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Support of interactive QoS based services in hybrid broadcast and mobile IPv6 environment

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Abstract – **Mobile terminal receivers with unidirectional network interfaces are not considered as a special case in the standardization of Mobile IPv6. For the interaction of unidirectional access technologies (DVB-H, DVB-T) and mobile networks (UMTS, WLAN, WIMAX) in heterogeneous IPv6 environment, there is a challenge for unified mobility and QoS management technologies supporting new interactive broadcast services, such as IP Datacast. This paper discusses protocol enhancements of Mobile IPv6 in order to support interactive QoS based multimedia services in hybrid broadcast and mobile IPv6 environment. Interaction of the Link Layer Tunnelling Mechanisms (RFC 3077) with the Mobile IPv6 and Fast Handovers based on "reverse tunnelling info" is used to provide uniform handover support for broadcast and mobile IP services.**

QoS management for broadcast access Internet network environment is proposed based on resource reservations for the two directions - downstream connection of the unidirectional broadcast network and return tunnel using wireless access network. QoS information base describing the capabilities of the unidirectional access networks and the IP return tunnel network ("feed") is used for enhanced QoS support of interactive services.

Index Terms - **broadcast network, convergence, IP Datacast, Link Layer Tunnelling, Mobile IPv6**

I. Introduction

Unidirectional broadcast technologies, such as Digital Video Broadcasting-Terrestrial (DVB-T) [1] and Digital Video Broadcasting-Handheld (DVB-H) [2] allow the provision of cost efficient broadband content delivery and mobile TV services [3], [4]. In order to benefit from the optimised costs, greater service range and enhanced QoS (Quality of Service) offered by the unidirectional broadcast technologies, unified mobility and QoS management technologies are required that enable synergy of the services developed for Mobile IPv6 and unidirectional broadcast networks. This will allow new business models and scenarios based on interactive mobile services in hybrid networking environment involving broadcast and mobile networks. Development of new mobility and QoS management services for combined broadcast (DVB-H, DVB-T) and mobile networks (UMTS, WLAN, WIMAX) using an IPv6 platform is a focus of research of the EU project DAIDALOS [5].

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Mobile IPv6 (RFC 3775) [7] and its enhancement for Fast Handover [8] are standardized in IETF to manage the handover of mobile nodes. However, MIPv6 and its extensions do not attempt to solve all general problems related to handovers, as for instance when a node moves to unidirectional broadcast network and needs the emulation of a "return" channel. In Mobile IPv6, the integration of mobile nodes with unidirectional links based on Link Layer Tunnelling Mechanisms (LLTM) (defined in RFC3077 [9]) requires emulation of return link using an additional bidirectional mobile network interface.

In this paper, synergy aspects of broadcast networks and Mobile IPv6 are discussed focussing on:

- Unified interactive (IP Datacast) services for integrated broadcast and mobile IP platforms;
- Interactions between Mobile IPv6 and LLTM;
- Enhancements of Mobility protocols (Mobile IPv6 and Fast Handovers);
- Information bases about network capabilities (IEEE 802.21) and their extension to consider unidirectional networks;
- Unified QoS interfaces for converged broadcast and IP networks.

This paper is organized as follows. In section 2, the integration of mobile services using unidirectional networks is discussed. Section 3 proposes techniques for seamless handover to unidirectional networks based on Mobile IPv6 and Fast Handovers. Section 4 discusses resource management for interactive mobile services using unidirectional networks. Section 5 proposes an information base supporting unidirectional networks in mobile IPv6 scenarios.

II. Support of Interactive Mobile Services on Unidirectional Broadcast Networks

A. *Interactive mobile broadcast services using IP Datacast*

Today, different unidirectional technologies can be integrated as access networks in heterogeneous mobile Internet environment. Examples are DVB-T [1], DVB-H [2], Digital Multimedia Broadcast (DMB) and MediaFLO. Such broadcast networks can offer downstream channels at high data rates, which are used for cost efficient digital television and audio / video streaming to mobile handheld receivers and/or portable terminals (notebooks).

For instance, DVB-T [1] can provide television services in public transportation, in cars and in high speed trains. DVB-H technology adapts the DVB-T to the specific requirements of handheld, battery-powered receivers [2]. A typical scenario for DVB-H can be the delivery of up to 20 video streams (TV channels) to mobile terminals gaining additional revenue from the transfer of news, sports, weather and other content on-demand using interactive channels.

