Comparative Analysis of IP-Based Mobility Protocols and Fast Handover Algorithms in IEEE 802.11 Based WLANs

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Abstract. A rapid growth of IP-based networks and services created the vast collection of resources and functionality available to users by means of an uniform method of access – an IP protocol. At the same time, advances in design of mobile electronic devices allowed them to reach utility level comparable to stationary, desktop computers, while still retaining their mobility advantage. Unfortunately, the base IP protocol does not perform very well in mobile environments, due to lack of handover support and higher layer mobility management mechanisms.
In this paper we present an overview of the most popular and promising methods of handling mobility in IPv4 and IPv6 networks, covering both ISO-OSI layer 2 low level handover mechanisms in IEEE 802.11 WLAN systems and ISO-OSI layer 3+ mobility solutions.

Keywords: IP networks, IEEE 802.11 based WLANs, handover, mobility
protocols, analysis, comparison.

1 Introduction

With rapid growth of information and communication technologies during the last decade, two dominant technology trends can be observed. The first one is the Internet – an easily accessible internetwork offering numerous services based on a single network protocol – the Internet Protocol (IP). As utilization of IP protocol results in obtaining the largest possible group of potential users, service developers and providers consistently do so. This trend, which can be called "All-IP" approach, results in a uniform way in which services are provided to remote users. The second one is mobility. A rapid development of universal mobile devices, able to offer their users functionality comparable to stationary desktop computers has inevitably led to their integration with the largest available source of services – the Internet and IP protocol. Unfortunately mobility in IP network brings a number of problems, which need to be solved, if IP-based services are to be offered to end-users with satisfactory quality. Mobile users need to communicate without interruption while moving across different access networks, which results not only in necessity to change points of physical network access (handover) but also in probable changes of users IP addresses. To allow a user to retain an uninterrupted access to services under such conditions, a two-tier solution is necessary: an universal, IP mobility mechanism which will counteract adverse effects of necessary IP address changes, and methods of efficient and seamless handover. To provide insight into current state-of-the-art in this area,
we would like to present a description of the most promising IP-based mobility solutions being developed and deployed, complete with an overview of advanced handover solutions designed for IEEE 802.11-based networks – the most popular wireless local area network (WLAN) technology today.

2 Handover

As the mobile user moves it becomes necessary for him to change his physical point of network access. Such change can result in variety of additional requirements for the mobile node to fulfill, starting from simple change of network identification information in transmitted data frames, through performing a complete or partial association procedure with new access point, to a complete access technology change and/or change of network level addressing information
(also resulting in different routing paths). The complication of handover related procedure strongly depends on the type of handover, as specified below.
New technologies and applications have a strong impact on the handover requirements. The first point is the need for enhanced address concept, as in both IPv4 and IPv6 technology IP address is used both as host identifier and location information. Possible solutions are to hide address location or to include

user location into addressing concept [1]. The second case enables support for not-symmetrical (upward and downward) vertical handovers in heterogeneous networks. Upward vertical handover is time-critical, because duration of small cell layer is time constrained. Heterogeneous network implies that mobile host is able to operate in any technology that is used in the network. Operation means forwarding services, support for Authentication, Authorization, and Accounting (AAA) services and quality of service (QoS) support.

Roaming and handover (or handoff) refer to different aspects of the mobility support [2]. Roaming is the network operator-based term involving formal agreements between operators that allows a mobile to get connectivity from a foreign network. Handover (handoff) refers to the process of mobile node moving from one point of attachment to the network to the other. The are several types of handover defined depending on which layers of communication stack are affected [1,3,4]:

– *Layer 2 handover* occurs when a mobile node changes access point connected to the same access router interface. This type of handover is transparent to the layer 3, although link layer reconfiguration can occur.

– *Intra-AR handover* changes access router (AR) network interface to the mobile host. In other words serving access router remains the same, but route change internal to AR takes place.

– *Intra-AN handover* takes place if the mobile node changes access routers inside the same access network (AN).

– *Inter-AN handover* occurs when a mobile node moves between two access networks. Host mobility between ANs is typically supported by external IP core. Host mobility can involve e.g. new IP address assignment.

– *Intra-technology handover* is a handover between equipment of the same technology.

– *Inter-technology handover* occurs between equipment of different technology. Note that this may involve mobile host network interface change (see vertical

handover).

– *Horizontal handover* is defined as a handover in which the mobile host's network interface does not change from the IP layer point of view. In this scenario mobile host communicates with the access router via the same network interface before and after the handover. A horizontal handover is typically an intra-technology handover.

