Seamless Handover For Unidirectional Broadcast Access Networks In Mobile IPv6

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***Abstract*-- Mechanisms and protocol interactions for seamless handover of mobile multicast/broadcast services using unidirectional access networks in heterogeneous Mobile IP infrastructures are discussed and proposed. QoS based applications, such as content delivery, mobile TV, carousel and reliable downloads, requiring interaction channel, are considered, as well as recent standardization efforts for converged broadcast and mobile IP infrastructures. The proposed mechanisms are aimed to support handover of interactive mobile 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:**

- **Enhancement and interactions of link layer tunnelling mechanisms (IETF RFC 3077) for provisioning of bidirectional connectivity in heterogeneous Mobile IP environment;**
- **Access network selection and intelligent handover mechanisms based on IEEE 802.21 for services using unidirectional networks;**
- **Proactive resource management for interactive services using unidirectional access networks.**

***Index Terms*-- IEEE 802.21, LLTM, unidirectional network, DVB-H, QoS, mobile multicast, Mobile IPv6, policy**

1. INTRODUCTION

Unidirectional broadcast technologies, such as Digital Video Broadcasting-Handheld (DVB-H) [1], based on one-way transmission, are able to provide cost efficient and high speed transport of multicast/broadcast traffic to mobile receivers supporting scenarios for mobile television, streaming distribution, mobile content delivery, carousels and reliable file downloads.

Integration of multicast multimedia applications with interactive channels and asymmetric traffic on unidirectional broadcast access networks in heterogeneous mobile IP infrastructures requires efficient approaches for:

- Provision of "interactivity" path;
- Handover mechanisms and QoS (Quality of Service) mapping between unidirectional and bidirectional access networks,
- Policies controlling the usage of multiple path and the handover decisions,
- Intelligent access network selection for mobile nodes in converged heterogeneous infrastructures.

Recent standardization efforts focused on multimedia services and applications, such as IPDatacast [2] and DIMS [3], are aimed to support convergence of unidirectional broadcast and Mobile IP services.

Different architectures have been proposed for cost efficient support of content delivery, mobile TV and other interactive mobile multicast applications using broadcast media.

Examples are hybrid broadcast and cellular systems for Mobile TV [4], mobile ad hoc infrastructures with unidirectional links [5], mesh of wireless and broadcast networks [6].

The goal of this paper is to evaluate and propose efficient handover strategies to support mobile users with unidirectional network interfaces in heterogeneous mobile IPv6 environments based on combination of unidirectional broadcast networks (DVB-H) and bidirectional access technologies (such as UMTS, WIMAX and WLAN).

Different aspects for improving the handover performance using unidirectional access networks are discussed and novel solutions are proposed:

- *Enhancement of link layer tunnelling mechanisms based on IETF RFC 3077* [9] and analysis of interactions in mobile environment aimed at provisioning of bidirectional connectivity;
- *Intelligent network selection for applications*. The IEEE 802.21 media independent handover framework was proposed to support services allowing exchange of information for optimal handover [8]. Because the IEEE 802.21 framework does not consider the unidirectional media and the tunnelling for bidirectional connectivity, we propose enhancements for mobile nodes with unidirectional links.
- *Policies for mobile services using unidirectional links* aimed at automated handover decisions.
- *Proactive resource reservation considering specifics of* unidirectional broadcast access networks.

This paper is organized as follows.

In section 2, unidirectional broadcast networking architectures in Mobile IP environment, as well as on-going multimedia and TV services are introduced.

Section 3 discusses seamless handover based on enhancements of RFC 3077 for tunnelling of bidirectional connectivity.
In section 4, technologies for intelligent handover of services using unidirectional links are overviewed.
Proactive resource management is discussed in section 5.
Section 6 concludes this paper.

II. MOBILE SERVICES USING UNIDIRECTIONAL LINKS IN HETEROGENEOUS IP ENVIRONMENTS

A. Integration of unidirectional broadcast networks in Mobile IP architectures

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 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 was 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 technology for provision of mobile multicast/broadcast services and mobile TV is MediaFLO [12], which is Qualcom proprietary technology commercially available in USA.
Further possibility is T-DMB recently standardized also by ETSI [13].
This paper considers the QoS based mobile architecture of the EU IST project DAIDALOS for heterogeneous mobile IPv6 environment consisting of unidirectional access networks (DVB-H) and bidirectional wireless technologies (UMTS, WLAN, WMAX).
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 developed and evaluated 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 in heterogeneous access network environment [17];