New television services integrated into a mobile telephone are aimed to facilitate easy viewer interaction and enable sophisticated television programs based on interactivity channels [15]. With an interactive channel, viewers can request specific information, such as local guide services providing viewers with information on a city or region, weather forecasts, film trailers and multimedia guides.

For the collaboration of broadcast and mobile network operators in providing hybrid infrastructures offering interactive mobile broadcast services, different business models are deployed [15].

The deployment of new mobile services in hybrid IPv6 environments including broadcast media requires appropriate interactivity channels, full mobility and QoS support. Service interactivity can be achieved based on cooperation between broadcast and mobile telecommunication platforms. Broadcast Network Operator provides the broadcast network that carries the mobile broadcast services and the mobile operator supplies the mobile network required for the return (interactivity) channel.

IP Datacast is a platform that can be used for delivery of interactive services based on convergence of broadcasting and mobile IP-based platforms [3]. It is defined based on a unidirectional DVB-H downstream channel combined with a mobile interactivity path [28]. Dependent on the application, there are different QoS requirements for the interactive services, such as minimum delay and transaction response time. The entire interactive service offer can be obtained based on the Electronic Service Guide (ESG) [29]. Interaction based on IP Datacast is used for:

- Locally and remotely interactive content delivery,
- Transaction services,
- Subscription using interaction,
- Payment and billing,
- Requesting and receiving access rights,
- File transfer and software downloads.

B. *Emulation of bidirectional connectivity*

The combination of the unidirectional broadcast technology with the wireless return network for the provision of interactive mobile broadcast service depends on:

- Capabilities of the broadcast and wireless return networks and how they can provide the QoS required by the application and user;
- QoS/SLA 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.

For emulation of bidirectional connectivity for mobile terminals connected to unidirectional access networks, the Link Layer Tunnelling Mechanisms (LLTM) specified in RFC 3077 [9] can be used. LLTM was developed by the IETF Unidirectional Link Routing (UDLR) Working Group to support Internet routing and multicast scenarios on unidirectional networks, such as satellites and broadcast media. LLTM adds a layer between the network interface and the routing software to emulate the full bidirectional connectivity using Internet tunnels.

Different experiments have considered LLTM to support multicast services of a mobile terminal with “receive-only” interface. In fixed IPv4, LLTM is used for integration of IGMP services on unidirectional links [10]. Also for the multicast routing on unidirectional networks based on the DVMRP protocol, there is experience with LLTM [11]. Further experiments are based on interaction of IPv4 and IPv6 multicast reception using LLTM [12]. LLTM was also applied for PIM-SM based multicast routing on satellites [13]. In order to emulate the return channel, LLTM assumes an additional mobile network with bidirectional connectivity, to which the mobile node is connected. Dependent on the scenario, mobile access technologies with specific QoS capabilities, such as UMTS, WLAN (IEEE 802.11x), or WiMAX (IEEE 802.16x), can be used as return access network.

LLTM requires that the return channel is emulated using a tunnel established at the router connecting the unidirectional network to the Internet.

The mobile terminal with additional wireless link is a multi-homed node in Mobile IPv6 environment. Multi-homing for MIPv6 is standardized by the IETF [16]. So far the applications of LLTM are only proposed for fixed (non-mobile) Internet hosts, which learn dynamically the IP “feed” tunnel addresses at the access router for the unidirectional network using the “HELLO” message of the DTCP protocol. When the mobile node moves, the learning of the “feed” tunnel address will be delayed at least until a HELLO message is received by the mobile node at the next unidirectional network.

The emulation of the “return” channel to the IP “feed” requires that there is a route from an additional wireless network interface of the mobile terminal to the “feed” tunnel address. This can be critical, because LLTM includes no functionality to discover capabilities of the IP tunnel routing path for the return channel before the handover. The capabilities of the IP return tunnel interface (“feed”) are also needed to ensure that the IP “feed” supports the same tunnelling protocol as the mobile node. An example for a tunnelling protocol is the Generic Routing Encapsulation (GRE) [17].

This paper is aimed to propose a more efficient way for interoperation of LLTM and Mobile IPv6 allowing unified handover support for hybrid broadcast and bidirectional wireless networks.

