European Activities towards an All-IP Mobile Network

By Marcus BRUNNER,* Juan NOGUERA,* Hiroyuki OKAZAKI,* Amardeo SARMA* and Heinrich STÜTTGEN*

ABSTRACT Around the world, many activities exist to explore open, IP-based mobile networks. Within Europe, the European Government is sponsoring collaborative research towards end-to-end All-IP Mobile Networks. NEC's European Network Laboratories (NL-E) are participating in two major European projects. Within the Daidalos project we are working on IP based mobility across heterogeneous access networks. Within the Ambient Networks project our focus is on Capex/Opex reduction through intelligent management techniques, including flexible on-demand composition of heterogeneous networks, realizing the vision of "Always-best-connected."

KEYWORDS **All-IP Mobile Network, IP mobility, Autonomic management, Daidalos, Ambient networks**

1. INTRODUCTION

The evolution of mobile networks is progressing at a dazzling speed. There are two major trends that are driving this evolution. First the availability of wireless bandwidth is increasing rapidly. This enables new data and multimedia services even in networks that were originally mainly voice oriented, thus leading to a convergence of mobile voice and data networks. Consequently more and more packet communication, and with that more and more Internet technologies are finding their way into mobile networks. Secondly network operators are strongly demanding a noticeable reduction of their equipment (Capex) and operational (Opex) expenses. There is a hope in the industry, that an increased usage of IP technologies will help achieving this goal. However, there is certainly no agreement how big this reduction will be, once all the required control and management functions have been added to the originally simple and best effort Internet. The trend towards incorporating more IP technologies has been recognized by many players, including the 3GPP standardization body, who is currently defining requirements for an All-IP mobile network architecture.

The European mobile communication industry holds a very strong position in the world market. GSM, which was driven by Europe, has now been deployed in 210 countries in all continents. The GSM packet architecture called GPRS forms the basis for the 3G/UMTS packet service as well. This has allowed many European mobile network manufacturers to hold on to their strong market position when the 3G technology entered the market a few years ago. To maintain the competitive advantage of European manufacturers in mobile networks, the European government is strongly supporting collaborative research towards new open, IP-based mobile networks within its 6th Research and Development Framework program (FP6). NEC Europe's Network Laboratories (NL-E) are participating in two of the most prominent FP6 research projects called Daidalos and Ambient Networks which will be described below.

The remainder of this paper is organized as follows. Section 2 explains the European Research Program in general terms. In Section 3 we look at key requirements for All-IP Mobile Networks as identified by 3GPP. Then we describe the technical contributions developed by NL-E in Daidalos (Section 4) and Ambient Networks (Section 5). In Section 6 we briefly review the role of other fora e.g. IETF, concluding with an outlook on open challenges in this area.

2. EUROPEAN RESEARCH PROGRAM

The government of the European Union called European Commission (EC) has been facilitating and funding collaborative research activities in many areas including Information and Communication Technologies. Every couple of years the EC defines a research agenda for the next five to six years. Currently we are in the middle of the 6th Research Framework

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Program (FP6)[1] which lasts from 2002 to 2006, with individual projects mainly running from 2003 into 2008. Within FP6 many research areas are being addressed, from Life Sciences and Aeronautics to Nano-Technologies and Information Society Technologies (IST). Over the lifetime of the program government funding of 16.2B Euro has been allocated, which represents roughly half of the total project budget of 32B Euro. Typical large, so-called Integrated Projects (IPs) will consist of 20 to 40 different partners with a project budget of up to 50M Euro over six years. The objective of the EC is to bring together powerful consortia with enough critical mass to have a real impact on future markets. Hence most IPs include many industry key players that are normally fierce competitors, but who want to work together on a common goal in a pre-competitive research environment. This environment has proved to be a valuable tool to understand the requirements of technology users and drive future technology directions jointly with other key players. In the area "Beyond 3G" this means that projects will typically include Network Operators, equipment manufacturers as well as leading academic institutions. Open collaboration between project partners is a key requirement for overall project success. Partners have to respect each other's requirements and utilize the different areas of expertise available among the partners to arrive at mutually acceptable and valuable solutions. Solutions, which however should be pre-competitive, they may impact standards but should not lead to "ready to sell" products, otherwise the EC could be accused of unfair subsidizing. It is this environment, in which the Daidalos and Ambient Network Projects are running.