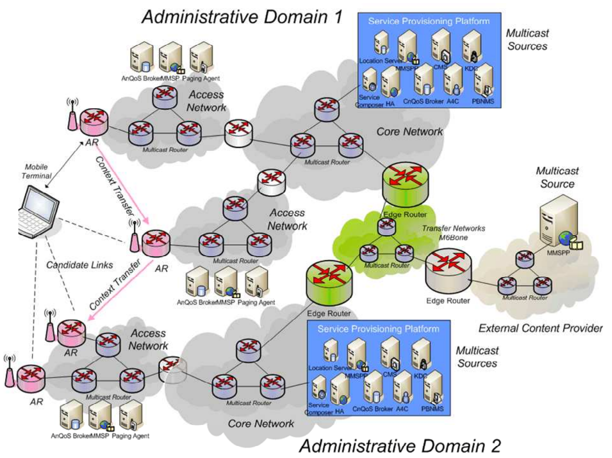

Figure 1. Mobile IPv6 architecture using access routers for integration of heterogeneous access networks

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 [8] and Network-Based Localized Mobility Management ([21]) are focus of research.
The integration of the unidirectional broadcast access networks (DVB-H) is based on the emulation of the bidirectional connectivity at a MAC sublayer using complementary wireless bidirectional network.
In particular, for integrations of unidirectional broadcast networks 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.

B. Interactive mobile multicast / broadcast services

Mobile multicast/broadcast services allow 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 can be provided 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. In DAIDALOS architecture, a particular focus are technologies for seamless vertical handover between heterogeneous mobile (UMTS) and broadcast (DVB-H) networks.

The deployment of interactive services using unidirectional broadcast networks in hybrid IPv6 environments including broadcast media requires appropriate interactivity channels, mobility and QoS support. Mobile multicast services on unidirectional links can be based on different models for interactions, such as one-way and two-way interaction (see figure 2):

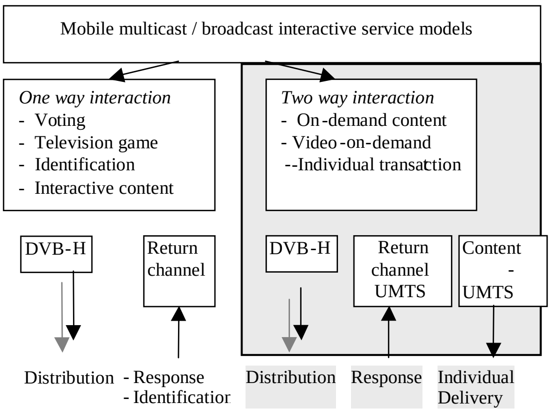

Figure 2. Interaction type of mobile multicast applications

Example for one-way interactive service is the mobile television integrated into a handheld multimedia device aimed to facilitate easy viewer interaction and enable sophisticated television programs based on interactivity channels [2]. With an interactive channel, viewers can request specific information for city or region, weather forecasts, film and multimedia guides.

Different services are deployed for converged broadcast (DVB-H) and mobile IP environment:

- Multimedia streaming using converged DVB-T/WLAN access networks involving central broadcast points for transmission and stream regeneration and cell main nodes, which support the connectivity of different kinds of networks [26];
- Media streaming and mobile TV scenarios aimed at 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 broadcast/multicast for alerts and emergency information transfer (earthquake and tsunami info) to groups of mobile users connected to unidirectional broadcast networks [31].

The standardisation of applications using mobile IP and DVB-H is based on *IPDataCast* (IPDC) aimed at the delivery of streaming and file transfer applications [23]. IPDC is designed on the "push" service concept. The service offer can be obtained from the Electronic Service Guide (ESG) [24].

Dynamic interactive multimedia scenes (DIMS) [4] is a recent 3GPP standardization effort for rich media applications using constrained devices combined with unidirectional broadcast (DVB-H) and mobile 3G (UMTS).networks.

Service interactivity is 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 return network for the provision of interactive mobile broadcast service 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.

A business model for combined broadcast and mobile networks aimed at provision of interactive multimedia multicast services in Mobile IP environments is shown.