– *Vertical handover* occurs if the mobile host's network interface to the access network changes. A vertical handover is typically an inter-technology handover. However, in the special case this can also be an intra-technology handover if the mobile host is equipped with several network interfaces of the same technology. When considering vertical handover in heterogeneous system, constructed from cells of different coverage, the *upward* and *downward*

vertical handovers can be defined. The upward handover is when MH moves from a access point at the lower hierarchical layer to the higher layer. The typical case can be leaving hot spot to GPRS network. The downward handover is from base station at a higher layer to the lower layer.

From the perspective of handover control the following categories can be distinguished:

– *Mobile-initiated vs. network-initiated handover.* In the first case the mobile host is the one who initiates the handover. In the latter, the network makes the initial decision to start it. For example, in IEEE 802.11 network the

Access Point is able to send disassociation message for network-initiated handover. On the other hand, the Mobile Station can initiate handover when leaving the coverage of Access Point.

– *Mobile-controlled vs. network-controlled handover.* In the first case the mobile host has the primary control over handover process. In the latter case the network takes over the control.

– *Mobile-assisted, network-assisted and unassisted handover.* In the first case the information and measurements from mobile node are used by the access router in handover decision. In the second case, the access network collects data that can be used by mobile host to execute handover. Unassisted handover is a handover where no assistance is provided by mobile host or access network to each other. However, it is possible that both AN and MH make measurement on their own and decide about handover.

– *Backward vs. forward handover.* Backward handover is the one initiated by Previous Access Router (PAR) or mobile host initiates the handover via PAR. The forward handover is the one initiated by or with support of the Next Access Router (NAR).

– *Proactive vs. reactive handover.* The proactive (i.e. expected) handover includes connection between PAR and NAR before the mobile host will connect with NAR. The reactive (also called unplanned) handover takes place if there is no signaling between ARs before mobile host moves to the new point of attachment.

– *Make-before-break vs. Break-before-make handover.* During MBB handover the mobile host can communicate with both PAR and NAR. Simultaneous communication is not possible in the BBM scenario.

– *Hard vs. soft handover.* A hard handover is when all radio links in the mobile host are disconnected before the new link (or links) is established. Soft handoff scenario assumes that there is always at least one link connection between MH and access network. Soft handoff can utilize e.g. macro diversity.

The performance aspects of handover are as follows:

– *Handover latency* (or delay) is a time difference between when a MN is last able to send and receive an IP packet by the way of PAR until MH is able to send and receive packet through NAR. During handover the Mobile Node is unable to send or receive packets both due to link switching delay and IP protocol operations.

– *Smooth handover* aims primarily to minimize packet loss with no concern about packet delay.

– *Fast handover* strives to minimize delay with no explicit interest in packet loss.

– *Seamless handover* is a one that does not introduce any change in service capability, security or capability. In practice, some service degradation is expected.

– *Lossless handover* is the one when no user data is lost during the procedure.

3 Layer 2 Handovers – Transitions between APs in IEEE
802.11 Standard – Based WLANs

The IEEE 802.11 standard was initially published in 1997 [5] by Institute of Electrical and Electronics Engineers (IEEE). The standard has been prepared as a wireless extension of existing IEEE 802.3/Ethernet standards. Many amendments were merged into the standard since, resulting in its current, vastly extended version, named IEEE 802.11-2007 [6]. The most recent additions seem to concentrate on providing support for creating complex network systems (both homogenous and heterogeneous). Handover mechanisms, as an important element of such systems' functionality, are also being rapidly developed – layer 2 handover support procedures were described in IEEE 802.11f amendment [7].

The document introduced a way of exchanging information about Mobile Stations between Access Points. However, the extension did not gather the expected popularity and had been withdrawn. When the mobile station moves between Infrastructure BSSs it will reassociate with AP in the new BSS, i.e. perform Layer 2 handover. To facilitate seamless handover the neighbour APs are configured to operate on different channels to overlap the coverage. The station first scans all physical channels by switching radio frequency for APs in vicinity. In the next steps the station executes 802.11 authentication and association with Access Point. The mobile station may also execute 802.1X authentication on the top of the 802.11 association. In case when the access points are under consolidated management there is a number of mechanisms designed to facilitate the handover process and help mobile client to make a seamless transition. Apart from a number of proprietary solutions (most often based on dedicated wireless network controllers) introduced by hardware developers, there is a widely recognized IEEE 802.11r standard amendment [8].

