ICT-MobileSummit 2009 Conference Proceedings
Paul Cunningham and Miriam Cunningham (Eds)
IIMC International Information Management Corporation, 2009
ISBN: 978-1-905824-12-0

Towards efficient integration of unidirectional links into LMDs

David WAGNER[1], Jens MOEDEKER[2], Karl JONAS[3]
[1]*Fraunhofer Institut FOKUS, Schloss Birlinghoven, 53754 Sankt Augustin, Germany*
Email:david.wagner@fokus.fraunhofer.de
[2]*Fraunhofer Institut FOKUS, Schloss Birlinghoven, 53754 Sankt Augustin, Germany*
Email:jens.moedeker@fokus.fraunhofer.de
[3]*Fraunhofer Institut FOKUS, Schloss Birlinghoven, 53754 Sankt Augustin, Germany*
Email:karl.jonas@fokus.fraunhofer.de

Abstract: This paper presents and discusses several approaches to integration of unidirectional links like DVB-H / DVB-T into heterogeneous Localised Mobility Domains (LMDs) with support for multihoming. The assessment of these approaches is focused on the efficiency of routing and the overhead caused by tunnelling mechanisms. It also provides an outlook on further research in the integration of unidirectional links into the future internet.

1. Introduction

In the last years the development of mobile usage of networks is characterised by a huge increase of diversity concerning the available technologies as well as the available end user devices. Current mobile internet devices cover a range from (still rare) sensor nodes, mobile phones, PDAs to netbooks and powerful notebooks. Nowadays most of these devices are equipped with several wireless technologies which are able to provide internet connection based on different standards. Current mobile phones offer at least GSM, UMTS and Bluetooth, high end devices also offer WLAN (802.11b/g) and DVB-H/-T receivers. On one hand there has been reasonable research into integrating these unidirectional broadcast links like DVB-H seamlessly into 4G environments [1][2] including proposals for mobility and QoS support [3]. On the other hand the option to have several interfaces concurrently active on a mobile node (MN) is attractive because of the increased available bandwidth and the higher flexibility: seamless make-before-break handovers of flows from one interface to another can be easily facilitated. This situation is called multihoming and is a current research and standardisation topic [4], e.g. Mobile IPv6 will be extended by multihoming support [5]. Unfortunately the use of Global Mobility Protocols like Mobile IPv6 causes quite a lot of signalling traffic and handover delays that are much higher than caused by link layer handover and IP address configuration [6]. Therefore a lot of research [7] was done to handle mobility in so called Localised Mobility Domains (LMDs) without using Global Mobility. In this paper the special situation of the integration of unidirectional links in heterogeneous LMDs supporting multihoming will be studied.

In the next section the common way of integrating unidirectional links [8] will be presented as it was implemented in the DAIDALOS2 project [9] followed by a short introduction to Localised Mobility Domains. Section 4. shows three different approaches to integrate unidirectional links into LMDs, which will be reviewed in section 5. This section includes an analysis of which approach is best suited for which network situation. Section 6. gives an outlook on future work and the last section draws first conclusions.

2. Common approach to integrate unidirectional technologies

Since most protocols, applications and services inherently assume a link to be bidirectional it is necessary to provide a bidirectional interface to these protocols for a seamless integration of broadcast links. Therefore all presented approaches emulate bidirectional link-layer connectivity and provide a virtually bidirectional interface.

The established "Link Layer Tunneling Mechanism" presented in RFC 3077 [10] assumes the nodes to be multihomed and makes use of a second bidirectional link. For each physical unidirectional interface a virtually bidirectional interface is set up. The frames sent to that virtual interface are tunnelled to the access router (AR) of the unidirectional network using the bidirectional internet connection, see figure 1. This AR terminates the tunnel and forwards the packets to their destination. By tunnelling link layer frames the tunnelling requires more bandwidth than a higher layer tunnelling but it is transparent to all higher layers.

