Seamless Handover and QoS mechanisms for efficient DVB-H and Mobile IPv6 integration

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Abstract- *Seamless handover and QoS provision of applications in converged DVB-H and Mobile IPv6 networks are discussed. The goal is to support efficiently interactive mobile broadcast/multicast services using unidirectional broadcast media (DVB-H) combined with bidirectional mobile access technologies (UMTS, WLAN, WIMAX) in heterogeneous Mobile IPv6 environments. In particular, the focus is:*

- Handover strategies based on usage of Link Layer Tunneling Mechanisms (IETF RFC 3077) for emulation of bidirectional connectivity of DVB-H access networks in heterogeneous Mobile IP environment;

- Network discovery and handover optimization for DVB-H access networks considering IEEE 802.21;

- QoS mechanisms of interactive multicast streaming and download services using DVB-H access networks.

Keywords*: DVB-H, IPDatacast, seamless handover, QoS, Mobile IPv6, IEEE 802.21, Link Layer Tunneling, unidirectional connectivity, return channel*

I. Introduction

Digital Video Broadcasting-Handheld (DVB-H) [1] is a one-way transmission technology able to provide cost efficient and high speed transport of multicast/broadcast traffic to mobile receivers including scenarios for mobile television, streaming distribution, mobile content delivery, carousels and reliable file downloads.

Recent standardization efforts focused on multimedia services and applications, such as IPDatacast [2] and DIMS [3], describe services and applications for converged DVB-H and Mobile IP environments. Deployment of multicast / broadcast applications with interactive channels and asymmetric traffic on combined DVB-H and mobile IPv6 infrastructures requires efficient solutions for:

- Provision of “interactivity” path for the applications;
- Seamless handover considering Mobile IPv6 and DVB-H network facilities,
- Mechanisms for mapping of QoS requirements of Mobile IPv6 applications to the DVB-H QoS provisioning mechanisms.

The goal of this paper is to discuss handover and QoS mechanisms at network and data link layer for efficient provisioning of interactive multicast services using DVB-H technology combined with bidirectional access networks (such as UMTS, WIMAX and WLAN) in heterogeneous mobile IPv6 environments. Enhancement of DVB-H with MAC layer based on the Link Layer Tunneling Mechanisms (LLTM) (see, IETF RFC 3077 [9]) and LLTM interaction with Mobile IPv6 for bidirectional connectivity are described. Further topics are QoS mechanisms for resource reservation in integrated Mobile IPv6 and DVB-H environment, as well as technologies for network discovery and handover optimization considering IEEE 802.21 [8].

This paper is organized as follows. In section 2, convergence of DVB-H and Mobile IP environments are discussed. In section 3, IPDatacast and further applications and services for DVB-H are overviewed. Section 4 is focused on the seamless handover of interactive applications using DVB-H networks in the Mobile IPv6 environment. In section 5, handover issues on data link layer and intelligent handover support using IEEE 802.21 are discussed. Section 6 describes QoS provisioning mechanisms on different layers for integrated DVB-H and Mobile IPv6 networks. Section 7 concludes this paper.

II. Integrated DVB-H and mobile IPv6 infrastructure

Unidirectional broadcast technologies for video and audio distribution, such as DVB-H, MediaFLO, T-DMB, can be integrated as access networks in heterogeneous mobile Internet environment to provide services for mobile TV, streaming and multimedia

Manuscript received January 2007, revised January 2007

content delivery, as well as reliable downloads to groups of receivers. Unidirectional networks are based on one-way transfer and require additional bidirectional network to support interactivity channels. The benefits of the unidirectional broadcast cells, such as large coverage area, support of huge amount of subscribers and great number of active users per cell, make these technologies especially attractive for integration in heterogeneous mobile IP environment.

DVB-H (Digital Video Broadcasting - Handheld) is an open European (ETSI) standard for bringing broadcast services to handheld devices [1]. DVB-H is specified based on DVB-T (Digital Video Broadcasting – Terrestrial) and is currently widely used to bring mobile TV and content delivery to the mobile phones [11]. Similar broadcast technologies for provision of mobile multicast/broadcast services are MediaFLO [12], which is Qualcom proprietary technology commercially available in USA and T-DMB recently standardized by ETSI [13].

The Mobile IP (layer 3) network services (IPv6 flows) are mapped to DVB-H MPEG-2 Transport Streams (TS) on data link layer using MPE (Multi Protocol Encapsulation) and Forward Error Correction (FEC) [49]. To organise the IP services on the DVB-H stream multiplex and access them, functions for Service Information (SI) and Program Specific Information (PSI) are used. The IPv6 address mapping into TS identification is specified by the INT (IP/MAC Notification) table.

Network Layer	IP flow	
	MPE	SI/PSI
Data Link Layer	MPEG-2 Transport Streams	
Physical Layer	DVB-H	

Fig.1. Mapping of IPv6 flows to DVB-H

In integrated DVB-H and mobile IPv6 networks, multicast/broadcast IPv6 flows (streaming video and audio, file downloads, carousel) with different QoS and traffic characteristics are mapped to the DVB-H streams. The streams containing the IP multicast flows are distributed to the IP/DVB-H encapsulators, which output the DVB-H transport streams with time slicing and MPE-FEC facilities. These streams are then transferred by the DVB-T/H transmitters.

