCC 2007.

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DENNIS BIJWAARD (bijwaard@alcatel-lucent.com) is a senior member of technical staff at Bell Labs, The Netherlands. He studied computer science at the University of Twente, graduated with an M.Sc. from Océ, and worked at the National Aerospace Laboratory in The Netherlands on distributed software and engineering workflows. At Alcatel-Lucent, he worked on quality of service for wireless LANs, the Alcatel-Lucent MiLife™ Intelligent Services Gateway SDK, and visualization of software behavior and mobility for heterogeneous 3G networks in the Dutch Freeband 4GPLUS project. In the Daidalos project he led the service provisioning architecture activity, and is now leading activities on context-aware service provisioning and network management. His research interests are in seamless efficient personalized multimedia content distribution across user devices.

LORIS MARCHETTI (loris.marchetti@telecomitalia.it) received a degree in computer science from the University of Pisa in 1988. Since November 1988 he has been working for TILAB (formerly CSELT), the Research Centre of Telecom Italia Group, in the Control Layer and Communication Platform Innovation Department. His present position is senior researcher, and he is responsible for the Wireless Networking Laboratory. He is currently work package leader in the IST-Daidalos II Integrated Project under the EU FP 6 Programme. He is also involved in internal research projects concerning multi-access seamless mobile networking. In the past he has been involved in several ESPRIT/ACTS/IST and Eurescom projects on topics including MANs, ATM, IP multicast, and mobile IP.

PIOTR PACYNA (pacyna@kt.agh.edu.pl) received an M.Sc. degree in computer sciences and a Ph.D. degree in telecommunications in 2005 from AGH University of Technology, Krakow, Poland, where he is an associate professor. His research activities focus on next-generation wireless communications systems, mobility, and security. He has been active in research projects funded by the European Commission: Broadband Trial Integration (1997–2000), Moby Dick (2001–2003), and IST Integrated Project Daidalos (2003–2006). In Daidalos II (2006–2009) he serves as a member of the architecture design team. Sabbatical leaves have been spent at CNET France Telecom, Paris (1997–1998) and the University of Carlos III, Madrid, Spain (2005–2007).

RICCARDO PASCOTTO (Riccardo.Pascotto@t-systems.com) received a diploma in technical computer science from the University of Applied Sciences of Berlin, Germany in 1996. Next, he joined TEKO Ingenieurbüro as an engineer for consultation and support in the field of telecommunications. Since 1998 he has been a project manager in the Department of European and International Projects at Deutsche Telekom Berkom/T-Nova Berkom, contributing to the 4th R&D Framework Programmes ACTS and TAP. He has been involved in a number of EU framework FP4/TAP and ACTS projects: CHIN (as deputy coordinator) and WISE; ACTS AMASE (project coordinator); IST Youngster (project coordinator); and IST Daidalos I and II (integrated project coordinator). Currently, he is a senior project manager and team leader at T-Systems Enterprise Services GmbH, Line of Business Products and Services, leading activities of IP Daidalos II.