IEEE 802.11r-2008 [8] is an amendment to the IEEE 802.11-2007 standard that introduces Fast Basic Service Set Transition. The handover has already been supported under the base 802.11-1999 standard and four messages were required to connect to the new AP in the typical case. However, as the standard is extended, the number of necessary messages went up dramatically. In this situation IEEE 802.11r-2008 amendment proposes algorithms to bring the number of messages required for handover down to the level of 802.11-1999. This is expected to be achieved by limiting the number of messages in 802.1X authentication and 802.11e admission control procedures. Introduction of Fast BSS Transitions (FT) allows Mobile Station (MS) to fully authenticate only with the first AP in the FT Domain and use shorter association procedure with the next APs in the network. The amendment defines the FT Domain as the group of APs that support FT Protocol and are connected over a Distribution System (DS). The MS session i.e. security and QoS information is cached by the network. When the station associates with the first AP in the FT Domain it is now pre-authenticated with other

APs in the domain. The first AP the station authenticates to, will cache its Pairwise Master Key (PMK – the starting point of key hierarchy) and use it to derive session keys for other APs. The first AP is named R0 Key Holder (R0KH) as it holds level 0 PMK (PMK-R0). When MS reassociates to the next AP in the domain, R0KH generates PMK-R1 and forwards that to the next AP, which is called R1KH. The R1KH interacts with the R0KH, rather than directly with AAA server. Next, when the MS requests R1KH to prepare reassociation with consecutive AP, R1KH communicates with the R0KH. R0KH generates PMK-R1 and forwards that to the consecutive AP.

The amendment defines two methods of FT: over-the-air and over-the-DS. In the first case MS communicates over a direct 802.11 link to the new AP. In the over-the-DS method the MS communicates with the new AP via the old AP.

In the Over-the-air FT protocol the Mobile Station is already associated with the old AP from the domain. At some point MS decides to reassociate with nAP sending 802.11 Authentication frame with Information Elements required by FT Protocol. The new AP responds with 802.11 Authentication frame that contains the same types of Information Elements as request. In the next step MS sends 802.11 Association Request message with FT information elements.
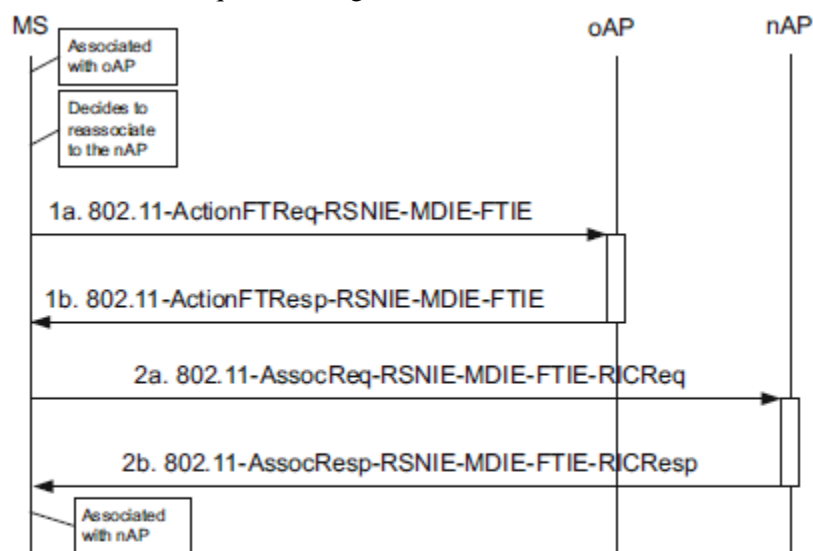

Fig. 1. Over-the-DS FT Protocol

Access Point responds with 802.11 Association Response message that also convey FT information elements.

Figure 1 presents Over-the-DS FT protocol version. The MS uses Action frame to communicate with the current (old) AP, providing the address of the new AP. Old AP communicates over the DS with new AP forwarding STA request. The new AP responds over DS and oAP sends Action FT Response to MS. At this step MS is authenticated with nAP. Then, MS switches the channel and begins association procedure with nAP. The type and content of information elements is the same using both methods: over-the-air and over-the-DS. The IEEE 802.11r-2008 handover performance is discussed in [9,10]. The handover with FT algorithm is much faster comparing to the legacy mode, simply because 802.1X Authentication phase can be substantially shortened.

4 IP Mobility Protocols

Apart from low-layer handover procedures regarding fast and seamless change of physical point of network attachment, a number of issues concerning IP protocol operation must also be addressed. The exact mechanisms required depend on a specific mobility type [11] – for example terminal mobility is the ability for a user terminal to access the network when the terminal moves. Another type of mobility

– user mobility – is the ability for a user to access the network under the same identity when the user changes location and often includes the ability to access the network from the different terminals under

the same identity. Service mobility is the ability for a user to access the service regardless of user location. All of these mobility types bring different challenges and require specialized solutions.