Because the DVB-H network is unidirectional, only one-way IP flows and network QoS requirements can be directly mapped to the DVB-H networks.

Integration of DVB-H networks in Mobile IP context depends on the requirements of applications for interactivity, handover scenarios and mobility patterns (frequencies of handoffs).

In order to provide interactive services, the integration of the unidirectional broadcast access networks (DVB-H) requires additional mechanisms for emulation of the bidirectional connectivity at a MAC sublayer using complementary wireless bidirectional network.

This paper considers the QoS based mobile architecture of the EU IST project DAIDALOS [10] for heterogeneous mobile IP6 environment consisting of unidirectional access networks (DVB-H) and bidirectional wireless technologies (UMTS, WLAN, WIMAX). Access routes are included in the architecture to connect mobile users using multiple network interfaces to IPv6 core. In order to support seamless handover for mobile services using heterogeneous access networks different technologies have been deployed in the DAIDALOS context, such as:

- Candidate access router discovery and optimization of next access network selection using CARD [15];
- Context Transfer applied for transfer of states (control data) between access routers related to the mobile node's services [14];
- Resource reservation, QoS mapping and adaptation for seamless service continuation using the heterogeneous access network environment [17].

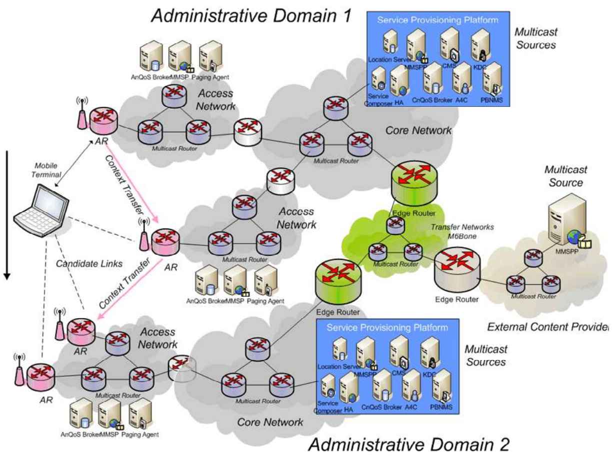

Fig. 2. Mobile IPv6 architecture using access routers for integration of heterogeneous access networks

One of the focuses of the DAIDALOS architecture is the integration of mobility-enabled broadcast (DVB-H) in advanced network infrastructures and access technologies. To support these technologies, operators need to rely on unified interfaces, integrating heterogeneous technologies, and considering furthermore the multicast/broadcast services.

The project envisions a seamless vertical handover between broadcast networks made of DVB-H cells and telecommunications networks providing multicast / broadcast content in WLAN hotspots or UMTS cells enhanced with MBMS capability [5].

The focus covers also cross-layer interactive mobile multicast services involving access routers for on-demand streaming and reliable multicast distribution to mobile receivers using context transfer [22].

A typical DAIDALOS scenario involves a family travelling by car, with passengers watching a movie from their broadcast access network (DVB-H). When the car crosses the country border, the program is no longer available through this network, so the car terminal triggers a vertical handover and the multimedia content is seamlessly transferred to another access network, as for instance the local cellular network [5]. The access network topology has an impact on the performance (handover delay and packet loss) and has to be selected considering the application and mobility requirements [19]. For more flexible mobile service and movement pattern support, in the second stage of the DAIDALOS project, mobility technologies including IEEE 802.21 Media Independent Handover [8] and Network-Based Localized Mobility Management ([21]) are focus of research. The user environment is also an important factor for the handover decision. In particular, for integration of DVB-H in mobile infrastructure, following goals can be taken into consideration:

- Support for interactive services based on emulation of bidirectional connectivity (RFC 3077 [9]);
- Reducing of control overhead and improvement of handover performance for mobile applications with frequent handoffs using micro-mobility protocols [20], such as Cellular IP, Hawaii, and Hierarchical Mobile IP.
- Cost efficient solutions for mobile applications and users with multiple network access technologies.
- Decoupling the intelligent interface selection from the specificities of each access technology by introducing an Abstraction Layer framework, which provides a generic interface to the upper layer modules [4];
- Optimizing the handover decision by mapping the signal quality measured in each technology into a generic and unified quality level supplied through the abstract interface [4].

III. Interactive Mobile Services for DVB-H Access Networks

Mobile multicast/broadcast services for converged DVB-H and Mobile IPv6 networks are aimed to provide video and audio streaming, multimedia content delivery, carousel and reliable file downloads to multiple mobile receivers with mobile phones, pocket TV's, portable radios and other mobile terminal devices. Such services are used in scenarios for the entertainment industry (life broadcast TV, voting, browsing, audio), broadcast distribution for weather, travel and financial news, as well as web file delivery, business with e-mail, e-commerce and logistics integrated in mobile devices. Multicast services using DVB-H in mobile IP environment require bidirectional connectivity (interactivity channel) for different reasons, such as:

- IP Mobility protocols, such as Mobile IPv6 [33] and Fast Handovers [34] require bidirectional connectivity for address configuration;
- IP network layer protocols, such as PIM-SM and DVMRP for routing and MLDv2 for multicast group management, are operating based on bidirectional link layer connectivity.