C. *Handover scenarios of mobile terminals with unidirectional interfaces*

In the discussed scenarios, mobile nodes with multimedia content delivery services are assumed, which at least use interaction channels to send acknowledgments for the downstream data to the service provider platform. When in Mobile IPv6 a mobile node moves to a new access network, it must configure a new Care-of-Address (CoA), which identifies a mobile node's new point of attachment to the Internet and makes it possible to connect from a different location without changing the device's home address (permanent IP address).

Fig. 1 shows a scenario, in which a mobile node moves from bidirectional wireless network (UMTS) to unidirectional broadcast network (DVB-H).

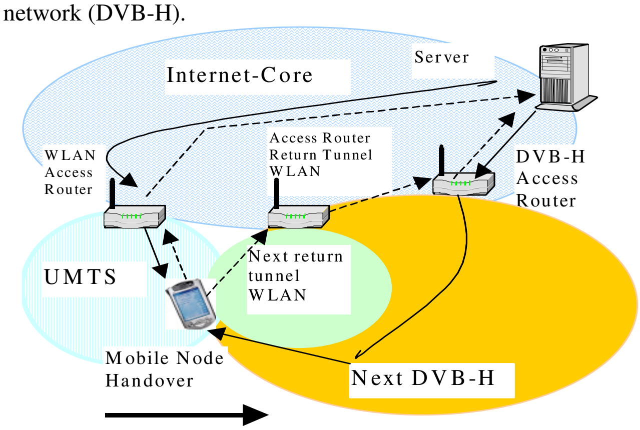

Fig. 1: Handover scenario from WLAN to DVB-H

Such handover can be initiated by the network mobility management in order to achieve optimized usage of the resources [26]. Using an additional mobile access network, a bidirectional communication link for interactive services can be emulated (using a tunnel from the WLAN interface to the DVB-H access router). Before the handover, the mobile node must receive a CoA prefix for the next unidirectional access network (DVB-H) and a CoA prefix for the “return” tunnel access network (WLAN). For establishment of the “return” tunnel, the mobile node needs the IP “feed” address at the DVB-H access router. The resources are reserved separately on the unidirectional broadcast network and the upstream return tunnel connections.

Another scenario (fig. 2) 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. The configuration and registration of a CoA for the next “return” channel

WLAN is requested. Resources at the new "return" channel access WLAN network have to be reserved and resources on the old network have to be released.

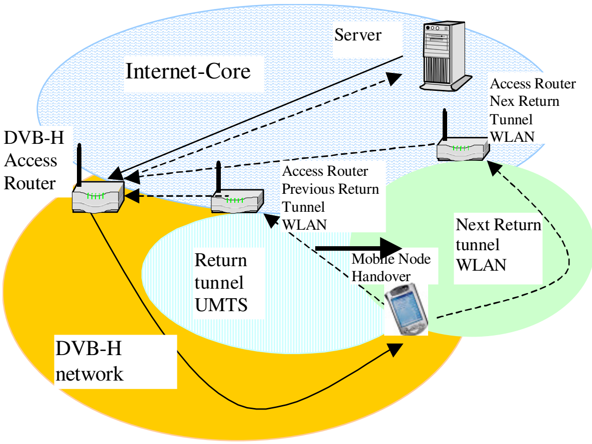

Fig. 2: "Return" mobile network change while the downstream unidirectional broadcast network is still the same

In the third scenario (fig.3), a handover is performed between different unidirectional access networks (DVB-T to DVB-H).

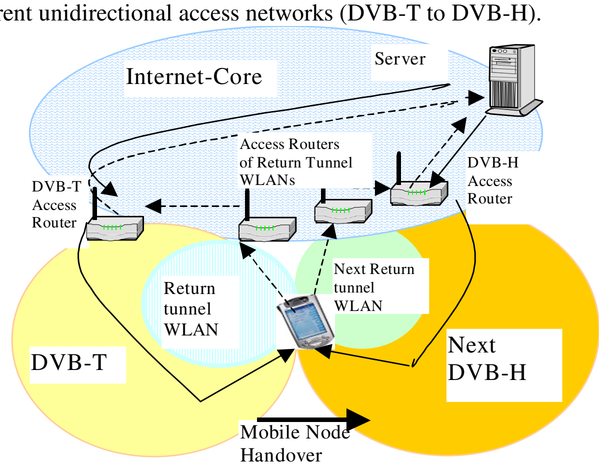

Fig. 3: Handover between unidirectional broadcast access networks

In fig. 3, the mobile node leaves the DVB-T service range and enters the DVB-H cell. Before the handover, the mobile node must receive its CoAs for the new broadcast access network (DVB-H) for the downstream and next "return" WLAN for the upstream return tunnel, as well as register his new CoAs.

