Handovers for Ubiquitous and Optimal Broadband Connectivity among Cooperative Networking Environments

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Abstract. The handover function is a key enabler for seamless mobility and service continuity among a variety of mobile/wireless access technologies supporting IP connectivity. The paper focuses on the key research challenges regarding inter-system handover operations among various radio cooperative networking environments (3G, WLAN, WiMAX and DVB) that are going to formulate future/near future business cases for both broadcasters and telecom operators in the context of a Fixed-Mobile Convergence (FMC) communications environment. In this context, relevant efforts from the IETF, IEEE 802.21, IEEE 1900.4, 3GPP and DVB are reviewed and incorporation of the IEEE 802.21 functionality inside the mobility management protocol stack is discussed.

Keywords: Heterogeneous Wireless Networks, Seamless Mobility, Media Independent Handovers.

1 Introduction

For several years, service providers, telecommunication equipment manufacturers and other vendors have faced the great challenge of networks and services convergence. Beyond the core fixed infrastructure, which has already largely migrated towards IP, the explosion of broadband and, simultaneously, the launch of 3G mobile networks have accelerated the synergy between heterogeneous networks, leading to an all-IP network. As a result, the challenge of delivering services like voice, data, content, video communications and video broadcasting can be realized in a ubiquitous manner.

The 3GPP and 3GPP2 have specified the IP Multimedia Subsystem (IMS) that aims to provide a workable and coherent solution for both fixed and wireless networks for delivering new generation converged services. This opportunity, stimulated also by the ETSI TISPAN [1], is rising fast and is largely contributing to the wide, although recent, recognition of IMS as the future direction of Fixed-Mobile Convergence (FMC). The FMC is a new dimension for the communications industry and presupposes the existence of multimode mobile terminals that are able to operate in virtually any mobile or wireless broadcasting communication network, such as 3G or DVB, and jump seamlessly to any WLAN or WMAN technology, including WiFi or WiMAX. Mobile terminals have to be capable of accessing different multimedia

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applications and advanced services while roaming across domains covered by different access technologies.

In the above context, the communications research and development community is investigating new ways to facilitate interworking among the various Radio Access Technologies (RATs) on providing seamless mobility and service continuity among them. A key enabling function for seamless mobility and service continuity among a variety of mobile/wireless access technologies supporting IP connectivity is the handover, in any IMS, pre-IMS, or combined network. In such environments, a strong constraint is the ability of multimode terminals to take full advantage of all added functionalities in the most profound way.

With respect to this, key challenges include the investigation, design, implementation and testing of inter-system handover operations among various radio cooperative networking environments (e.g., 3G, WLAN, WiMAX and DVB) that are going to formulate future/near future business cases for both broadcasters and telecom operators in the context of an FMC communications environment. As far as the optimization of the vertical handover operation is concerned, major contribution has been provided by the IEEE 802.21 working group, which has specified standardized mechanisms for closer-to-seamless handovers among 3GPP, 3GPP2 and several IEEE 802-based networks.

In this paper, which extends the work presented in [2], we discuss the challenges associated with the handover operation and review existing and emerging protocols and architectures that aim to support handovers between heterogeneous next-generation wireless systems. The relevant efforts of the IETF, IEEE, 3GPP and DVB are presented and the potential of IEEE 802.21 to deliver a framework for optimized handover operations is discussed.

The rest of the paper is organized as follows. Section 2 formulates the handover problem, while Section 3 gives a brief overview of current standardization efforts concerning inter-system handovers. Section 4 discusses open research and development issues related to inter-system handover. The components of a framework that aims to provide optimized handover operations are presented in Section 5, while conclusions are given in Section 6.

2 The Handover Problem Formulation

Mobility management is comprised of two components: location management and handover management. The former is needed to track the location of the terminal and, thus, enable packet reception. Handover management, on the other hand, is needed to keep the connections active while the mobile node moves from one location to another.