A particular focus of the paper are technologies for handover and QoS support of interactive mobile multicast / broadcast services in heterogeneous mobile IPv6 environment using DVB-H.

The deployment of interactive services requires appropriate interactivity channels, mobility and QoS support. With an interactive channel, viewers can request specific information for city or region, weather forecasts, film and multimedia guides.

One-way interaction is based on the identification (request for delivery) followed by the delivery of the service. Two-way interactive service can be based on:

- Multicast/broadcast service distribution;
- Interaction to request a specific information;
- Interaction to deliver the requested information to the mobile node.

The ETSI standardization of the mobile IP services using DVB-H networks is based on the IPDataCast (IPDC) platform. The IPDatacast is focused on streaming and file download IP services using DVB-H [23]. IPDC is designed on the "push" service concept. The service offer can be obtained from the Electronic Service Guide (ESG) [24]. IPDatacast describes content delivery services and protocols [48] for different media, such as streaming audio and video and file distribution. QoS requirements for multicast/broadcast services and content delivery are specified for business scenarios and use cases [50]. IPDatacast involves an additional network to allow IP based protocols and services requiring interactive channels. For instance, the TCP traffic, which is based on acknowledgement and retransmission mechanisms, is provided on the additional data link network allowing interactivity.

The service and protocol stack of IPDatacast architecture [2] is shown in figure 3.

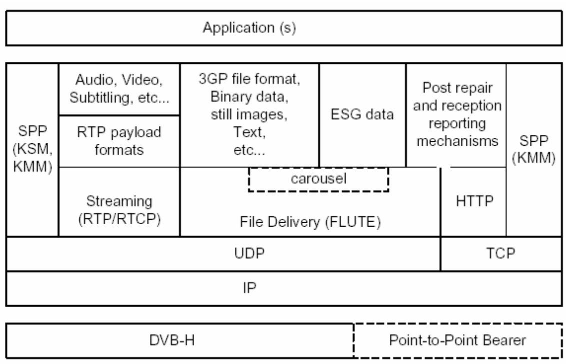

Fig. 3. IPDataCast service and protocol stack

Convergence and interoperability for support of rich media services using constrained devices and combined unidirectional broadcast (DVB-H) and mobile 3G (UMTS) networks is considered in a 3GPP Dynamic Interactive Multimedia Scenes (DIMS) proposal [3].

Service interactivity can be achieved based on cooperation between broadcast and mobile telecommunication platforms [27]. Broadcast Network Operators provide the broadcast network that carries the mobile broadcast services and the mobile operators supply the mobile network required for the return (interactivity) channel. The planning of combination of the unidirectional broadcast technology with the wireless interaction network technology depends on:

- Capabilities of broadcast and wireless return networks and how they can provide the QoS required by the application and user;
- QoS agreements between the broadcast and mobile operator as well as content providers;
- Network interfaces available at the mobile terminal;
- QoS characteristics of applications (QoS parameters required for the downstream and return channel);
- User QoS requirements, profiles and preferences.

Business models for combined broadcast and mobile networks for provision of interactive multimedia multicast services in Mobile IP environments include service management and resource provisioning functions optimizing the usage of the DVB-T resources for different kind of applications.

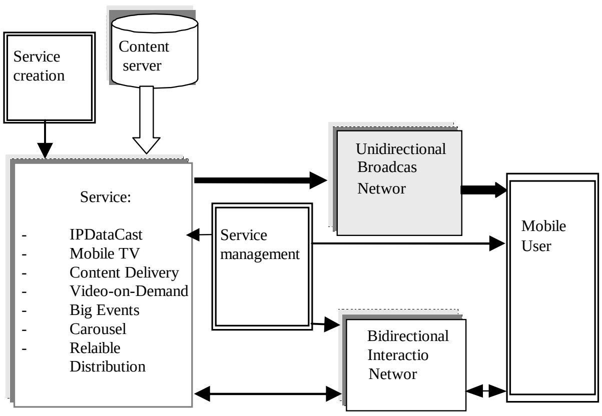

Fig.4. Business model for interactive broadcast services

Multicast/ broadcast application and services for converged broadcast (DVB-H) and mobile IP environment are deployed for different scenarios:

- Multimedia streaming involving central broadcast points and cell main nodes for transmission and stream regeneration using DVB-T/WLAN access networks [26].
- Media streaming and mobile TV scenarios allowing sharing of home experience for big events, such as Olympic Games [28].
- Social Mobile TV – a service using DVB-H broadcast services in combination with point-to-point interaction for interactive mobile TV [29].
- Reliable emergency multicast considering groups of mobile users connected to unidirectional broadcast networks [31]. Examples are alerts to mobile devices, such as earthquake and tsunami info.

IV. Handover for interactive services using DVB-H

IV.A. Link Layer Tunneling for interactive services

To provide bidirectional connectivity of IP hosts with unidirectional network interfaces, the Link Layer Tunnelling Mechanisms (LLTM) (RFC 3077 [9]) protocol defined by IETF Unidirectional Link Routing (UDLR) Working Group, s used.

LLTM supports emulation of bidirectional connectivity at MAC sub-layer, which is a mediation layer between data link (L2) and network layer (L3) [32]. LLTM configures dynamically IP tunnels from receivers to end-points at the sender, called “feeds”.