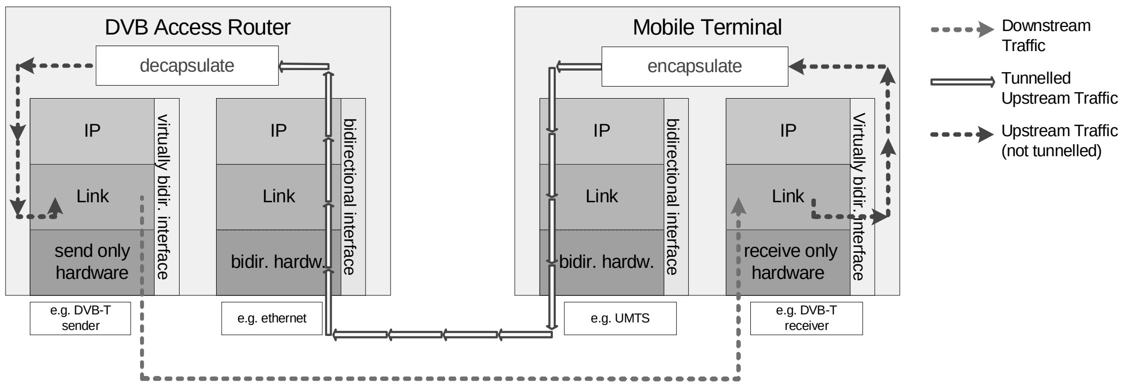

Figure 1: Link Layer Tunneling Mechanism

This guarantees that protocols of layer 3 and above, namely of the IP protocol family (IPv4, IPv6, ICMP, ARP...), work smoothly without any modification. Only the driver providing the interface needs to be installed on the system, the TCP/IP stack remains untouched. Although the choice of the tunnelling protocol is left open, the usage of standardised protocols like GRE allows independence from the network operator of the bidirectional link used for the tunnel. In particular the two networks (unidirectional and bidirectional) may be owned and operated by different companies, although in this case most probably an encrypted tunnelling protocol would be preferred. On the other hand this approach results in suboptimal routing: all packets sent from layer 3 protocols, namely the IP stack, to the virtual interface will be first tunnelled to the AR of the unidirectional link, decapsulated at this node and then forwarded to their destination.

3. Heterogeneous Localised Mobility Domains with support for Multihoming

The IETF formed a working group called "Netlmm" which addresses the idea to locally manage mobility in certain domains so that neither the Mobile Nodes (MN) nor their communication partners (correspondent nodes, CN) have to change their protocols or behaviour. The Netlmm WG has published a problem statement [6] and defined the goals [11] of Network-based Localised Mobility Management in RFCs. The motivation is to reduce the handover latencies and the signalling traffic and at the same time to protect the MNs privacy better. IPv4 and IPv6 shall be supported without changes to the protocol.

The general architecture of such a domain is based on two elements: the so called Local Mobility Anchors (LMAs) and the Mobile Access Gateways (MAGs). The LMA(s) of an LMD manage the information concerning where and which MNs are connected and provide forwarding packets for these nodes to their current MAG. The MAGs monitor attachment and movement of MNs and inform the respective LMA about changes.

There are several proposals which shall achieve these general goals. Some approaches make sure that MNs don't change IPs while moving within the same LMD by having address configuration coordinated by the LMA. Thus an MN will always get the same IP after reattachment [12]. Concerning multihomed MNs there are proposals to assign the same IP to all active interfaces connected to the LMD [13]. This makes sure that devices with several active interfaces won't change their IP address even for soft handovers between different access technologies. These LMDs that cover heterogeneous access networks and support multihomed MNs (hmLMDs) are the most interesting and promising ones and therefore this paper focuses on their properties. The concurrent use of one IP address for several interfaces of an MN means that IPs can't be used for routing decisions in the usual way. The packet routing is therefore a very important and interesting issue which can be handled on a flow or even packet basis. In Proxy Mobile IPv6 [12] environments the Service Selection [14] mechanism may be used to manage the binding of flows but this is based on bidirectional links and can't be used for unidirectional ones without adaptation. Nevertheless these mechanisms are out of scope in this paper.