In general, handovers occur when a mobile node changes its Layer-2 network Point of Attachment (PoA), i.e., the end-point of a Layer-2 link between the mobile node and the network. Proper handover management must ensure that there is no noticeable interruption to running applications. This ultimate goal can be achieved if a number of sub-requirements are satisfied:

- Successful connection to target PoA: The mobile node must be able to connect to the target PoA. This presupposes that the mobile node is eligible for connection and that resources are available.

- Service continuity: After handover, the applications should be able to continue their operations without need for session reestablishment. For applications running on top of existing transport protocols like TCP and UDP this means that the applications must continue using the same logical connection; that is, the endpoint IP addresses must remain intact.
- Minimum handover delay and data loss: The time period during which the mobile cannot send or receive packets due to interface change must be kept to a minimum and actions must be taken to avoid or limit packet loss.

Handovers between links of the same technology are called intra-technology or horizontal handovers, while those occurring between different access technologies are called inter-technology or vertical handovers. The change of Layer-2 PoA (Layer-2 handover) may subsequently trigger reconfiguration of the IP address (Layer-3 handover) used by the mobile node as location identifier. This is the case when the current and the target PoAs are served by different Access Routers (ARs). Layer-3 handovers (whether horizontal or vertical) that occur between PoAs served by different ARs are called intra-system handovers when these ARs belong to the same access system, and inter-system handovers when the ARs belong to different access systems (usually distinct administrative domains).

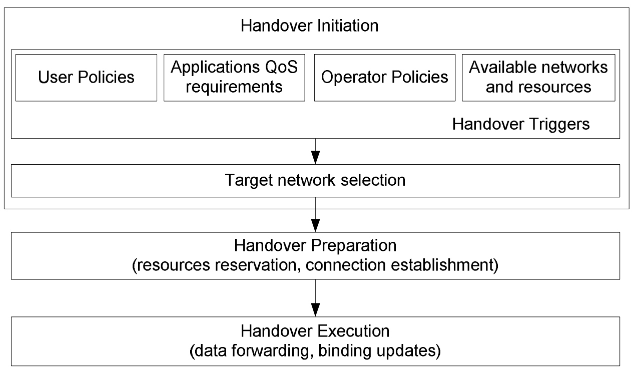

Fig. 1. Phases of the handover operation

Handovers take place during a session (i.e., when the terminal is in active mode; in idle mode, the switch of networks is usually called re-selection). The reasons triggering the handover as well as any pre-handover preparative actions should be clearly distinguished from the handover execution itself. In general, the handover operation can be separated in three phases (Fig. 1):

- Handover initiation: This refers to the decision mentioning the necessity for a terminal to change network. A reason could be either because the current network can no longer fulfill the end-user requirements or because it has been observed that another network could fulfill them in a better way. The outcome of this phase is the selection of the target network.
- Handover preparation: This phase involves preparations for the establishment of Layer-2 and Layer-3 connections to the target network, reservation of resources

and, if applicable, transfer of context (i.e., information regarding access control, QoS profile and header compression).

- Handover execution: This includes the events concerning the disconnection from the previous network and the connection to the target one. Furthermore, this stage addresses data forwarding from the previous network (if such a feature is supported by the mobility management protocol) and IP address binding update.

The role of handover initiation is to compile information about applications QoS requirements, user preferences, operator policies (reflecting also regulatory constraints) as well as available networks and take firm decisions on the need of the handover and the target network. The network selection is often treated as an optimization problem, the complexity of which increases with the number of the handover decision criteria and constraints and the number of available networks. Since handovers are costly (in terms of network signaling and processing power) and in many cases not seamless, decisions to switch networks must be made when it is deemed necessary.

However, in a rapidly changing and highly unpredictable mobile communication environment securing the handover decision and determining the right time to start handover preparation is not an easy task. Early handover decisions are usually due to incorrect predictions and lack of stable information (e.g., about signal strength deterioration or availability of other networks) and, thus, may not be optimal. Even worse, they may need to be cancelled before completion of the handover operation or shortly after (leading, for example, to the undesirable ping-pong effect). Mature handover decisions, on the other hand, may come too late to allow for efficient handover preparation; this can cause increased handover delay and packet loss. Clearly a trade-off between the two approaches is needed.