The Dynamic Tunnel Configuration Protocol (DTCP) is used to provide information about the “feeds” to the receivers. The new feeds are announced by “Hello” message of DTCP protocol, based on which the receiver must create a tunnel to enable bidirectional communication. When the unidirectional link is down or when a “feed” is down, the receivers must disable their tunnels. For the IP tunnelling, the Generic Routing Encapsulation (RFC 2784 [35]) can be used. The basic interactions are illustrated in the following figure:

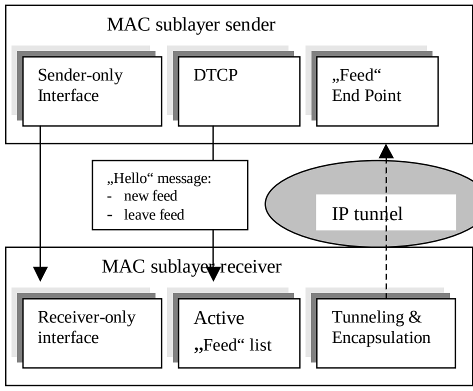

Fig.5. Basic interactions for tunnel establishment

LLTM technology was basically used to support IP multicast and content delivery services on unidirectional links in satellites and fixed IP platforms. For example integration of unidirectional links was performed based on IGMP [36], DVMRP [37] and PIM-SM multicast routing [38], as well as integration of LLTM in satellite environment for large scale distribution [39].

Usage of LLTM for integration of unidirectional links in mobile IP infrastructures is reported in a few studies and experiments. In [6], a tunnelling approach for routing in Mobile Ad Hoc Networks using unidirectional links is analyzed, focusing on performance parameters of the tunnelling mechanisms, such as window and timers. In the Cisco/Boeing effort on global mobile router mobility, the tunnelling facilities are used to provide roaming capability in unidirectional satellite IP infrastructures [40].

IV.B. Using LLTM for unidirectional access networks in Mobile IP

In the mobile QoS architecture of DAIDALOS project, LLTM is used for integration of unidirectional broadcast networks in heterogeneous Mobile IPv6 environment aimed to support interactive mobile multicast/broadcast services.

IV.B.1. LLTM model based on Mobile IP

In heterogeneous mobile IP access environment involving mobile receivers with unidirectional link interfaces (such as DVB-H networks), the LLTM is used to support the bidirectional connectivity between mobile terminal with "receive only" capability and access routers providing the connectivity to IP Core.

In the LLTM network model (fig.6), the access router (AR) connecting (downstream) the unidirectional network to the IP Core is called a "feed"-AR. This AR provides IP tunnel end-points ("feeds") for the emulation of the return channel from the mobile node. The return channel is built between the mobile receiver and the "feed"-AR using additional bidirectional wireless access network (called "interaction" or "return" access network), "return" – AR and IP tunnel.

A network model describing the bidirectional tunnelling in mobile IP using LLTM is given:

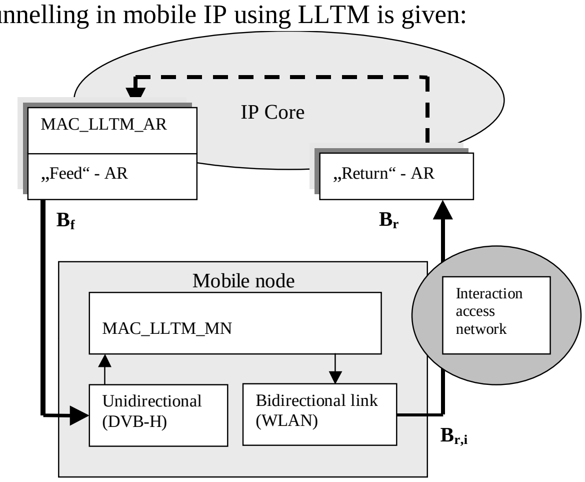

Fig. 6. Tunnelling based on RFC 3077 for unidirectional links in heterogeneous mobile IP access infrastructures

Dependent on the QoS and business goals, as well as the network availability, the "interaction" networks can be based on different wireless technologies, such as UMTS (3GPP), WLAN (IEEE 802.11x), or WiMAX (IEEE 802.16x). The bandwidth requirements at the "feed"-AR are analyzed, considering combined unidirectional and "interaction" networks for provision of asymmetric services. Assuming B_f is the bandwidth for the downstream unidirectional connection and B_r is the bandwidth for the upstream connection (tunnel).

For the bandwidth provision at the "feed" AR is required that

$$B_r = \sum B_{r,i} \quad \text{with } i = 1 \ldots N,$$

where *N is the number of the mobile nodes with return tunnels to the "feed"-AR.*

Assuming that $B_{r,m}$ is the mean traffic of a mobile receiver in upstream (return) direction, than the resources at the "feed"-AR are obtained considering the number of mobile receivers N with tunnels to the "feed"-AR.

$$B_r = N \cdot B_{r,m}$$

Different resources can be assigned to specific IP "feed" addresses (attachment points). In order to plan the bandwidth configuration of the "feed" router, the number of the mobile users with interactive services has to be monitored and forecast.