Mobile IP introduced the concept to decouple the host and network identifiers that had been fundamental in traditional IP addressing. With the introduction of two addresses Mobile IP solved the problem of delivering IP datagrams to the mobile host that moves between networks. The base concept was later

improved in multiple fields like routing optimization, handover efficiency and deployment cost. Classical MIPv4 solution contains a significant disadvantage in form of triangle routing – the data from Corresponding Node is delivered to Home Agent in MH's home network, which in turn delivers it to MH's current IP address. The Route optimization extension [12] was proposed to overcome that problem. In case of MIPv6, an extension of registration procedures allows MH to inform its corresponding nodes of its current IP address – such knowledge then permits them to transmit data directly to MH's current address, without retransmission by Home Agent. The handover efficiency oriented algorithms concentrates on optimization of data paths, which reduces transmission latency, packet loss during handover and consumption of network resources. Because of often encountered in IP systems division of network into hierarchical domains, the mobility can be divided into two broad types: inter-domain mobility and intra-domain mobility. Such an approach opens the possibility of performance optimizations. A domain is defined as a large wireless network under a single authority. Inter-domain mobility (also called macro-mobility – Fig. 2) is related to a movement from one domain to another. Such mobility most often results in complex handover procedures including full low-layer handover, full authentication, new IP address acquisition and verification, mobile node registration and

radical data path change. On the other hand intra-domain mobility (also called micro mobility – Fig. 2) refers to user's movement within a particular domain.

In this case many of the necessary handover procedures can be simplified – for example: fast reassociation in place of full association/authentication procedure and no IP address change. Mobile IP stays the most popular solution for macromobility support. It is not considered as the efficient solutions but provides the required mobility support for the infrequent movements between domains. The number of solutions strives to provide low latency handovers for micro-mobility (e.g. Cellular IP, HAWAII and TIMIP). Similarly Hierarchical Mobile IP [13,14]
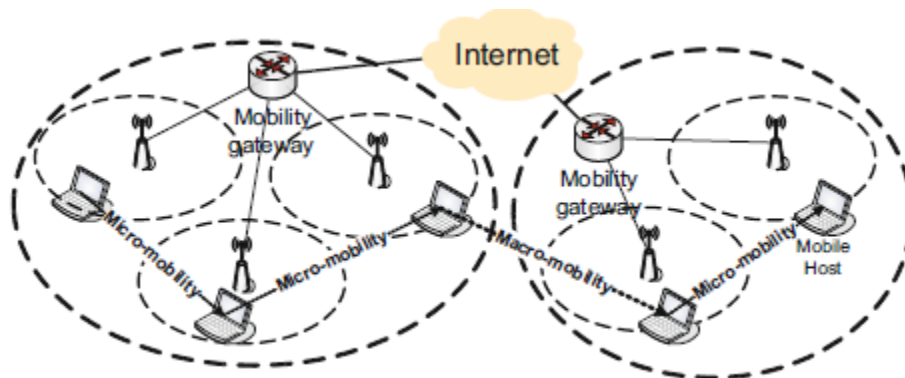
Fig. 2. Micro and macro-mobility

introduces regional mobility agent called Gateway Foreign Agent that facilitate local mobility. The different approach to decrease the handover delay is usage of link layer triggers. The Mobile IP extensions, named fast handovers [15] or low latency handovers [16], aim at forecasting handover and preparing the transition to the new Access Router (AR) before the connection to the old AR is lost. The

deployment of Mobile IP requires both network architecture changes as well as changes in the mobile host protocol stack. Even though the solution is on the IETF standardization track for a long time the protocol implementations are still not widely available. For those reasons the alternative solutions are proposed.

The first concept assumes that mobility can be handled completely inside the network. Thanks to that no changes are required to the current mobile hosts. Proxy Mobile IPv6 extends that concepts. The second group of protocols utilizes NAT concept that is already widely used in the IP network. The authors argue that NAT-based solution is easier to deploy with the compromise to the functionality. For example Reverse Address Translation (RAT) [17] is the macromobility approach based on NAT that supports only UDP traffic. On the other side Mobile NAT [18] provides both micro- and macro-mobility support and can be deployed as the Mobile IP replacement. New trend in mobility support utilizes effective cross-layer mechanisms combining low-layer (ISO-OSI layer 2) and network-layer handovers. The example algorithm – Simultaneous Handovers IEEE 802.11r for Mobile IPv6 – is described in details. The IEEE 802.21 standard will include a universal architecture that provides service continuity while a MH switches between heterogeneous link-layer technologies. The standard will also provide mechanisms for the intra-layer communication that is required for certain groups of handover algorithms. The IEEE 802.21 standard introduces Media Independent Handover (MIH) Function that is considered a shim layer in the network stack of both network node and the network elements that provide