The next phase in handover operation, namely the handover preparation, deals with the actions that can be taken in advance to mitigate the impact of handover execution on applications' performance. Compared to handover initiation, this step depends more heavily on the mobility management protocol involved in handover (which, in turn, may depend on the type of the handover and the involved RATs). For Layer-2 handovers this phase addresses resource allocation to the target network and Layer-2 authentication and association. For Layer-3 handovers, it may further facilitate movement detection and expedite the configuration of the IP address used in the target network. Additional actions include preparations for data forwarding from network nodes of the previous network to the AR of the target network.

The last step in handover operation is handover execution, during which the mobile node connects to the target network. The network entities in previous and target networks may, furthermore, cooperate to forward data to the mobile node until location update is completed. As soon as this happens, resources are released in previous network and normal data forwarding to the mobile terminal is resumed.

Handover mechanisms that are able to provide seamless mobility are quite complicated and depend on functionality that spans across several layers in the networking protocol stack (from physical to network and application). Thus, smooth cooperation of these functions is essential for efficient realizations targeting complete system solutions.

3 Brief Overview of Recent Standardization Efforts Concerning Inter-system Handovers

3.1 IETF Efforts

The basis for terminal mobility management in IETF is provided by Mobile IPv4 (MIPv4) [3]. MIPv4 works by allocating two addresses to a Mobile Terminal (MT): a permanent global address (home address) belonging to the address space of the home network, and a temporary local address (care-of-address) allocated to the MT at the visiting network (usually this address is provided by a router called foreign agent). Traffic destined to the MT is always routed to the home domain and is collected by a router called home agent. This router, subsequently, tunnels the packets to the foreign agent based on the mapping between MT home and care-of-address is has previously created. After appropriate processing of the packets (tunnel decapsulation), the foreign agent forwards them to the MT.

Mobile IPv6 (MIPv6) [4] introduces several advantages over MIPv4 that aim to optimize the communication between correspondent nodes and MTs. In MIPv6, foreign agents are not needed, route optimization is supported as part of the basic functionality, and there is inherent support for coexistence of route optimization and routers performing “ingress filtering”. However, direct communication between correspondent nodes and MT presupposes that the former are able to support mobility-aware operations.

The Mobile IP schemes just presented introduce significant handover latency due to procedures like movement detection, new care-of-address configuration and location update. This latency is often unacceptable for real-time applications. Two protocols have been proposed to reduce the handover latency of MIPv6: Fast MIPv6 [5] and Hierarchical MIPv6 [6]. The former is an enhancement to the MIPv6 protocol that mitigates handover delay by involving communication between the previous and the next access routers in the foreign network, while the latter adds extensions to MIPv6 that support localized mobility management (i.e. management of topologically small movements within an access network). Hierarchical MIPv6 and Fast MIPv6 have complementary capabilities and functions, and, thus, can be used in parallel to further improve the handover experience. Combination of these schemes is known as Fast Hierarchical MIPv6 [7].

The protocols described thus far are terminal-based in the sense that the MT needs to be provisioned with functionality to perform handover and location management signaling when it moves between access network subnets. Recently, there was an interest from IETF to define a network-based localized mobility protocol (NETLMM[8,9]) that would allow MTs to move between subnets within the same access network (operational domain) without requiring changes in the IPv6 protocol stack.

The protocol that was specified within the NETLMM Working Group, called Proxy MIPv6 [10], introduces functionality for first-hop routers and special nodes in the access network called Local Mobility Anchor Points (LMAPs), which act as localized home agents. The first-hop router performs mobility management on behalf of the mobile by providing, in cooperation with the LMAP, router advertisements that make the MT believe it is still connected to the home network (and thus it can keep the same address). After detecting the movement of the MT, the first-hop router initiates signaling with the LMAP to update the route to/from the MT’s home address.