If return-AR or "feed AR are overloaded with return traffic, traffic redirection and vertical handover to another access networks can be performed. The QoS capabilities of the IP "feeds" (bandwidth, performance, load) are also important, as well as supported encapsulation procedures at the "feed"-AR (see, GRE [35]). In mobile IPv6 environment, especially in the multi-homed [43] scenarios, the "feed" capability list maintained by the LLTM component at the mobile receivers will include also information about the mobile node's "interaction" access network interface:

Feed_info = {IP_Feed, BW_feed, ENC_Feed, IP_P2P}

where

IP_feed is the "feed" IP address,
ENC_Feed is the supported encapsulation method,
BW-feed is the corresponding bandwidth,
IP_P2P is a bidirectional local mobile network used for the "interaction" tunnel.

Because LLTM was designed for fixed IP environment, the "feed" IP address capabilities are learned using DTCP protocol without interactions with mobility protocols to care for handovers. When the mobile node moves to a new DVB-H network, the learning of the corresponding IP "feed" tunnel address for emulation of bidirectional connectivity will be delayed at least until a HELLO message is received by the mobile node at the next DVB-H network.

The interval between the HELLO messages (D_{dtcp_feed}) is (RFC 3077[9]) is 5 sec. This means that the establishment of bidirectional connectivity, which is required for some standard multicast and routing protocols, will wait for the next HELLO message, and this interval is too long.

IV.B.2. Mobility scenarios and requirements for LLTM operation

Currently, the IP mobility (MIPv6 [33], FMIPv6[34]) and address configuration ([44], [45]) protocols are based on the assumption that the network interfaces of the mobile node are bidirectional. The unidirectional link and a bidirectional wireless network for "return" connections can differentiate in the coverage range, bandwidth, signal strength, delay and other performance characteristics, which impacts the connectivity of the combined access network infrastructure.

Assuming that D_{unid} is the handover delay to a new unidirectional DVB-H network and D_{int} is the handover delay to a new "return" access network, then the application performance will depend on the sum of handovers required for the two networks.

In particular, the handover delay of the combined access network infrastructure depends on the particular scenario. Unequal transmission range of DVB-H and "return" network can result in frequent handovers and loss of connectivity in the downstream or upstream direction for a small or longer duration. The coverage range of the unidirectional broadcast networks (such as DVB-H) is usually greater than the coverage range of the "interactive" wireless network, such as WLAN or UMTS, so that it is to expect that handovers of the "return" channel happens more often than for the downstream connection. The scenario (fig. 7) handles the case, when the mobile node receiving services on a DVB-H access network looses its return connectivity (UMTS) and must perform a handover to a new mobile network (WLAN) providing the return channel.

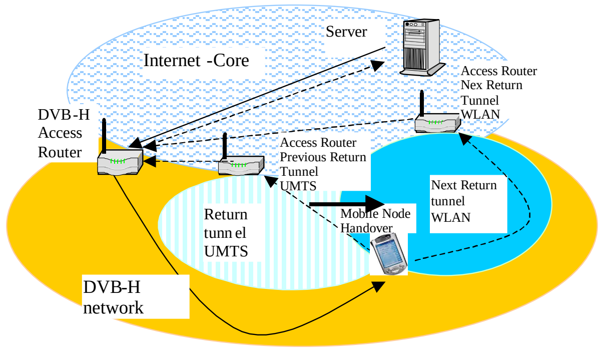

Fig. 7. Handover in case of lost connectivity to the "interaction" access network (scenario 1)

Mobile TV and mobile content delivery can require vertical handover in some scenarios. When the mobile node moves from a bidirectional access network (UMTS) to the unidirectional broadcast link (DVB-H), handover must be performed to the two new networks - DVB-H and its "return" network WLAN (see, fig.8).

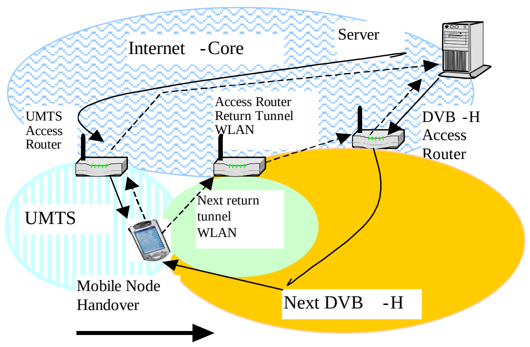

Fig.8. Handover scenario from bidirectional (UMTS) to combined l (DVB/WLAN) access networks (scenario 2)

In this case, the handover to the "interaction" wireless network (WLAN) must be finished before the handover to the DVB-H network, because the reverse connectivity is required for the handover operations (CoA address configuration) of the DVB-H network.

Another scenario (fig. 9) shows the mobile node moving between different DVB-H cells, but not changing its "interaction" WLAN. Although no handover of the return network, there is a need to change the tunnel to the new "feed" access router.