To establish some level of coordination between many different European wireless research efforts, several European network manufacturers initiated a new consensus forming, pre-standardization forum, called the Wireless World Research Forum (WWRF)[2] in 2000. The organization now has roughly 180 members, including manufacturers, network operators and research organizations. Although the WWRF originated in Europe, it now has members also from America, Asia and Australia. NEC Europe Ltd. is a sponsoring member of the WWRF.

The objective of the forum is to formulate visions on future directions in mobile and wireless networking. It is intended to constructively contribute to standardization activities in 3GPP, IETF and other bodies. In this role it is a place for many European and non-European research projects to contribute their R&D visions and try to incorporate them into a common vision of future networks. Hence many conceptual results from research projects like Daidalos or Ambient Networks may be incorporated into future WWRF vision books.

3. REQUIREMENTS FOR All-IP BASED NETWORKS

The SA1 group in 3GPP started working on future All-IP Network (AIPN) requirements in Jun. 2004 under a Work Item (WI) that was supported by twelve companies, including NEC. AIPN is defined as a network concept in which IP is pervasive through the whole network (mobility, security, service control, QoS, etc.) The Technical Report resulting from AIPN requirements discussions[3] was practically finalized in Jan. 2005 and will be presented for approval at the 3GPP SA plenary meeting in Mar. 2005. At this point of time, it is expected that 3GPP will start formal work on AIPN stage 2.

The AIPN work in SA1 has studied requirements that an evolved 3GPP system should consider. This work has mainly focused on evolution of the PS Core Network, including IMS, but it is generally agreed that some of the requirements may have an impact on radio access network evolution as well.

The three main targets of AIPN have been:

1) CAPEX and OPEX cost reductions for 3G networks.
2) Access independence (efficient mobility management, service control, etc).
3) Introduction of advanced networking concepts (moving networks, PAN, network composition, etc.)

A significant part of NLE's input into AIPN has been possible thanks to the expertise acquired on the several European Projects. As a matter of fact, the first AIPN target above is a main issue within the Ambient Networks Project. The second AIPN target is being intensively studied within the Daidalos Project. And the third AIPN target is shared by Ambient and Daidalos Projects, as well as other projects NL-E is or has been involved in.

In addition SA1 is studying requirements on mobility, security, network performance, QoS, network composition and service/user control.

In Dec. 2004, RAN and SA plenary groups decided to start 3GPP evolution studies in RAN working groups and SA2 respectively. These studies are part of 3GPP Rel-7(release 7) and are expected to run for 18 to 24 months and look at the feasibility of the

different architectures proposed by different parties. In practice, it is possible that a prioritization of AIPN requirement happens, with those being more interesting from a network or business point of view getting higher priority and solutions for them being standardized within Rel-7 work items that result from the evolution studies. Lower priority requirements would then be fulfilled in later 3GPP releases.

4. EUROPEAN DAIDALOS PROJECT

4.1 Daidalos Objectives and Overview

The Daidalos vision is a world in which mobile users can enjoy a diverse range of personalized services seamlessly and transparently using a personal or embedded device. Mobility is fully supported through open, scalable and seamless integration of a complementary range of heterogeneous network technologies and types, including ad hoc, moving and sensor networks. Broadcast integration plays a key role here. The final goal is to enable network and service operators to develop new business activities and provide profitable services in such an integrated mobile world[4].

The work is built on results delivered by the previous project Moby Dick[5], which has provided results that are taken as the starting point. These are the support of seamless mobility over heterogeneous access (wireless and wireline) technologies, as well as the integration of AAA (Authentication, Authorization and Accounting) and QoS (Quality of Service) support alongside mobility. Daidalos provides MARQS support with vertical optimization from the link up to the service layer as shown in **Fig. 1**.