Another approach to handle mobility in IP-based networks is the Session Initiation Protocol (SIP) [11]. SIP is an application-layer control (signaling) protocol for the creation, modification and termination of sessions with one or more participants. These sessions include Internet telephone calls, multimedia distribution, and multimedia conferences. SIP addresses mobility at the application layer, and while it is capable of performing location management (through appropriate binding of SIP addresses to current location, namely IP address) it requires session reestablishment every time the MT changes its network address.

3.2 IEEE Efforts

The intention of the IEEE 802.21 standard [12] is to provide generic link layer intelligence independent of the specifics of mobile nodes or radio networks. As such, the IEEE 802.21 is intended to provide a generic interface between the link layer users in the mobility-management protocol stack and existing media-specific link layers, such as those specified by 3GPP, 3GPP2 and the IEEE 802 family of standards.

The standard specifically describes a logical entity (called Media Independent Handover Function - MIHF) residing between the link and upper layers, which provides three services to Media Independent Handover (MIH) users [12]:

- The Media Independent Event service, which detects events and delivers triggers from both local as well as remote interfaces;
- The Media independent Command service, which provides a set of commands for the MIHF users to control handover relevant link states;
- The Media Independent Information service, which provides the information model for query and response, thus enabling more effective handover decisions across heterogeneous networks.

Incorporation of IEEE 802.21 services in terminal and network nodes has the potential of optimizing the initiation and preparation phases of the handover operation and, thus, providing enhanced service experience to mobile users.

Optimized radio resource usage in composite wireless radio environments cannot be achieved unless efficient handover decision making is supported by both the network and the terminals. Towards this direction, a Working Group inside the IEEE (IEEE 1900.4 [13]) took action to address the broader problem of dynamic network re-configurability, one key enabler of which can be the handover operation (the standard further addresses two other key enablers: dynamic spectrum assignment and dynamic spectrum access). The standard specifies the building blocks that are necessary, both at the network and the terminal's side, to support distributed reconfiguration decision making. The addressed system architecture is comprised of three building blocks [14]:

- Network Reconfiguration Manager (NRM) entity that facilitates the derivation of network policies, which constrain the resource selection strategies of user terminals;
- Terminal Reconfiguration Manager (TRM) entity with facilities for enabling user devices to perform a (distributed) self-management-based optimization of their respective resource usage strategies subject to policies imposed by the NRM;

- Radio Enabler (RE) entity, which addresses the transfer of information between the network and the terminal reconfiguration management entities.

The TRM and NRM exchange context information (e.g., terminal and network capabilities and measurements, terminal location, user preferences and application QoS requirements), the collection of which is supported by appropriate measurement collectors at both the terminal and network sides. The NRM formulates reconfiguration (e.g., handover) policies and constraints, and forward them to the TRM via the RE. This is the first level of decision making; the second level of this network/terminal distributed process involves decisions taken by the TRM based on the policies and constraints received by the NRM.

3.3 3GPP Efforts

Future wireless networks will work on a cooperative manner and support mobility of terminals among heterogeneous systems/technologies. With respect to this challenge, the 3GPP is addressing the evolution of its system architecture (System Architecture Evolution – SAE), in conjunction with the evolution of the access system (Long Term Evolution – LTE), in order to deliver an evolved network able to support a variety of different access systems and access selection based on combinations of operator policies, user preferences and access network conditions. In this context, mobility-related requirements of the new architecture include the following [15]:

- Mobility management functionality shall be responsible for mobility within the evolved 3GPP system, as well as between that and different types of access systems including for example WiMAX and WiFi;
- The evolved 3GPP mobility management shall allow the network operator to control the type of access system being used by a subscriber;
- Mobility procedures within 3GPP access systems and between 3GPP and non-3GPP access systems shall provide seamless operations of both real-time (e.g. VoIP) and non real-time applications and services by, for example, minimizing the packet loss and interruption time.