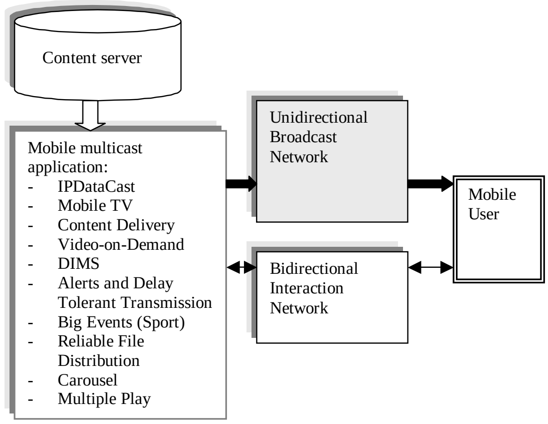

Figure 3. Business model for provision of interactive mobile multicast/broadcast services

III. Mobility Management for Interactive Servces Using Unidirectional Links

A. Introduction to Link Layer Tunnelling

Bidirectional connectivity for services used on broadcast unidirectional links can be required in mobile IP environment for different reasons, for instance:

- 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.

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, is 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 using LLTM and DTCP facilities for tunnel establishment are illustrated in the following figure:

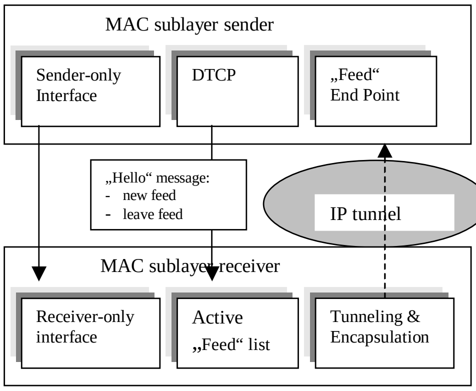

Figure 4. Basic interactions for tunnel establishment

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 a Cisco/Boeing effort on global mobile router mobility, the tunnelling facilities are used to provide roaming capability in unidirectional satellite IP infrastructures [40].

B. Using of 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 to support interactive mobile multicast/broadcast. services.

B.1. LLTM model based on Mobile IP

In heterogeneous mobile IP access environment involving mobile receivers with unidirectional link interfaces, 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.5), 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" access network), "return" – AR and IP tunnel.
A network model describing the bidirectional tunnelling in mobile IP using LLTM is given:

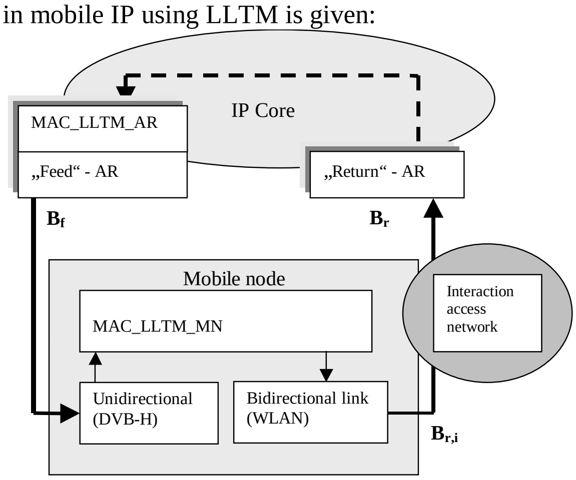

Figure 5. Tunnelling based on RFC 3077 for unidirectional links in heterogeneous mobile IP access infrastructures

Dependent on the QoS and business goals, the "interaction" networks can be based on different wireless technologies UMTS, 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" router 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 bidirectional connection emulation 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.

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

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 at the access router for emulation of return channel,
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" capabilities are learned using DTCP protocol without interactions with mobility protocols to care for handovers. When the mobile node moves to a new unidirectional 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 unidirectional 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.

<u>B.2. Mobility scenarios and requirements for LLTM operation</u>

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 link and D_{int} is the handover delay to a new "interaction" 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 unidirectional broadcast and "interaction" 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. 6) handles the case, when the mobile node receiving services on a broadcast access network looses its return mobile network connectivity (UMTS) and must perform a handover to a new mobile network (WLAN) to provide the return channel.

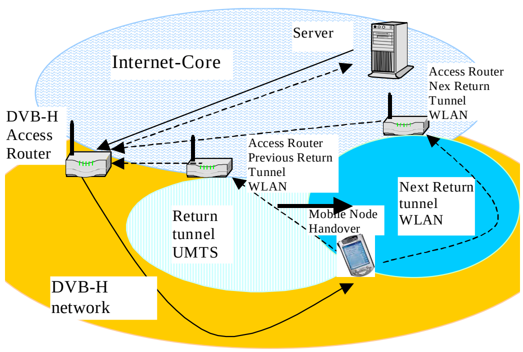

Figure 6. Handover in case of lost connectivity to the "interaction" access network (scenario 1)

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 an unidirectional broadcast link (DVB-H), handover must be performed for the two networks - DVB-H and WLAN (see, fig.7).