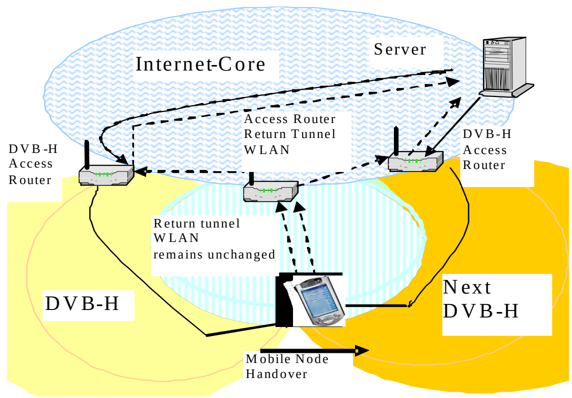

Fig. 9. Handover to a new DVB-H network without change of the "interaction" mobile network (scenario 3)

When the mobile node is changing its point of attachment (for DVB-H and corresponding "interaction" network), LLTM must be informed by the mobility system about:

- Need of handover for each direction;
- Changes of the states of the IP "feeds" (such as "feed" deactivation, establishment of a new "feed") at the DVB-H access router;
- Requirement to use another "interaction" network interface for tunnelling to already existing "feed".

When there is a change in the DVB-H "feed" access router, there is a need to inform the mobile node to change the "feed" router description in the internal lists.

For this purpose, following events have to be processed by the LLTM entity at the mobile node:

- FEED_BUILD - Establishment of tunnel to a new "feed", because the access router for the DVB-H network changed (scenarios 3 and 2);
- FEED_DROP - Delete the "feed", because the DVB-H access network is not more used (scenario 3);
- ROUTE_UPDATE - Change of the "interaction network" corresponding to the "feed" due to handover (scenario 1).

IV.C. Handover enhancements for LLTM in Mobile IP

In this section, we focus on enhancements to reduce the handover, when a mobile node is moving to unidirectional DVB-H access network (D_{unid}). So far LLTM (RFC 3077 [9]) operation was specified based on fixed (non mobile) IP architectures, enhancements are required to support efficiently seamless handover in heterogeneous mobile IP environment.

IV.C.1. Mobile IPv6 handover delay for LLTM based unidirectional access networks

In mobile IPv6, the configuration of a new Care of Address (CoA) for the mobile node is defined based on the enhancements of IETF documents for Neighbour Discovery, stateless [44] and stateful [45] address configuration, which do not specify special handling of mobile nodes with unidirectional interfaces. Considering the abstractions [46], the handover delay of a mobile node in Mobile IPv6 (RFC 3775 [33]) is

$$D_{\_mipv6} = D_{L2} + D_{RD} + D_{DAD} + D_{BU} \qquad (1)$$

where

- D_{L2}, *data link handover delay, aimed to change the link layer parameters of the connection between the mobile node and the base station (access point);*
- D_{RD} *is the delay to receive unsolicited Route Advertisements (RA). In MIPv6 to acquire the new CoA, the mobile node waits for RA from the new access router. RA are sent in RtAdvInt interval, which can be randomly varied for MIPv6 ([33], [47]) between MinRtAdvInt = 30 ms and MaxRtAdvInt = 70 ms.*
- D_{DAD} *– Duplicate Address Detection (DAD) procedure performed by the mobile node for configuration of the new Care of Address (CoA) after a movement from the current sub-network is detected.*
- D_{BU} *– Binding update signalling.*

When the mobile node connects to a new DVB-H network, the IP "feed" tunnel address for emulation of bidirectional connectivity is required to execute DAD. The mobile node must wait until the HELLO message of the DTCP protocol is received and the "feed" is configured (D_{dtcp_feed}).

Thus, for a mobile node moving in MIPv6 to DVB-H access network using LLTM, the handover delay is:

$$D_{dtcp\_mipv6} = D_{L2} + max\,(D_{RD},\, D_{dtcp\_feed}) + D_{DAD} + D_{BU} \qquad (2)$$

When the mobile node performs the L2 handover (D_{L2}), the address of the IP "feed" is not known and the mobile node must wait for the HELLO message of DTCP. Simultaneously, it receives also the RA message with the new prefix. D_{dtcp_feed} interval is longer compared to D_{RD} interval. If D_{dtcp_feed} is decreased, the problem arises that too much control traffic will overload the network. The LLTM technology for learning of the "feed" addresses based on DTCP was designed for fixed networks and is not efficient for mobile environment, where the traffic to the mobile receivers must be reduced.

IV.C.2. Reducing of LLTM handover delay for MIPv6

In MIPv6, access routers advertise their presence and supply the network address prefix for stateless address auto-configuration using RA (unsolicited), as well as in response to Router Solicitation messages sent by the mobile terminals.

To reduce handover delay and support unified technology for converged broadcast and mobile IP environment, our proposal is to include the IP "feed" addresses in (unsolicited) Router Advertisement. The "feeds" for the bidirectional connectivity and the address prefix for the new Care-of-Address (CoA) are received together and the address configuration including DAD can be done in uniform way for unidirectional (DVB-H) and bidirectional mobile access networks.

When a mobile node performs a handover to the new DVB-H network, it receives an unsolicited RA with "feed info", including the "feed" IP address description (see, fig. 10). This requires that LLTM at the DVB-H access router provides information to the mobile infrastructure protocols about the established IP "feeds". After receiving the next IP "feed" address, the mobile node can configure the CoA for unidirectional network.