4. Integration of unidirectional links into LMDs

The simplest approach to integrate unidirectional networks into hmLMDs while keeping the TCP/IP stack untouched is to apply the usual LLTM to LMDs as illustrated in figure 2. In the following three more efficient approaches will be presented which are suited for different scenarios.

4.1 LMA based approach

One property of an LMD is that all packets to a specific MN pass the LMA. Therefore the LMA can serve as tunnel endpoint as it does the MAG-DVB in the usual LLTM approach. There are two ways to implement this: on one hand the MAG-DVB could inform its MNs that the tunnel endpoint IP address is the one of the LMA. On the other hand the LMA could know all its MAGs serving undirectional networks and the tunnelling protocols in use. With this information the LMA could identify the tunnel packets to a MAG-DVB, intercept them, decapsulate the layer 2 frames and forward them transparently to their destination. The main advantage of this strategy is that it works transparently for the MAG-DVB, the MNs and the CN. Therefore the LMA could even switch from this mechanism to the usual LLTM and vice versa seamlessly without any changes on MAG-DVB and MNs. Figure 3 shows the packet flow of a communication with a CN outside the LMD. Since this approach is aimed to be layer 3 transparent it is necessary to to keep up the integrity of the logical layer 2 domain of the unidirectional link. Therefore frames which don't contain IP packets or IP packets to non-global IP addresses (e.g. private addresses for IPv4, link local addresses for IPv6, multicast addresses) have to be tunnelled to the MAG-DVB.

The MAG-DVB decapsulates these frames and forwards them to their destination in particular broadcasts frames on the unidirectional link. This is necessary to make work classical mechanisms for address resolution like ARP or Neighbor Discovery and multicast listener management protocols like IGMP or MLD.