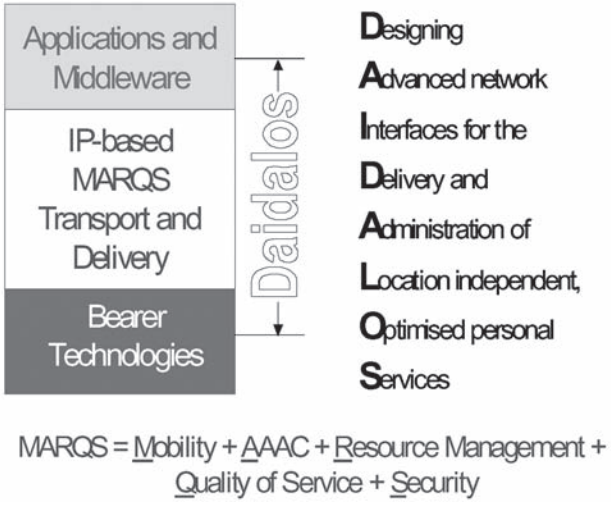

Fig. 1 Daidalos MARQS support.

Beyond MARQS, Daidalos will address the integration of ad-hoc and moving networks with the infrastructure. A major innovation is the use of a user identity (virtual identities or pseudonyms) as the "handle" for not only services but also mobility. This is based on the concept of separation of the user and the device, as the user may "own" a device for limited time and for only parts of a session, while at the same time many users may share a device, such as a large video screen.

Daidalos uses a user-centered, scenario based approach. Two basic scenarios form the cornerstone of Daidalos — the University and Automobile scenarios.

4.2 NL-E Technology Contributions

In the Daidalos project, NL-E has focused on three areas:

1) Support of enhanced mobility functions and their combination,
2) Integration of sensor networks with a particular focus on security requirements,
3) Modeling support for the overall project prototyping, in particular for mobility functions.

Figure 2 provides the context of NL-E's work. It shows the Daidalos network architecture including parts contributed by other partners. Further it shows the access technologies supported including broadcast (DVB-T/S/H - Digital Video Broadcast) and sensor networks. A key difference of sensor networks is that they provide an overall data service, and do not allow the individual addressing of nodes. The three key NL-E areas are described in more detail in the next sections.

4.2.1 Enhanced Mobility

To provide mobility support comparable to what customers expect in today's 2G and 3G networks, much more than just Mobile IP must be supported.

NL-E's focus is on the advanced mobility functions including (**Fig. 3**):

- Candidate Access Router Discovery (CARD) that supports finding the most appropriate of several possible access routers that a mobile terminal could connect to.
- Fast handover that can be initiated both by the terminal and by the network e.g. for resource optimization reasons.
- IP paging integration with terminal network adapters in power save mode.

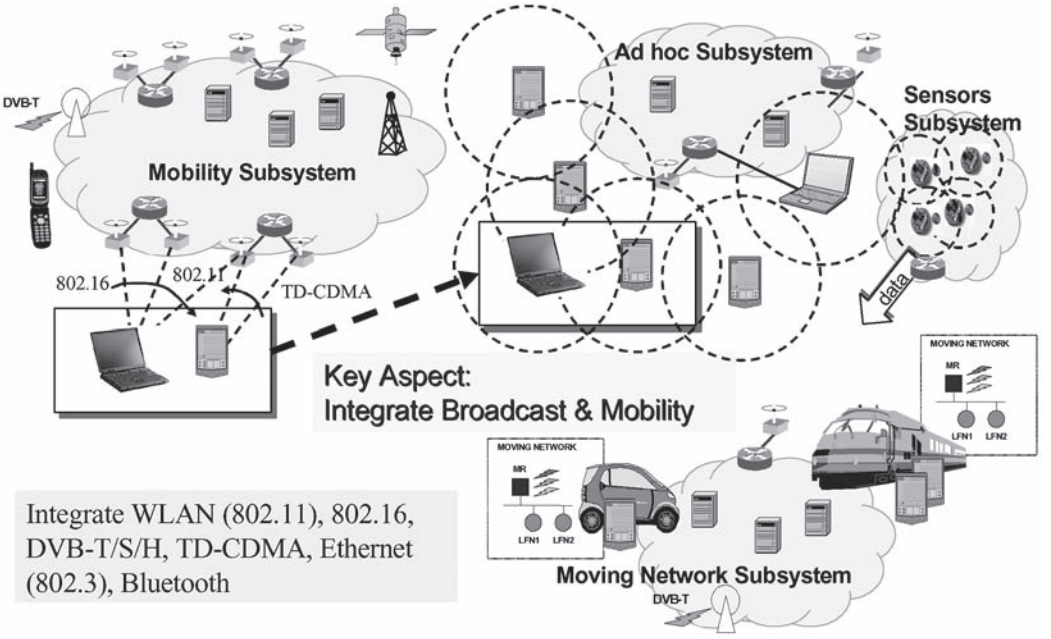

Fig. 2 Daidalos network architecture.