3GPP leverages on network-layer mobility management protocols from IETF for its evolved network architecture. The 3GPP SAE paradigm shows that mobility management protocols, like MIPv4, MIPv6 and its extensions (e.g. Hierarchical MIPv6 and Proxy MIPv6), have been considered as candidate components for mobility between existing and emerging heterogeneous networks.

3.4 DVB Efforts

Taking into consideration the support for mobile Digital TV, ETSI introduced the DVB-H specification, which substantially comprises of a set of extensions to DVB-T which are oriented to handheld use. DVB-H inherits all the benefits of its predecessor and adds new, mobile-oriented features, focusing on IP datacasting and including better mobility and handover support, adaptive per-service error protection and power saving capabilities.

IP Datacast (IPDC) over DVB [16,17] is an end-to-end broadcast system for delivery of any type of digital content and services using IP-based mechanisms optimized for devices with limitations on computational resources and battery. An inherent part of the IPDC system is that it comprises of a unidirectional DVB broadcast path that may be combined with a bi-directional mobile/cellular interactivity path. IPDC is thus a platform that can be used for enabling the convergence of services from broadcast/media and telecommunications domains (e.g., mobile/cellular).

In order that all developed services can be deployed in a uniform basis a lot of standardization effort is devoted regarding architecture and software issues. Towards this direction, the DVB CBMS (Convergence of Broadcasting and Mobile Services) Working Group has set an initial framework for use cases and services of DVB-H [16] and illustrated the way the components in IP Datacast over DVB-H work together [17].

Convergence of Internet and Broadcasting Systems [18] is at the moment at its infancy with many efforts resulting out of European driven initiatives. In most cases, vertical handover decisions are driven by overlooking gateway and/or management entities that 'decide' on the access network the user should be attached.

4 Open Research and Development Issues Related to Inter-system Handover

Legacy systems were designed and optimized without interoperability in mind, thus resulting in isolated communication networks with very tight bounds in geographical and service mobility. However, the advents of Beyond 3G have fuelled collaborative activities within the IEEE, IETF and 3GPP to construct a logical bridge between legacy systems to promote global roaming. Likewise, there has been recent interest from the broadcasting world to additionally integrate broadcasting services on a common service platform to address future market scenarios, thus raising significant future design challenges which include:

- New compatibility requirements to the IEEE 802.21 MIH architecture to provide cooperative dialogue with the DVB networking world;
- The seamless challenge (vertical handover involving DVB is a technical challenge) since the networks may not be synchronized, and even the content stream may not be identical (i.e., for the broadcasting case, the compression rates may not be the same).

The optimized operation of all phases of a handover procedure taking also into account downlink-only technologies like DVB that create new business cases, constitutes an open R&D issue that could also affect the evolution and well establishment of Next Generation Networks (NGNs) that are going to stimulate FMC vision. Obviously, this operational optimization is tightly related to the dynamics of all handover phases (initiation, preparation, execution), as well as the interfacing of handover operation to upper service layers that assist seamless mobility and service continuity through MIP and SIP.

A great research challenge that builds on top of recent research advances on both the handover procedure phases and upper service layers, is related with the investigation, design, implementation, testing and standardization of enabling technologies for optimized inter-system handovers operations among various radio cooperative networking environments (like 3G, WLAN, WiMAX and DVB) that are going to formulate future/near future business cases for both broadcasters and telecom operators in the context of a FMC communications environment.

Alongside with this research challenge, 3GPP, IEEE 802.21, IEEE 1900.4 and IETF provide new functional blocks that aim to facilitate further inter-system handover procedures. However, from a systems perspective view, the ability of these functions to cooperate in a harmonized fashion still has to be evaluated. Equally important is to investigate the interactions among these functions and the functions of upper layers (MIP/SIP) in any IMS, pre-IMS, or combined network.