mobility support [19]. MIH Function provides abstracted services to the upper layers. There also exists a number of application level mobility solutions. They trend to perform well within bounds of their utility, which is limited to a single application or application-layer protocol. A good example of such approach is a Session Initiation Protocol (SIP) [20] and Extended SIP Mobility [21]. This protocol allows two or more participants to manage a session consisting of different media stream types and uses Uniform Resource Identifiers (URI) in place of IP addresses and provide a decent level of mobility support. The following section reviews the most popular IP mobility protocols. The summary is presented in Table 1.

Table 1. Comparison of IP mobility protocols

Protocol	Mobility Type	Handover Type	Link Detection	Registration	Address Translation
Mobile IPv6 (basic)	Macro	Hard	Router adv.	At Home Agent	Encap.
Hierarchical Mobile IPv6	Universal	Hard	Router adv.	At Mobility Anchor	Encap.
Proxy Mobile IPv6	Universal (net-based)	Hard	Events or DNAv6	At Mobile Access Gateway	Encap.
Fast Handovers	Universal	Hard	Proxy Router adv.	At Home Agent	Encap.
Cellular IP	Micro	Semi-soft / Hard	Network specific	Route Updates	No
HAWAII	Micro	Forward.&non-fw. schemes	Network specific	Path Updates	No
RAT	Macro	Hard (no TCP sup.)	Network specific	At reg. server	NAT
MobileNAT	Universal	Hard	Using DHCP ext.	At Home NAT	NA(P)T
Extended SIP	Macro	Hard (no TCP sup.)	Network specific	At SIP router	via SIP server

4.1 Mobile IP

The IETF Mobile IP [22,23] is an oldest and the most widely known approach for mobility support in IP networks. There are two versions of the algorithm, namely for IPv4 and IPv6 protocols. Both solution are on standard track run by IETF organization. Mobile IP offers mobility support in the network layer and isolates higher layers from mobility. The key idea introduced in Mobile IP is the usage of a couple of addresses to manage user movement. Mobile host owns its own IP address which can be referred as traditional IP address. Mobile IP introduces a term of home address for such an address. Each time the mobile host connects to the network, the temporary IP address for the current network is obtained. The host stays reachable by the way of both home and temporary addresses. For

Mobile IP the temporary IP address is named Care-of Address (CoA). A correspondent host addresses datagrams destined to the mobile host using its IP home address and the datagram is tunneled via Mobile IP infrastructure to

the mobile node current location. Mobile IPv6 extends IP infrastructure by the concept of Home Agent (HA). HA is located in the home network, which is defined as the network that mobile IP address belongs to. In the Mobile IPv6 the MH is able to create its own CoA using its link-local address and automatic address configuration (i.e. merge subnet prefix with own hardware address).

Mobile IPv4 adds also Foreign Agents (FA) that are located in any network that can be visited by the mobile host and facilitates CoA generation. Mobile IPv6 Access Routers sends periodically Agent Advertisement message (an extension of ICMP Router Discovery message [24]) with fields for mobility support. Mobile Host can solicit Agent Advertisement by sending Agent Solicitation message.