These are required to interact with the functions provided by Daidalos partners:

- Context Transfer for fast QoS support (VoIP) and network authentication.
- Performance Management for capacity optimization and network control, interacting with network-initiated handover.

4.2.2 Secure Sensor Networks

Within the overall scheme, sensor networks are used to provide specific kinds of data. An example for the Daidalos automobile scenario is to warn drivers of hazards on roads, such as ice on bridges or fire in tunnels or from the roadside, e.g. animals crossing, via sensors that aggregate relevant data.

NL-E is focusing on security issues, such as the secure aggregation of data (concealed data aggregation) and the mutual authentication of sensor nodes (zero common knowledge)[6]. The focus is on lightweight security taking into account the restricted power of sensors.

4.2.3 Modeling Support

For the management of such a large project with many partners, the mandatory use of modeling using UML (Unified Modeling Language) was agreed. The project is using a modeling tool, which includes strong validation techniques based on SDL (Specification and Description Language) as the state machine description. The intention is to ensure consistency throughout the project and validate complex concepts e.g. the combination of mobility protocols before going

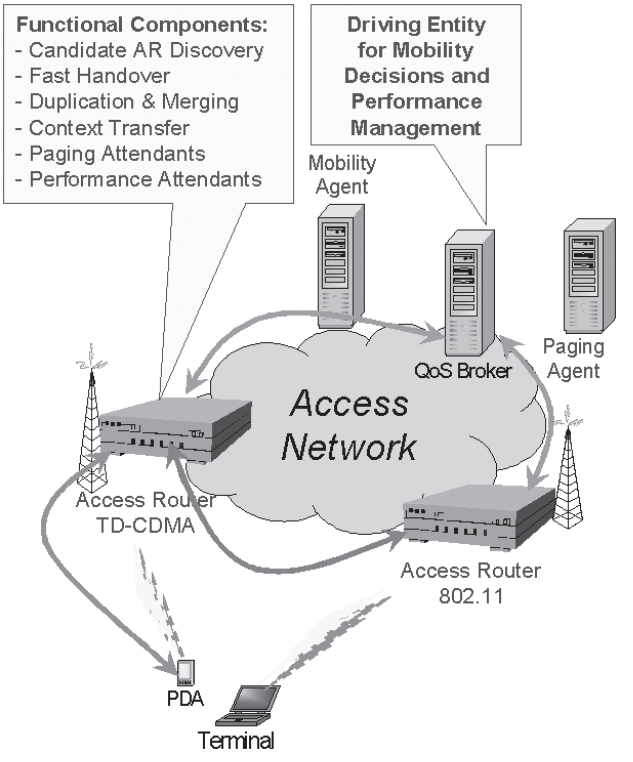

Fig. 3 Mobility support in Daidalos.

for implementation.

A first overall model has been created, giving a formalized overview at the architectural level showing the components and subsystems used. In addition, a first detailed model of the behavior of the combination of network and terminal initiated handover has been developed. Modeling was used to find conceptual errors early that are not detectable otherwise. This allows eliminating them during design instead of during testing after implementations.

4.2.4 Project Status

First Daidalos modeling and simulation results were shown at the first audit in Dec. 2004. A standalone demo of sensor networks implementations is already available, and an integrated system with advanced mobility functions is scheduled to be demonstrated by the end of 2005.

5. AMBIENT NETWORK PROJECT

The Ambient Network project targets next generation mobile networks as well, but takes a longer term approach compared to the Daidalos project. The NL-E contributions are also in a different area, namely in autonomic networking, overlay networks, and self-management.

5.1 Ambient Networks Objectives and Overview

One of the main goals of the Ambient Networks project[7] is to enable seamless interoperation between heterogeneous networks including all current and future mobile and wireless access networks. An Ambient Network can be of different kind in size, technology, and administration. It includes, for example, personal area, car, train, and mobile operator networks with different technologies and different business models including big operators as well as very small network connectivity providers in a local area.