In addition, resources at these access networks have to be reserved for the two directions separately and the old reservations have to be released.

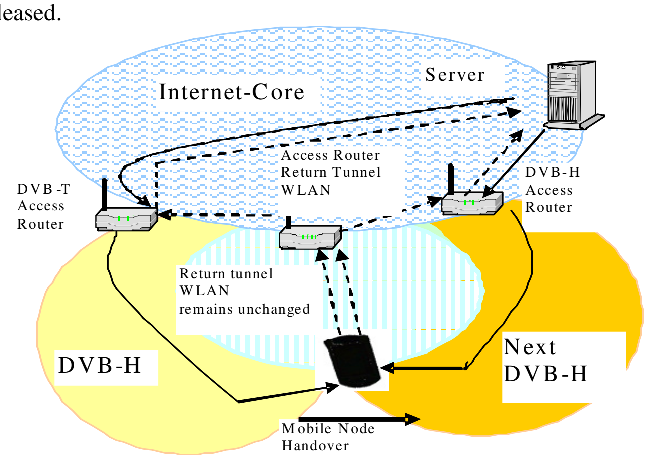

Fig. 4: Handover to a new unidirectional broadcast network with same mobile access network for "return" tunnel

In fig. 4, the mobile node moves between unidirectional access networks of the same type (DVB-H), but does not change its "return" channel WLAN. As result of this handover, a new "return" tunnel should be established from the WLAN access router to the IPv6 "feed" tunnel address at the next DVB-H access router.

The resources at the next unidirectional access networks have to be reserved. Because the "return" WLAN does not change, no resource reservation for the "return" tunnel at the wireless access network is needed. However, resource must be reserved at the Internet core network for the tunnel between the access router of the WLAN and the next DVB-H access router.

III. Seamless Handover to Unidirectionl Broadcast Access Networks in IPv6

A. *Interaction of Mobile IPv6 and LLTM*

Currently in the mobile IPv6, the configuration of a new CoA for the mobile node is defined based on the IETF documents for Neighbour Discovery [18], stateless [19] and stateful [20] address configuration, which do not specify special handling of mobile nodes receiving services from unidirectional broadcast networks.

The problem of a mobile node, which performs a handover to unidirectional broadcast networks in Mobile IP6 [7], is that the CoA address configuration needs a return channel:

- In the stateless auto-configuration, a return path is required to test the uniqueness of the IPv6 address with the Duplicate Address Detection (DAD) procedure;
- In the stateful address auto-configuration (e.g. DHCP), a return path is used to request the CoA address from the server.

At the time receiving the address prefix for the unidirectional broadcast access network, the mobile node may not know the IP return tunnel ("feed") address for the emulation of the return channel. The CoA address configuration will wait until the mobile node receives at the next unidirectional network the IP "feed" using the HELLO message specified in LLTM RFC 3077 [9].

In order to support unified handover technologies for interoperable broadcast and mobile networks in Mobile IPv6, our proposal is to obtain the IP "feed" addresses for the next broadcast access network together with the IP CoA address prefix for the next broadcast access network. This will allow following benefits for the convergent broadcast and mobile infrastructure

- Avoiding of the delayed reception of the IP "feed" using the HELLO message and QoS disturbances due to the later address configuration;
- Earlier knowledge of the capabilities of the IP "feed" allows to check the encapsulation method for the return tunnel and the availability of a routing path from the return wireless network to the IP "feed";
- Seamless operation of IPv6 multicast services in hybrid broadcast and mobile environment. Examples are services using Multicast Listener Discovery [21] and Independent Multicast Routing Sparse Mode (PIM-SM) [22] protocols.

The IP "feed" and their capabilities are contained in a data structures describing the "reverse tunnel info", as it is described in [14]. This structure can be used as enhancement of MIPv6 or Fast Handovers in order to establish dynamically the bidirectional connectivity of a mobile node moving to an unidirectional network.