The IPv6 handover example is presented in Fig. 3 When a mobile host leaves its home IP network it detects foreign networks based on Router Advertisement messages that can be solicited. To begin data transmission mobile host updates bindings with Home Agent and corresponding nodes if any. From the perspective of the correspondent host, the mobile host is identified by its home address.
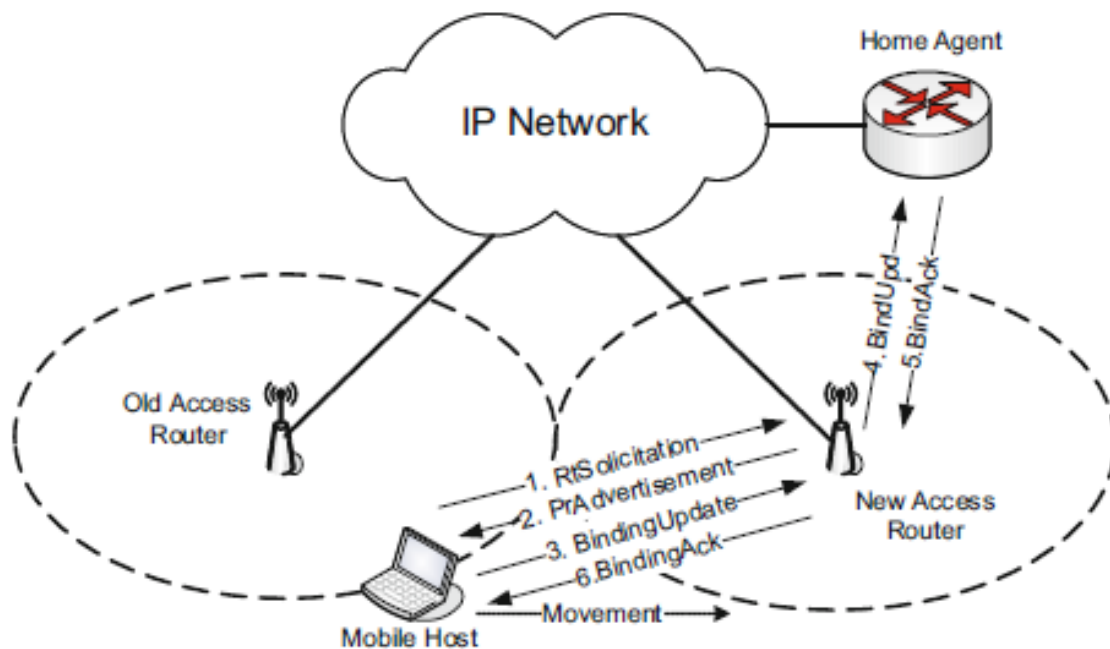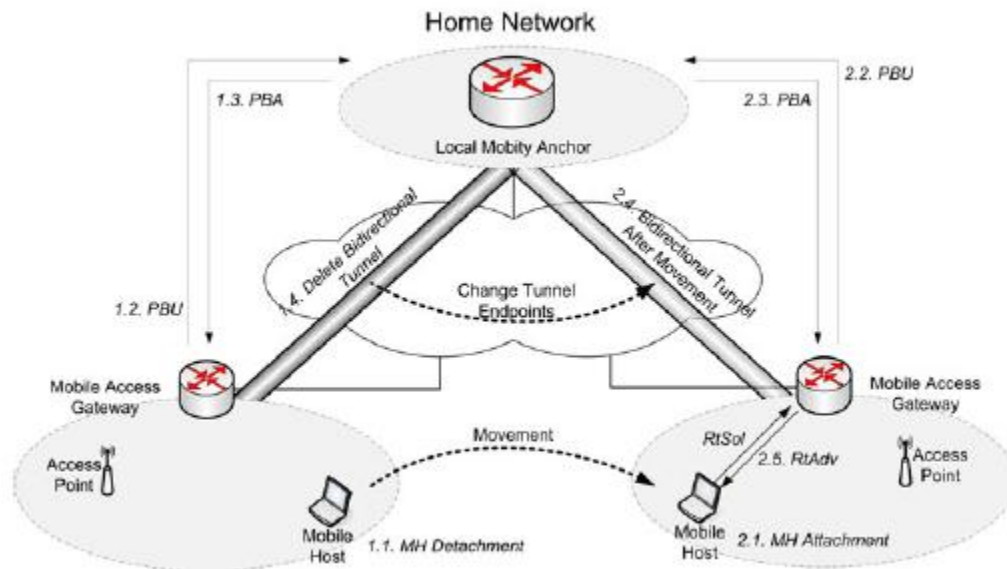

Fig. 3. Mobile IPv6 handover

When the packets are sent to the mobile host, HA intercept packet based on home address of mobile between home address of the host and its current Care-of address. The datagram is tunneled from HA to a mobile host.

4.2 Proxy Mobile IP

As opposed to Mobile IPv4 and Mobile IPv6 which are host-based mobility standards, Proxy Mobile IPv6 (PMIPv6) [25] presents a network-based approach, which lacks any kind of client-side mobility agent. Such solution brings numerous advantages, such as simplified management, ability to support legacy clients and better efficiency of radio-link utilization. PMIPv6 extends and reuses a proven MIPv6 idea, however it does not require any modification of a standard mobile node's IPv6 stack. A network-side proxy mobility agent in used in place of MIP client-side agent, and performs signaling and management on behalf of the mobile host. As a result PMIPv6 provides efficient solution without tunneling and signaling overhead on radio access link. Nevertheless Proxy Mobile IPv6 cannot be deployed as a standalone global mobility system, due to lack of standardized macro-mobility procedures and mechanisms.