Ambient Networks aims at establishing this interoperation through a common control plane distributed across the individual, heterogeneous networks. This new control plane functionality can be deployed both as an integral component of future mobile network architectures that have better intrinsic support for network heterogeneity or as an add-on to existing, legacy networks allowing them to interoperate with future networks.

The main characteristics of an Ambient Network are shown in **Fig. 4**.

An Ambient Network can be dynamically composed with several other networks. Cooperating Ambient Networks could potentially belong to separate administrative or economic entities. Hence, Ambient Networks provide network services in a cooperative as well as a competitive way.

- Ambient Network mobility mechanisms include all types of mobility in particular moving networks and moving sessions. The mobility runs across business and administrative boundaries, which

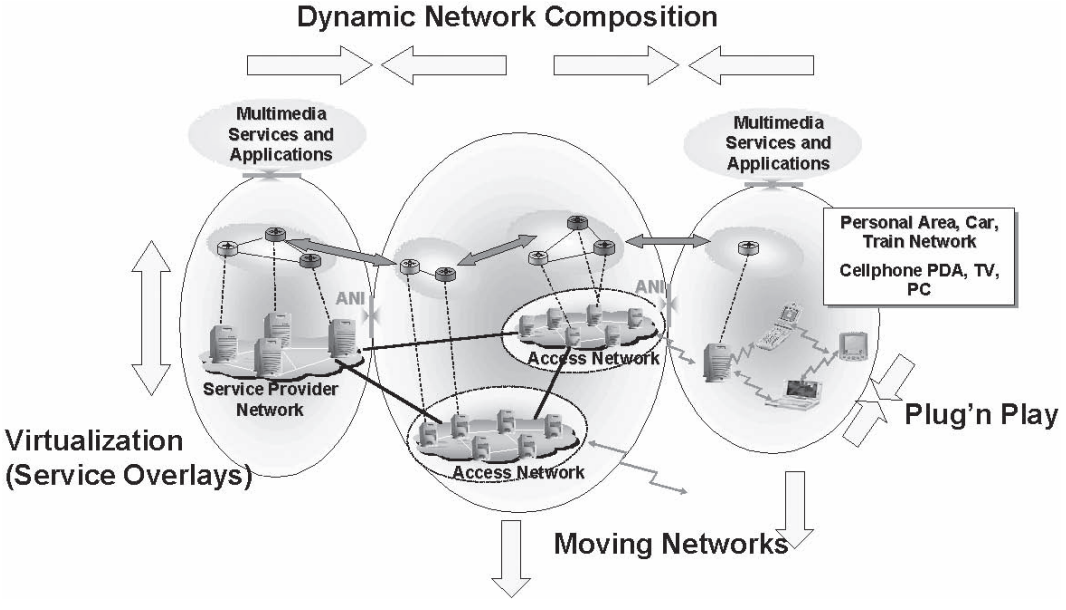

Fig. 4 Architectural vision.

requires solutions for ensuring the security of inter-domain operation, and mobility of networks.

- The concept of virtual networks enables the introduction of service-specific handling within the network to deliver services in the best possible quality to the customers taking into account the environment and capabilities of networks and devices.
- Autonomic and self-managing systems are key for the reduction of operational cost to create affordable and scalable next generation mobile networks.

5.2 NL-E Technology Contributions

5.2.1 Plug-and-Play Networks and Devices

The plug-and-play paradigm aims at minimizing configuration (ideally complete self-configuring) of base stations, mobile terminals, and mobile routers. It is very appealing from a business point of view, since it enables a vendor to build affordable and scalable systems lowering operational cost. Also most medium to small companies, as well as most end-users, are not capable of configuring networks correctly, therefore self-configuration will become a differentiating capability of network devices in the market place.

An autonomous, self-organizing, and decentralized configuration and management system for base stations including routers for wireless networks is designed and implemented (see **Fig. 5**).

The main functions include the autonomous (re-) configuration of channels, send power, and other network wide configuration information such as IP addresses and routing protocol configuration. As an input to the decision engine of the plug and play system, we use local monitoring information received from neighbors as well as from special clients running additional software to communicate monitoring results to the base stations. Particularly, the reach-ability information from third party clients improves the configuration, e.g. knowledge about hidden, but conflicting neighbors. Additionally, IP routers automatically distribute the available IP address space among themselves, configure subnets for client connectivity on their wireless and wired interfaces, and configure the routing protocols appropriately.