B. *Integration of "reverse tunnel info" into Mobile IPv6*

In MIPv6, access routers advertise their presence and supply the network address prefix for stateless address auto-configuration using Router Advertisement Messages periodically (unsolicited), as well as in response to Router Solicitation messages sent by the mobile terminals. The "reverse tunnel info" can be integrated in the

"Options" Part of the Router Advertisement Message [7], as it is shown in fig. 5. When a mobile node performs a handover to the new "receive-only" unidirectional broadcast network, it may receive an unsolicited Router Advertisement Message with “reverse tunnel info” (see, fig. 5). After receiving of “reverse tunnel info” (i.e. IP “feed” and their capabilities), the mobile node can configure its CoA for the unidirectional broadcast network. For this purpose, it uses the return tunnel to the IP “feed” address.

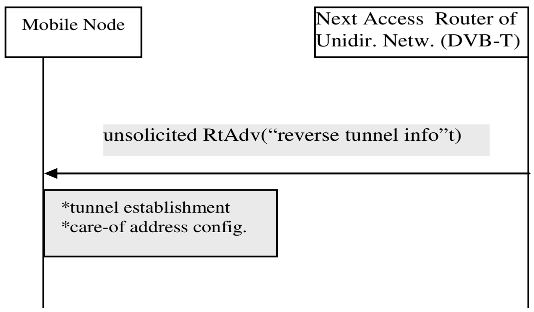

Fig. 5: Usage of “reverse tunnel info” in MIPv6

C. *“Reverse tunnel info” for MIPv6 Fast Handovers*

Fast Handovers for MIPv6 has been proposed in order to minimize the interruption during the handover experienced by the mobile node, when it changes its point of attachment [8]. It integrates two strategies for movement of mobile nodes called predictive and reactive handover. To advertise the address prefix of the new CoA, the Proxy Router Advertisement Message is used. A mobile node sends RtSolPr to its current access router to resolve one or more Access Point Identifiers (AP-ID)s to subnet-specific information. In response, the access router replies to the mobile node with a PrRtAdv message, which contains one or more elements describing access router capabilities [AP-ID, AR-Info].

In case of access routers for broadcast networks, the PrRtAdv message can be enhanced with an option including the “reverse tunnel info” describing the IP “feed” for the return tunnels established by LLTM. With the information included in the PrRTAdv message, the mobile terminal establishes the tunnel for the reverse channel emulation and configures the next CoA for the downstream unidirectional broadcast network. The enhancement of the MIPv6 Fast Handovers signalling with “reverse tunnel info” option and the corresponding message exchange in case of handover to unidirectional broadcast network is shown in fig. 6:

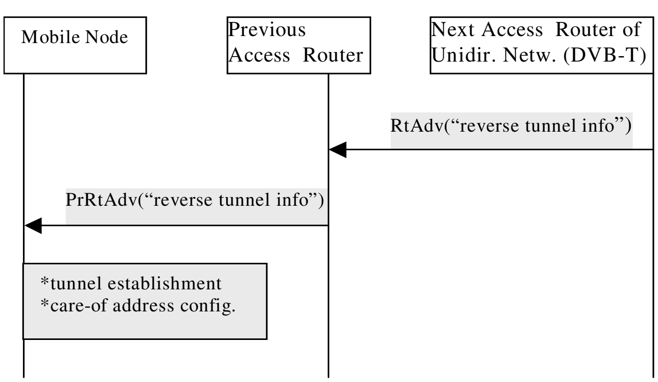

Fig. 6: “Reverse tunnel info” in Fast Handovers

D. *Information base for unidirectional network selection*

For seamless handovers in heterogeneous mobile Internet networks, addressing and capabilities information of access networks is required. The information about the capabilities of the unidirectional broadcast networks can include IP “feed” tunnel addresses and resources, which can be reserved for the tunnels. This information allows the selection of the optimal next access network for a mobile node and its services, when performing handover [26].

The Media Independent Information Services (MIIS), which are standardized by IEEE 802.21 [25], can be used in order to provide information on capabilities, resources and QoS parameters of access networks in a media independent way in order to support seamless handovers in heterogeneous IP environments. In particular, MIIS supports the sharing of information elements, such as QoS parameters, neighbour maps, data link layer information and availability of service reports. Currently, IEEE 802.21 is focused on bidirectional technologies including 802.11 (WLAN), 802.16 (WIMAX/Wireless MAN), 802.3 (Ethernet) and cellular technologies standardised by 3GPP.

In order to consider unidirectional networks, MIIS will need specifications of QoS and resource parameters for different directions separately. Further useful information is the description of the capabilities of the unidirectional access routers, such as QoS parameters for the downstream direction, return tunnels, the IP “feed” tunnel addresses, tunnel encapsulation protocols, as well as resources parameters, which can be requested for the return tunnel. Such information can be used to support the handover and multicast context transfer in a mobile IPv6 environment.