Proxy Mobile IPv6 (as defined in [26]) uses two specialized network elements: Media Access Gateways and Local Mobility Anchors (Fig. 4). Media Access Gateway (MAG) is responsible for tracking the MH movements, creating bidirectional tunnel to Local Mobility Anchor and managing connectivity between MH and LMA. Local Mobility Anchor (LMA) is similar to HA in Mobile IPv6. It is responsible for maintaining routes and forwarding information for all MHs in domain.

Fig. 4. Proxy Mobile IPv6 Domain

4.3 Routing Path Optimizations

The triangle routing problem was addressed by route optimization extension [12]. It adds binding update to inform the corresponding node on the current CoA. When the handover occurs the old FA communicates with the HA using binding warning. Thanks to the HA can update binding in the corresponding node. The drawbacks of the solution are the new requirements on the CN – ability to encapsulate IP packets and store CoA. Moreover, route optimization increases the signaling overhead. The extension proposed in [27] adds link and signaling cost functions to capture the trade-off between the signaling cost and processing load. The alternative approach presents DHARMA [28] that uses overlay network to select location-optimized mobility agent from the distributed set of home agents to minimize routing overheads.

4.4 Handover Performance Optimizations

The generic Mobile IP protocol does not differentiate between local and global handovers. In consequence the amount of signaling is large, especially if HA is distant from the mobile host. Moreover, MIP applies the same scheme for horizontal and vertical handovers which makes performance optimizations difficult. For those reasons micro- and macro-mobility concepts were introduced. In case of micro-mobility, MH moving inside an area called mobility domain does not need to perform all the procedures described for macro-mobility scenario when change of physical network access point becomes necessary. It is sufficient to employ much simpler signaling with local mobility support entities, which is enough to provide correct data routing to MH's public address within a given mobility domain. This approach allows reducing handover time significantly. For example Cellular IP [29] adds the micro-mobility support to the MIPv4. It also addresses a problem of MIPv4 scalability by adding local caches to support slow moving and sleeping nodes. Handoff Aware Wireless Access Internet Infrastructure (HAWAII) [30] is another micro-mobility support extension to MIPv4 that optimizes both handoff latency and data paths, by including cross-layer triggers and improved IP QoS maintenance. Another concept is used in fast handovers [15,16]. Such solutions are typically applied for intra-technology handovers and are tightly coupled with link layer protocols. Those protocols utilize the physical triggers from lower layers, like "Link Going Down" or "Link Down" to speed up the handover. The simultaneous handover discussed later is the next step to

improve the handover performance. Based on the fast handovers concept, the link later and IP layers handovers are executed in parallel.

4.5 Deployment Cost Optimizations

Several alternative IP mobility protocols were introduced that address deployment issues related to the Mobile IP. Reverse Address Translation (RAT) [17] is the macro-mobility approach competitive to the Mobile IP, based on NAT procedure. It advertises easier deployment over MIP by the cost of limited functionality (e.g. no TCP session support). Mobile NAT [18] provides both micro and macro-mobility support and can be deployed as the Mobile IP replacement.

Contrary to the Mobile IP the solution is based on NAT instead of tunneling. Proxy Mobile IP also falls into that category, as it addresses the problem of MIP implementations availability for the mobile hosts. Basic characteristics of described protocols is described in the Table 1.