5.2.2 Service-Specific Overlay Networks (SSON)

SSONs virtualize the network to handle multimedia sessions in a service or application specific way within the network. The Service-Specific Overlay Network Architecture (SSON, **Fig. 6**) for Media Delivery supports pervasive and massively scalable services spanning heterogeneous networks. Also it is compatible with varied communication paradigms including unicast, multicast, peer-to-peer, and content delivery networks. Further it hides network complexity from the user.

For this purpose the SSON architecture builds overlays using intelligent nodes (called Overlay Node) that perform media processing. These intelligent nodes are responsible for adaptive media routing, media flow-based routing, and smart caching.

The main functionality in the Overlay Control System (OCS, Fig. 6) is the intelligent selection of

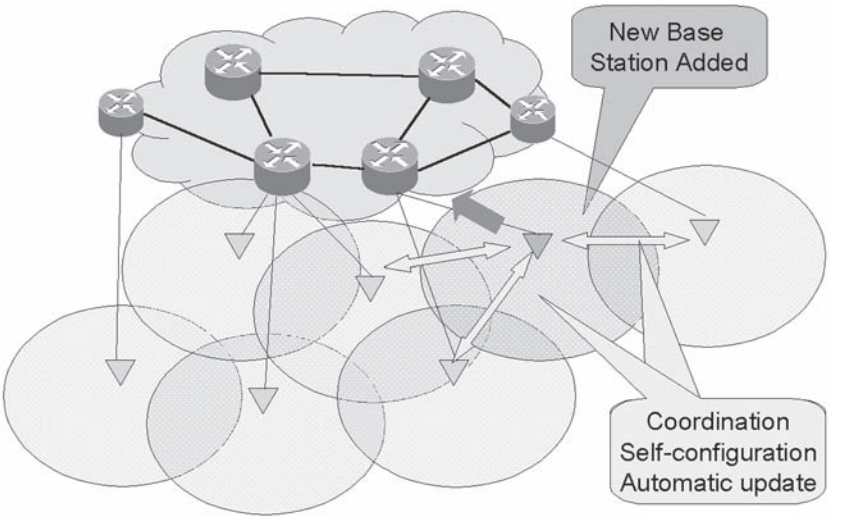

Fig. 5 Plug and Play base station.

Overlay Nodes to be included in the SSON and the configuration of the service-specific media handling functionality, including the possible adaptations of media at these nodes. These actions are based on the specific needs of the service and the user (user context and preferences).

The search for potential Overlay Nodes use a path-directed search algorithm, where the concept of dynamic search along the path is used. The basic idea of this algorithm is to limit the scope of the search to a configurable area along the end-to-end path (given traditional IP routing) between communicating peers. It starts from the source node and expands along the end-to-end routing path towards the destination nodes with a sideway expansion of a given distance (e.g. based on the number of hops, delay, or other parameters). Depending on the type of resource, function, or service that is searched, this parameter can be changed. Since the multimedia processing functions are not assumed to be directly on the path, but should ideally be located near the path, the path-directed search pattern is ideal to find appropriate overlay nodes on demand.

5.2.3 Turfnet: Towards an Autonomic and Composable Network Architecture

The basic principles of the original Internet architecture include end-to-end addressing, global routeability, and a single namespace of IP addresses that are locators and host identifiers at the same time. As the Internet evolved from a small research network to a worldwide information exchange, a growing diversity of commercial, social, ethnic, and governmental interests led to increasingly conflicting requirements among the competing stakeholders. These conflicts create tensions that the original Internet architecture struggles to withstand. When IP networks will be used also in the mobile network space, those problems of the Internet architecture needs to be solved first.

The TurfNet architecture focuses on enabling interoperation between otherwise autonomic networks. To achieve this autonomic behavior, every TurfNet encompasses its own independent network addressing, independent control plane functionality, such as routing protocols, address resolution mechanisms, and autonomic management for self-healing, self-configuration, and self-optimization. Additionally, TurfNet hides their internal structures, characteristics, and policies.

Besides the autonomic behavior, the key architectural features of the TurfNet architecture include explicit separation of host identities and host locators, dynamic network composition, easily movable networks, location privacy, and autonomous decisions. Such a modular network architecture suites the requirements of future mobile and fixed network communication well. A first preliminary prototype of the Turfnet architecture has been implemented, and the scalability of the architecture is currently evaluated for a global scale network using the Internet structure.