Furthermore, the functional requirements for integrating other emerging technologies like DVB-T/H have to be identified and evaluated in an explicit manner. Towards this direction, a Task Group inside IEEE 802.21 has been recently formed to start the IEEE P802.21b project, which aims to investigate required extensions to the IEEE 802.21 standard to support handovers between 3GPP or IEEE 802, and DVB downlink-only technologies. DVB and other down-link only technologies pose extra challenges since a bi-directional physical link is not always available and services are primarily broadcasting-oriented [19].

5 Components of a Framework for Optimized Handover Operations

As already mentioned in subsection 3.2, IEEE 802.21 provides generic link layer intelligence, which is independent of the specifics of mobile nodes or radio access networks. This is done by the introduction of the MIHF logical entity residing between the link (Layer-2, L2) and upper layers (Layer-3, L3, and above) of the mobility management protocol stack. MIHF exploits triggers from the link layer to facilitate handover initiation (network discovery, network selection, handover negotiation) and handover preparation (L2 and IP connectivity). Issues like handover control, handover policies, algorithms involved in handover decision making and handover execution are not covered by the standard [12].

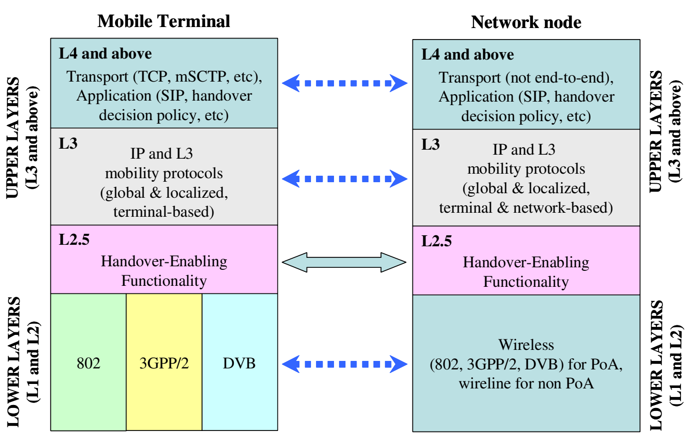

Fig. 2. IEEE 802.21-based mobility management protocol stack

The logical placement of the MIHF (identified as handover-enabling functionality residing at Layer-2.5, L2.5) within a mobility management protocol stack that is intended to deliver optimized handover operations (i.e., handover operations that rely on link-layer intelligence and global network information to realize closer-to-seamless experience) is illustrated in Fig. 2. The mobility management protocol stack presented in this figure is compatible with the hierarchical mobility management foreseen for next-generation networks (addressing mobility at both local and global levels) and the need to incorporate network-based mobility solutions. It is also compatible with the necessity to incorporate functions at Layer-2.5 for handover initiation and preparation, and functions at higher layers for handover decision policies (i.e., access selection), which can be provided, for example, by IEEE 1900.4. Mobility management in the network layer and above is addressed by IETF protocols (e.g., MIP, Proxy MIP, mSCTP [20] and SIP).

According to IEEE 802.21, a mobile terminal featuring MIH functionality may communicate with peers in the network. When the peer resides inside the same network entity as the mobile terminal's point of attachment, the communication between the two peers can be done through L2 message exchange (L2 transport has been specified for several IEEE 802 based technologies). However, if the peer is located deeper in the network, the communication takes place over Layer-3. When the mobile node is connected to a 3GPP network the communication with the peer is done only over Layer-3.

The mobility management protocol stack depicted in Fig.2 can be used as a basis for a framework targeting handover operations that are able to provide end-users with closer-to-seamless handover experience. This framework will rely on a) appropriate entities at the network side hosting functionality for mobility management (different entities may be responsible for different parts of the functionality presented in Fig. 2) and b) on efficient communication between the network entities themselves as well as between these and the MT.