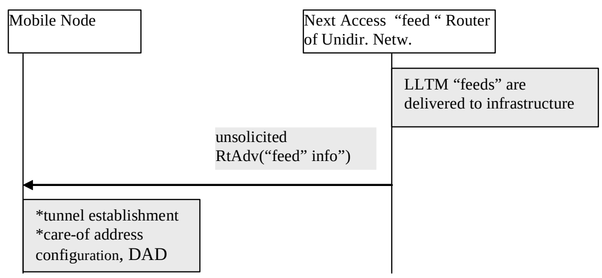

Fig. 10. Usage of "feed" info in MIPv6

There is no need to wait for "feed" addresses from HELLO message, therefore the handover latency can be expressed by the usual delay D_{mipv6} , see formula (1).

IV.C.3. Reducing of LLTM handover for Fast MIPv6

Fast Handovers for MIPv6 (FMIPv6) has been proposed in order to minimize the handover delay based on the handover initiation phase, in which the CoA address is preconfigured before L2 handover [34]. Generally, based on the abstractions [46], the FMIPv6 handover delay can be expressed by:

$$D_{h\_fmipv6} = D_{L2} + D_{fna} + D_{BU} \quad (3)$$

where

- D_{L2}, *data link handover delay, aimed to change the link layer parameters of the connection between the mobile node and the base station (access point);*
- D_{fna} *informs the new AR about the presence of the mobile node;*
- D_{BU} *– Biding update signalling.*

In formula (3) the initialization phase is not included, because it is done before D_{L2} .

For a mobile node moving in FMIPv6 to the DVB-H network, it is not possible to obtain the “feeds” in the handover preparation phase.

The handover delay increases by the time to wait for the HELLO messages to the “feed” and to configure the new CoA.

$$D_{dtcp\_\_fmipv6} = D_{L2} + D_{fna} + D_{BU} + D_{dtcp\_feed} + D_{DAD} + D_{BU} \quad (4)$$

In FMIPv6 (similar to MIPv6), an option including the “feed” information for the tunnelling is integrated in the Proxy Router Advertisement Message PrRtAdv.

It is used for CoA pre-configuration in the handover initiation phase.

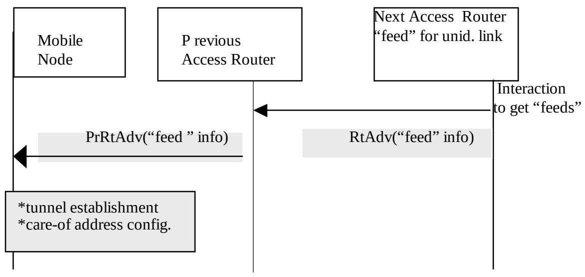

Fig.11. Usage of “feed” info in Fast Handover for MIPv6

The enhancement allows the configuration of the CoA in the handover initiation phase and avoidance of the additional delay caused by the waiting for DTCP and HELLO message.

The resulting handover can be expressed by the usual handover delay $D_{h\text{-}fmipv6}$ for FMIPv6, see formula (3).

V. Intelligent DVB-H handover support in Mobile IP

To support seamless handover in Mobile IPv6, it is important to consider the requirements for seamless handover on different OSI layers. In the previous section, seamless handover techniques on the IP layer for interactive applications using DVB-H networks were discussed; in this section, data link and application support for seamless handover is addressed.

The data link layer handover for DVB-H networks is activated considering monitored values of specific link layer parameters [50]:

- Received Signal Strength Indicator (RSSI);
- Derived Power (DP);
- Signal to Noise Ratio (SNR));
- Bit Error Rate (BER);
- Packet Error Ratio (PER);
- MPE-FEC Frame Error Rate.

For heterogeneous IPv6 environment in DAIDALOS architecture, the handover decision is optimized by mapping the signal quality measured in DVB-H and other wireless networks into a generic and unified quality level.

The DVB-H phase shift planning is further approach for seamless handover of mobile nodes using global multicast / broadcast applications and data carousels, which are active at the same time intervals in adjacent cells [49]. It is based on the shifting of the time slices of the common services in adjacent networks.

The terminal and the network mobility component have to learn different parameters for efficient handover decisions. For this purpose, technologies are used aimed to discover capabilities of the neighbour access networks and to select the optimal access network for the applications according specific goals.

Technologies for intelligent handover include:

- Intelligent interface selection at mobile node [25];
- Access network discovery [15], [16], [18];
- Policy management [7];
- Media independent handover and information base, allowing cross layer decisions [8];
- Context Transfer [14], [30].
- QoS mapping and proactive resource reservation [17].

A challenge today is to integrate such components allowing unified interfaces and cross-layer handover decision support for mobile terminals. The *IEEE 802.21 Media Independent Handover (MIH)* standardisation effort [8] is aimed to provide such cross-layer services that can request and deliver information at different communication layers. MIH defines services for managing and exchanging information, event and control messages between network devices and modules enabling handover decisions of mobile nodes with multiple network interfaces.

Local and remote data link layer (L2) interfaces deliver events and triggers to upper layers (network, transport and application). The upper layers issue commands to MIH middleware to control data link layer. MIH services are enhanced to support the handover process in FMIPv6 based on the provisioning of network address information (L3) of neighbour access networks [41]. The primitive "MIH-PrefixInfo", proposed in [46], is used to obtain the next access router information by the mobile node without router discovery. Currently, the IEEE 802.21 does not consider the handover of services using unidirectional access networks. 802.21 can be enhanced for unidirectional links to include:

- Information primitives describing "feed" IP addresses and capabilities of the access router;
- Information concerning the QoS of the "feed", i.e. the bandwidth and performance characteristics describing the attached interfaces;
- Events specifying the availability of the LLTM functions;
- Commands changing the state of the "feed" at the mobile node (deactivate "feed", establish "feed", assign new "interactive network).