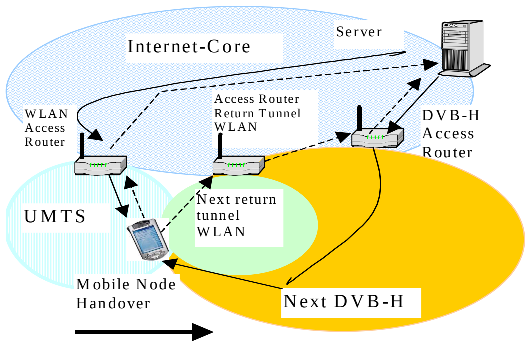

Figure 7. Handover scenario from bidirectional (UMTS) to combined l (DVB/WLAN) access networks (scenario 2)

In this case, the handover to the "interaction" wireless network (WLAN) must be finished before the handover to the unidirectional network, because the reverse

connectivity is required for the handover operations (CoA address configuration) of the unidirectional network.
Another scenario (fig. 8) 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.

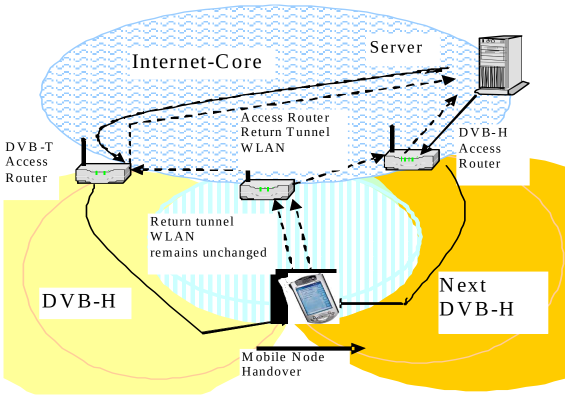

Figure 8. Handover to a new unidirectional broadcast network without change of the “interaction” mobile network (scenario 3)

When the mobile node is changing its point of attachment (for unidirectional or “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”)
- Requirement to use another “interaction” network interface for tunnelling to already existing “feed”.

When there is a change in the “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 unidirectional network changed (scenarios 3 and 2);
- FEED_DROP - Delete of the “feed”, because the unidirectional access network is not more used (scenario 3);
- ROUTE_UPDATE - Change of the “interaction network” corresponding to the feed, because of handover (scenario 1).

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 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.

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 given by

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

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} – Biding update signalling.

When the mobile node connects to a new unidirectional access network, the IP “feed” tunnel address 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 unidirectional link 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.

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 and bidirectional access networks.

When a mobile node performs a handover to the new "receive-only" unidirectional network, it receives an unsolicited RA with "feed info", including the "feed" description of the candidate access network (see, fig. 9).

This requires that LLTM at the "feed" access router provides information to the mobile infrastructure protocols about the "feeds".

After receiving the next IP "feed" address, the mobile node can configure the CoA for unidirectional network.

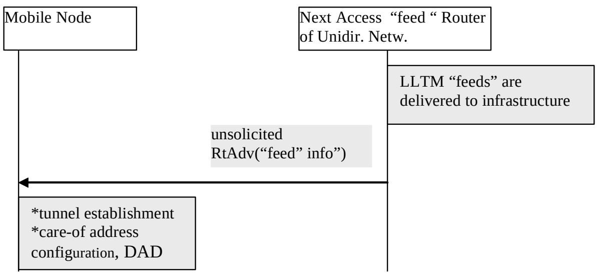

Figure 9. Usage of "feed" info in MIPv6

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).

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:

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

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 initialisation phase is not included, because it is done before D_{L2} . For a mobile node moving in FMIPv6 to the unidirectional link, 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.

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

In FMIPv6 (similar to MIPv6) an option including the "feed" information for the tunnelling is integrated in the Proxy Router Advertisement Message PrRtAdv for CoA pre-configuration in the handover initiation phase.

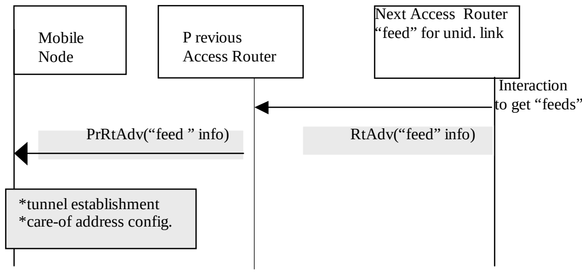

Figure 10. Usage of "feed" info in Fast Handover for MIPv6

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).