6 Conclusions

A key Fixed-Mobile Convergence driver is to provide ubiquitous high-speed wireless connectivity to mobile multimode terminals using cost-effective techniques. In such an environment, it will be necessary to support seamless handover without causing disruption to ongoing sessions. The achievement of this vision requires cooperative radio networks that share system information and assist in handover events resulting in a seamless end-user experience irrespectively of the application at hand.

This paper elaborated on the functionality that is needed for the initiation, preparation and execution phases of the handover operation, reviewed current standardization efforts regarding support for vertical handovers and presented the components of an optimized handover framework that is based on emerging technologies proposed by the IEEE and the IETF. This framework, which is built around the concept of IEEE 802.21, combines the strengths of protocols residing at different layers of the mobility management protocol stack and targeting different phases of the handover operation. Application of such a framework is promising to deliver optimized handover operations that constitute potential business cases for both Telecom Operators and Broadcasters in the context of the emerging Fixed-Mobile Convergence communications environment.

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References

[1] ETSI TISPAN, `http://www.etsi.org/tispan/`
[2] Sarakis, L., Kormentzas, G.: Handovers for Ubiquitous Connectivity in Next Generation Wireless Systems. In: Proc. ICT-MobileSummit 2008, Stockholm, June 2008, pp. 1/8–8/8 (2008)
[3] Perkins, C. (ed.): IP Mobility Support for IPv4, RFC 3344, IETF (August 2002)
[4] Johnson, D., Perkins, C., Arkko, J.: Mobility support in IPv6, IETF, RFC 3775 (June 2004)
[5] Koodli, R. (ed.): Fast handovers for mobile IPv6, RFC 4068, IETF (July 2005)
[6] Soliman, H., et al.: Hierarchical mobile IPv6 mobility management (HMIPv6), RFC 4140, IETF (August 2005)
[7] Jung, H., et al.: Fast Handover for Hierarchical MIPv6 (F-HMIPv6), Internet Draft draft-jung-mobopts-fhmipv6-00.txt, IETF (October 2005)
[8] Kempf, J. (ed.): Goals for Network-Based Localized Mobility Management (NETLMM), RFC 4831, IETF (April 2007)
[9] Kempf, J. (ed.): Problem Statement for Network-Based Localized Mobility Management (NETLMM), RFC 4830, IETF (April 2007)
[10] Gundavelli, S. (ed.): Proxy Mobile IPv6, RFC 5213, IETF (August 2008)
[11] Rosenberg, J., et al.: Session Initiation Protocol, IETF, RFC 3261 (June 2002)
[12] IEEE Std 802.21-2008, IEEE Standard for Local and Metropolitan Area Networks—Media Independent Handover Services (January 2009)
[13] IEEE P1900.4 Working Group on Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks, `http://grouper.ieee.org/groups/scc41/4/index.htm`
[14] IEEE Std 1900.4-2009, IEEE Standard for Architectural Building Blocks Enabling Network-Device Distributed Decision Making for Optimized Radio Resource Usage in Heterogeneous Wireless Access Networks (February 2009)
[15] 3GPP TR 23.882, 3GPP System Architecture Evolution: Report on Technical Options and Conclusions (Release 8), v8.0.0, 3GPP (September 2008)
[16] ETSI TR 102 473, Digital Video Broadcasting (DVB); IP Datacast over DVB-H: Use Cases and Services, v1.1.1, ETSI (April 2006)
[17] ETSI TR 102 469, Digital Video Broadcasting (DVB); IP Datacast over DVB-H: Architecture, v1.1.1, ETSI (May 2006)
[18] Convergence of Internet and Broadcasting Systems, Special Issue. IEEE Network Magazine 21(2) (March/April 2007)
[19] Miloucheva, I., et al.: Seamless Handover For Unidirectional Broadcast Access Networks In Mobile IPv6. Journal of Communications 2(6) (November 2007)
[20] Stewart, R., et al.: Stream Control Transmission Protocol (SCTP) Dynamic Address Reconfiguration, RFC 5061, IETF (September 2007)