Further mechanisms concerning discovery of capabilities of the networks are for instance the Candidate Access Router Discovery (CARD) [15] and dyCARD (A dynamic Access Router Discovery) protocols [18], proposed by IETF Seamoby Working Group, as well as Application Layer Information Service (AIS) [42]. The management framework for intelligent handover decision to unidirectional networks concerns both the access router and mobile terminal. The handover has to be performed with minimal interference of the mobile node. The mobile terminal makes handover decisions based on the received information about the capabilities of candidate access routers.

Automated policy management for heterogeneous mobile IP environments is aimed to support the handover decisions considering business goals of policy actors (users, service providers and network operators), preferences and profiles of actors and applications [7]. Possible scenarios for policy management of mobile applications with multiple interfaces using unidirectional broadcast networks include:

- Enforcement of QoS based handover strategies to support mobile multicast applications requiring DVB-H networks. Policies can control the mapping of QoS parameters between IPDatacast flows and DVB-H streams. For further business objectives, vertical handover between DVB-H and UMTS QoS parameters is required.
- Selection of "interaction" network interfaces and IP tunnel end-points with specific QoS characteristics. The network interfaces, corresponding to the IP "feeds" tunnel end-points, are characterized with bandwidth and other performance metrics, which can be chosen dependent on the asymmetric character of the application;
- Redirection of traffic from unidirectional network (DVB-H) to another overlaying cell in order to save resources or to perform traffic balancing;
- Adaptation of application services in case, that the interactivity channel is lost. The policy system can request the continuation in an adapted mode (as downstream service, only in one-way direction).

VI. QoS Provisioning for Interactive Services in DVB-H/IPv6 Environments

The resource reservation for DVB-H networks in Mobile IPv6 architectures depends on the business models and QoS / Service Level Agreements (SLA).

Interactive mobile broadcast services, such as multimedia content delivery and software downloads, are characterized with asymmetrical traffic for the downstream (unidirectional) and upstream (return) channels. The QoS management of IPDatacast services is based on separate bandwidth allocation for the:

- Downstream channel (involving DVB-H access network) and
- Upstream channel (Bidirectional "interaction" access network and IP tunnel).

At the access DVB-H network; the traffic can be planned in advance, or reserved on-demand by appropriate QoS provisioning technology considering mapping of IP services to DVB-H MPEG streams.

In DAIDALOS architecture, QoS brokers are responsible for resource reservation at core and access networks [4]. The access routers are requesting the resources for the mobile nodes sending signalling messages to the Access Network QoS Broker and Core Network Access Broker.

The resource reservation in Mobile IPv6 architectures is provided based on QoS specification for aggregated flows (DiffServ) and individual flows (IntServ/RSVP), which are mapped to DVB-H streams. Based on the time slicing method, the IP flows are mapped to DVB-H streams, identified by PID (Packet Identifier).

The QoS mapping of IP flows is based on bursts put in MPEG streams. Possible scheduling of IPv6 flows to DVB-H streams is shown in fig. 12.

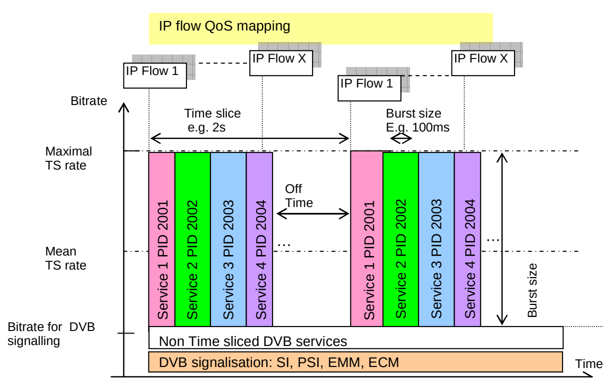

Fig. 12. Bandwidth allocation for IP flows in DVB-H

Each burst may contain up to 2 Mbits of data (including parity bits). The mobile node switches on only for the time interval when the burst of a selected IP service is received. Within this short period, the burst size is received, which can be either stored in the buffer for file downloads or playout in live streams application scenarios. DVB-H monitoring tools provide information about the usage of TS bandwidth for different kind of IP flows. This information can be used for IP / DVB-H dynamic QoS planning and resource reservation in advance based on application traffic patterns of different IP flows (audio and video streaming, burst applications and elastic traffic, carousels). The efficient multiplexing of IP flows in specific DVB-H streams can be planned considering specific requirements for duration, mean and maximum rate, burst size and other traffic patterns of the IP flows [17].

VII. Conclusion

The paper was focused on technologies aimed at seamless handover of mobile interactive multicast / broadcast services using DVB-H access networks in heterogeneous Mobile IPv6 environment. Signalling for reduction of the handover delay based on interactions of LLTM and IP Mobility protocols was discussed. Technologies for intelligent network selection, QoS mapping of IP flows and policy management, particularly based on IEEE 802.21, are overviewed.

Acknowledgements

This paper is based on results of the European IST project DAIDALOS [10]. Thanks to European commission supporting this project and to all the partners that contributed.

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