IV. INTELLIGENT HANDOVER SUPPORT FOR SERVICES ON UNIDIRECTIONAL LINKS

Technologies for intelligent handover are aimed to obtain the capabilities for the neighbour access networks and to select the optimal access network for the applications according specific goals. There are different components (technologies) for intelligent handover support, such as:

- Intelligent interface selection at mobile node [25];
- Access network discovery [15], [16], [18];
- Policy management [7], [22];
- 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 in a common architecture for handover support allowing unified interfaces and cross-layer handover decision support. 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 related to intelligent handover decisions 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 [8].

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 [22]. Possible scenarios for policy management of mobile applications with multiple interfaces using unidirectional broadcast networks include:

- Enforcement of specific handover strategies to support multicast applications requiring unidirectional links. For instance, for some business objectives, vertical handover between DVB-H and UMTS is preferred. Policies can control the mapping of service parameters between IPDatacast and MBMS.
- Selection of “interaction” network interfaces and IP tunnel end-points (“feeds”) with specific QoS characteristics. The network interfaces, corresponding to the IP “feeds” tunnel end-points, are characterised 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, for instance in order to save resources;
- 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).

V. Resource Management for Interactive Services on Unidirectional Link

Interactive mobile broadcast services, such as multimedia content delivery and software downloads, are characterized with asymmetrical traffic for the downstream (unidirectional) and upstream (return) connection. The QoS characteristics of the downstream and upstream connection can be required using parameters, such as bandwidth and delay.

The resource reservation strategies for mobile nodes using unidirectional networks depend on the business models and Service Level Agreements (SLA) between service (content) providers and network operators at the core and access networks.

In DAIDALOS architecture, QoS brokers are responsible for resource reservation at core and access networks [17]. 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 next figure shows a scenario including QoS brokers, when the mobile node moves to the next unidirectional broadcast access network and needs to reserve resources.

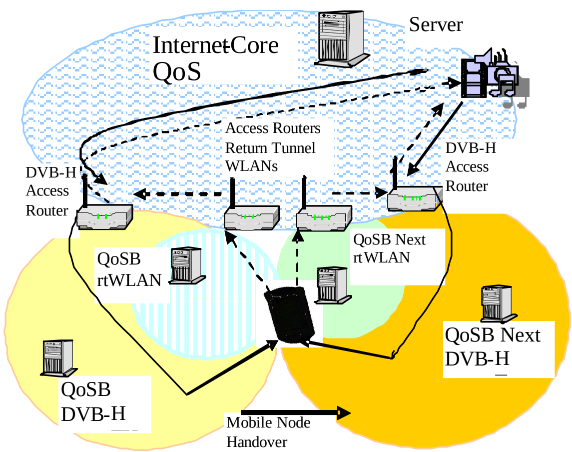

Figure 11. QoS brokers in scenario with unidirectional access networks

The QoS management of mobile services using unidirectional interfaces is based on separate resource reservation strategies for the:

- Downstream channel (Unidirectional broadcast network);
- Upstream channel (Bidirectional “interaction” access network and IP tunnel).

The reservation strategies differ for the IP Core and access networks.

At the *access networks*, the traffic can be planned, i.e. reserved in advance by the QoS brokers, using protocols for resource reservation in advance, primary based on RSVP modifications [24]. “On-demand” reservation scheme of the access QoS brokers are also possible.
The resource planning and reservation considers the:

- Downstream traffic at the unidirectional broadcast network and
- Traffic at “interaction” bidirectional access network for one-way or two-way mobile broadcast interactivity services.

Dependent on the SLAs for the applications and content providers, there are different schemes for resource reservation at the *IP Core networks*:

- “*Over-provisioning*” resource reservation for IP core based on long term advance resource reservation.
- *“On-demand”* resource reservation for core networks. This scheme is useful for services requesting bandwidth on-demand, such as real-time, emergency, rich media applications, GRID and medical applications.

VI. CONCLUSION

The paper was focused on technologies aimed at seamless handover of mobile multicast / broadcast services using unidirectional broadcast network.
The usage of LLTM for unidirectional links in heterogeneous mobile IPv6 environment was discussed. Reducing of the handover delay for services on unidirectional links based on interactions of LLTM and IP Mobility protocols to provide “feed” address and QoS information was proposed. In order to support the seamless handover for unidirectional links, technologies for intelligent network selection and policy management, particularly based on IEEE 802.21, are overviewed.

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