The QoS information can be delivered also by using of the Candidate Access Router Discovery (CARD) protocol [6] in form of capabilities and attributes.

IV. QoS Management of Mobile Services Using Unidirectional Broadcast Networks

Interactive mobile broadcast services, such as multimedia content delivery and software downloads, are characterized by asymmetrical resource demands for the downstream broadcast and upstream return connection in terms of provided QoS parameters, such as bandwidth and delay.

The tuning of asymmetrical downstream (unidirectional) and upstream (return) channels for reliable transport can enhance the performance and is focus of research [23].

Figure 7 shows a scenario including QoS brokers, when the mobile node moves to the next unidirectional broadcast access network and needs to reserve resources separately for the unidirectional broadcast network and the return tunnel using the bidirectional WLAN.

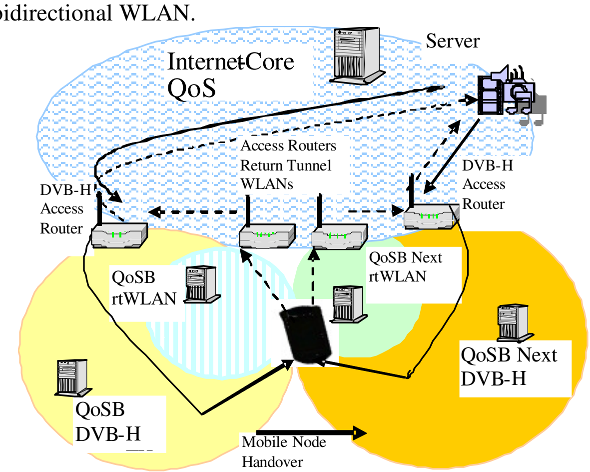

Fig. 7: QoS brokers in scenario with unidirectional access networks

In order to take advantage of the high bandwidth and the low delay of the unidirectional links for interactive and acknowledgment based multicast services, the flow control parameters for the unidirectional transfer should be defined taking into account the QoS and resource reservations for the return channel.

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

- The downstream (unidirectional) broadcast network and
- The upstream resources for the emulated return channel.

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

In DAIDALOS architecture, QoS brokers are responsible for resource reservation at core and access networks [24]. The access routers are requesting the resources for the mobile nodes sending signalling messages to the Access Network QoS Broker (AN–QoSB) and Core Network Access Broker (Core-QoSB).

Assuming content delivery and software download services, dependent on the SLAs for the applications and content providers, there are different schemes for resource reservation. In convergent broadcast and mobile IP environment, such reservation schemes are based on following approaches:

- *"Over-provisioning*" resource reservation for core network based on long term reservation in advance of resources for application in the core network combined with on-demand (immediate) QoS reservation in the access networks. Content providers can use such "over-provisioning" schemes for applications, which delivery can be planned, such as video streaming and data content delivery. This scheme simplifies the resource reservation in mobile environments requesting no resources from Core-QoSB.
- *"On-demand"* resource reservation for core networks and access networks. This scheme can be used for applications requesting bandwidth on-demand, as for instance real-time, emergency and mission critical multimedia data, GRID and medical applications.

In the "on-demand" scheme, the AN-QoSBs reserve resources at the unidirectional access network for the downstream connection and at the access mobile networks for the upstream connection. At core network, the Core-QoSB must also reserve resources for:

- The downstream channel from the application source to the access router of the unidirectional broadcast access network;
- The return tunnel between the access router of the bidirectional network and the access router of the unidirectional technology;
- The upstream traffic between the access router of the unidirectional broadcast network and the content server.

V. Conclusion

In order to support interactive multimedia and streaming content delivery to mobile terminals using combined broadcast and mobile IPv6 environments, enhancement of Mobile IPv6 protocol with "reverse tunnelling info" option is proposed. Extensions of the information bases and services about network capabilities (such as IEEE 802.21) with descriptions of unidirectional broadcast networks and their reverse access network channels support the QoS-aware selection of the broadcast media during the handover The proposed interaction of Mobile IPv6 and LLTM protocol allows:

- Deployment of hybrid mobile and broadcast network infrastructures using standardized platforms, such as IP Datacast,
- Rapid introduction of new interactive mobile content delivery applications (including mobile TV with interactive channel) using unified QoS interfaces for broadcast and wireless services.

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