6. OTHER PLAYERS

The Internet Engineering Task Force (IETF) is standardizing various bits and pieces around the Internet. In the area of mobile networks, a number of

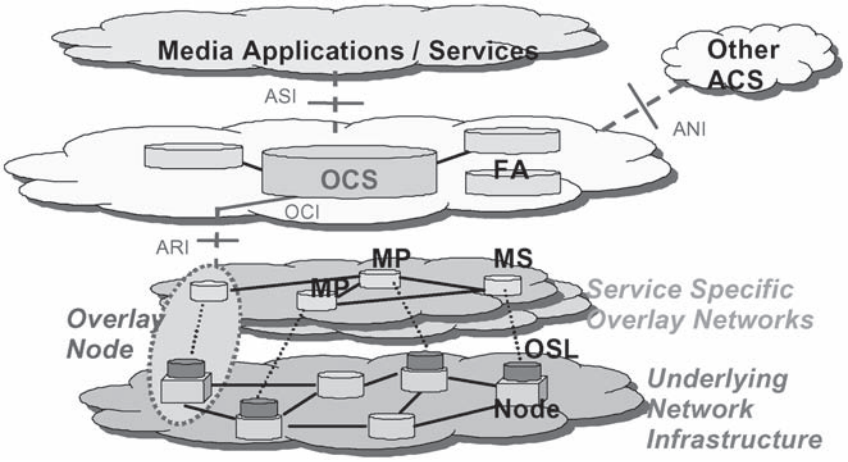

Fig. 6 SSON architecture.

protocols are currently and will be standardized in the future. However, the IETF does not prescribe any architecture or framework, but typically standardizes only protocols to be used in various environments. Still, for impacting the protocol design and speed up the time to market with IETF technology active involvement in the IETF is a prerequisite.

NL-E particularly is strongly involved in the standardization of IP Paging, Candidate Access Router Discovery (CARD) for fast handover, and in a newer activity on the standardization of Host Identity Protocol (HIP) together with some mobility extensions, which allows a new architecture along the line of the above-mentioned TurfNet network architecture.

Besides the network evolution activities explicitly addressed in this paper, there are other fora where network evolution is a prime subject and that may influence final outcome. NL-E is tracking some of these fora, mainly in the area of NGN (Next Generation Network), to be aware of potential synergies and conflicts. In particular, we follow ETSI TISPAN, which is specifying the ETSI version of NGN. TISPAN is the NGN group with the widest acceptance at this point of time, and the main source of input to NGN activities in ITU-T SG13 Focus Group on NGN (FGNGN).

7. CONCLUSION

This paper has described European activities towards an all-IP mobile network. The basic motivations of all-IP mobile networks are convergence of voice and data services, and reductions of both network equipment (Capex) and operational expenses (Opex). To realize such networks, Network Laboratories, NEC Europe Ltd., are participating in the EU FP6 IST projects Daidalos and Ambient Networks. The former is focusing on IP based mobility across heterogeneous access networks while the latter is pursuing Capex/Opex reduction through intelligent management technology. Many results of these projects are actively contributed to IETF and 3GPP standardization. At the same time these projects produce prototypes for next generation mobile networks that enable NEC to maintain its leading role in mobile networking.

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REFERENCES

[1] http://europa.eu.int/comm/research/fp6/
[2] http://www.wireless-world-research.org/
[3] 3GPP TR22.978 All-IP Network Feasibility Study
[4] http://www.ist-daidalos.org/
[5] M. Liebsch, X. Perez, et al., "Solutions for IPv6-based mobility in the EU project Moby Dick," XVIII World Telecommunications Congress, Paris, Sept. 2002.
[6] A. Weimerskirch and D. Westhoff, "Identity Certified Zero-Common Knowledge Authentication," ACM Workshop on Security of Ad Hoc and Sensor Networks in conj. w. the 10th ACM SIGSAC Conf. on Computer & Communications Security, ACM SASN'03, Dec. 2003.
[7] N. Niebert, et al., "Ambient Networks — An Architecture for Communication Networks Beyond 3G," IEEE Wireless Communications, April 2004, and http://www.ambient-networks.org.

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