5 Simultaneous Handover IEEE 802.11r for Mobile IPv6

As the need to perform both low-layer IEEE 802.11 and IP-layer handover is a common occurrence, an algorithm has been proposed which allows Mobile IPv6 procedures to be executed in parallel with IEEE 802.11 procedures (Fig. 5).
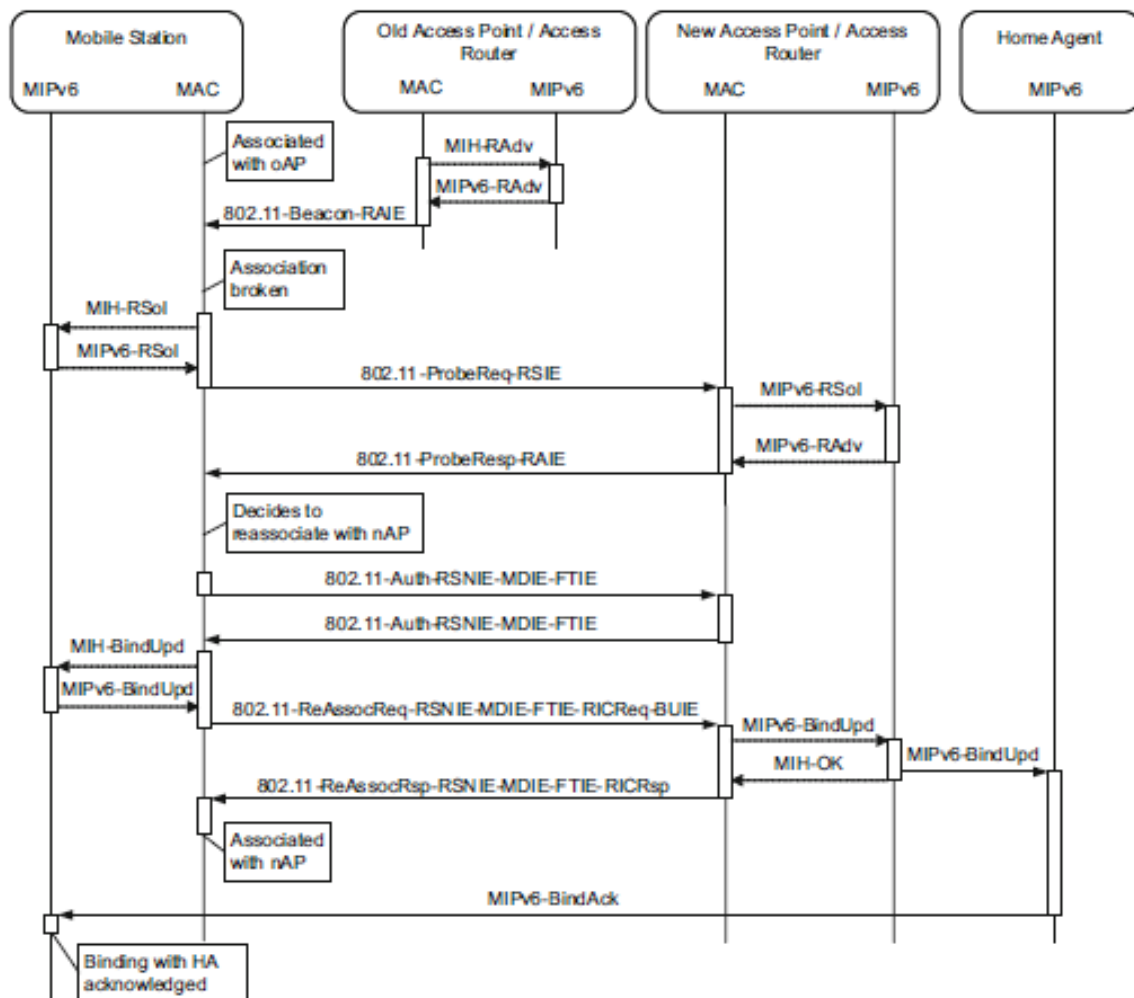

Fig. 5. Simultaneous handover IEEE 802.11r for Mobile IPv6

The algorithm shortens handover time as MIPv6 detection phase is minimized. MIPv6 handover starts as soon as 802.11 layer detects the new link and some 802.11 and MIPv6 procedures are executed simultaneously, which can decrease the handover delay up to 38% [31]. To achieve that, selected Mobile IPv6 frame formats are conveyed as IEEE 802.11 information elements and 802.11 Access

Point is coupled with MIPv6 Access Router in a single device. MIPv6 Router Advertisement (RA) unsolicited messages are distributed within RAIE together with 802.11 Beacon messages. When executing active scanning MS can requestMIPv6 RA by sending MIPv6 Router Solicitation together with 802.11 Probe Request. The Access Point / Access Router that supports simultaneous handover have to respond with 802.11 Probe Response that includes MIPv6 Router Advertisement. The RA is always known to the Mobile Station when either active or passive scanning method is used. When building Reassociation Request message the Mobile Station will sent MIH Binding Update event that is routed to the MIPv6 protocol instance. In response, MIPv6 will send Mipv6 Binding Update message destined to the Home Agent. The MIPv6 Binding Update message is intercepted by 802.11 protocol layer and compressed into BUIE. BUIE is sent together with Reassociation Request message. When received at the New Access Point BUIE is extracted to MIPv6 Binding Update and passed to the collocated Access Router. AR confirms message reception with MIH OK event. When event is received at MAC layer, it responds with Reassociation Response message. New Access Router sends Binding Update to the Home Agent. The Home Agent responds with MIPv6 Binding Acknowledge. This concludes the handover process.

6 Conclusions

The paper introduces the handover taxonomy and describes possible implementation of the procedure. In the next steps authors perform the analysis of the mobility support protocols at the different layers of the network protocol stack.

Fast transitions for 802.11 that were standardized by the "r" working group is explained in details. IP Mobility Protocols section gives the overview of the protocols that can provide better handover efficiency (in terms of both handoff latency and data path optimization) over the Mobile IP. The simultaneous handover methods are also presented as example of cross-layer approach to optimization of handover latency.

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