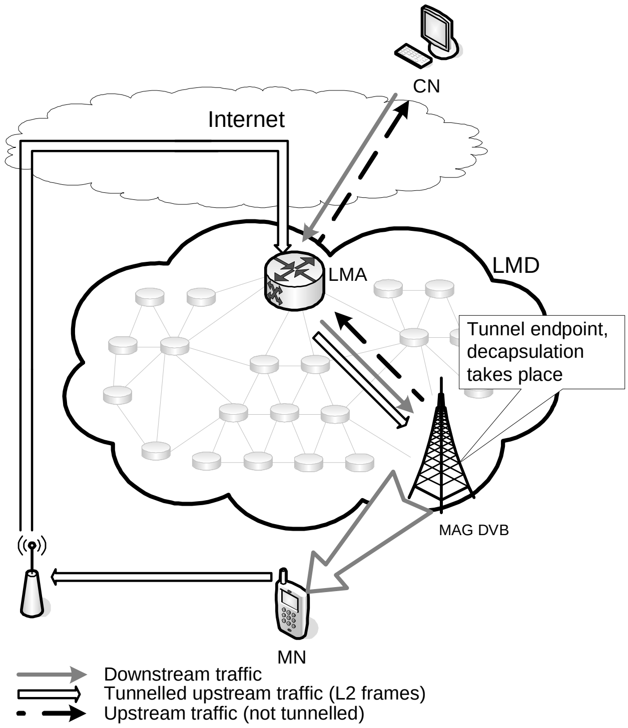

Figure 2: usual integration using LLTM

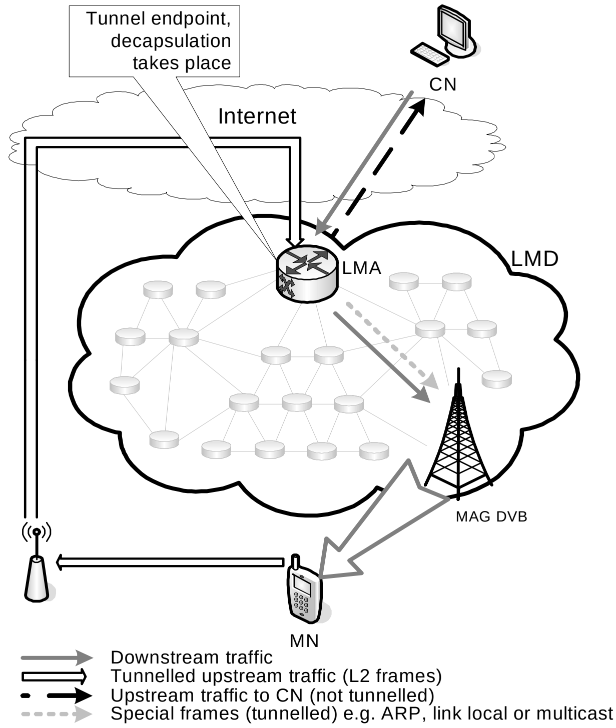

Figure 3: LMA based approach

4.2 *MAG based approach*

Another approach is to terminate the tunnel at the bidirectional MAGs and to route the packets optimally from there on which is shown in figure 4. If the MNs shall be able to use common protocols like ARP, IGMP or MLD it is also necessary for this approach to filter the decapsulated frames and to tunnel the frames mentioned above to the MAG-DVB. This approach does not rely on the bidirectional MAG being in the same LMD as the unidirectional MAG. Nevertheless another operator is not expected to provide that service in order to decrease the load of the LMD-operator's infrastructure. This approach would also fail if the operator of the LMD accepts only encrypted tunnelling from outside of his network. Therefore it is assumed that this approach most probably will only be avaible for MAGs belonging to the same LMD.

4.3 *MN based approach*

The third approach differs from the others as it requires support for asymmetric routing, i.e. routing based on unidirectional flows. In particular the MN has to route the return traffic for a specific transport layer connection via another interface than the one which receives packets for this connection. Of course also the LMA has to support management of unidirectional flows but this can be achieved quite easily: if the LMA doesn't apply reverse path filtering the default routing / tunnelling mechanisms will be sufficient. Please note that if standard IP mechanism like ARP or Neighbor Discovery shall be used by the MNs it is still necessary to provide some kind of tunnelling these messages to the MAG-DVB. This tunnelling can be executed by the MN directly as depicted in figure 5 or by the MAG of the bidirectional network. Nevertheless it is quite likely to have some adaptions or general evolution of protocols before such scenarios will take place.

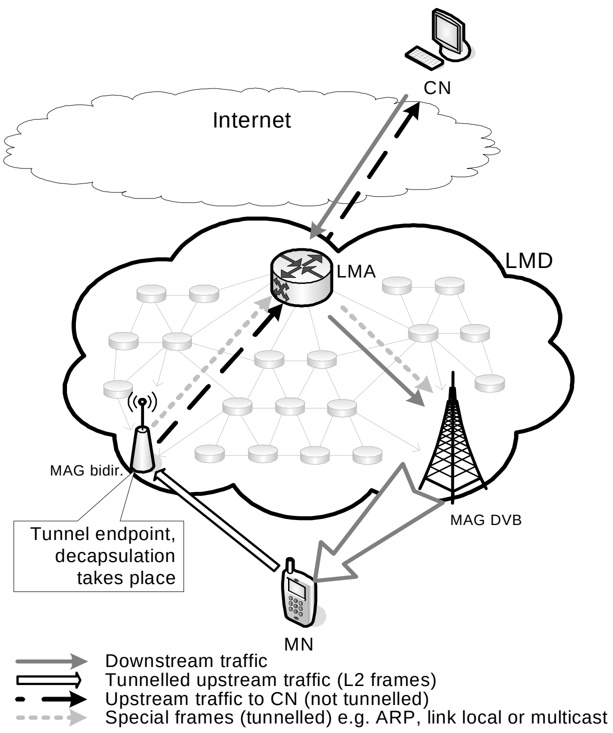

Figure 4: MAG based approach

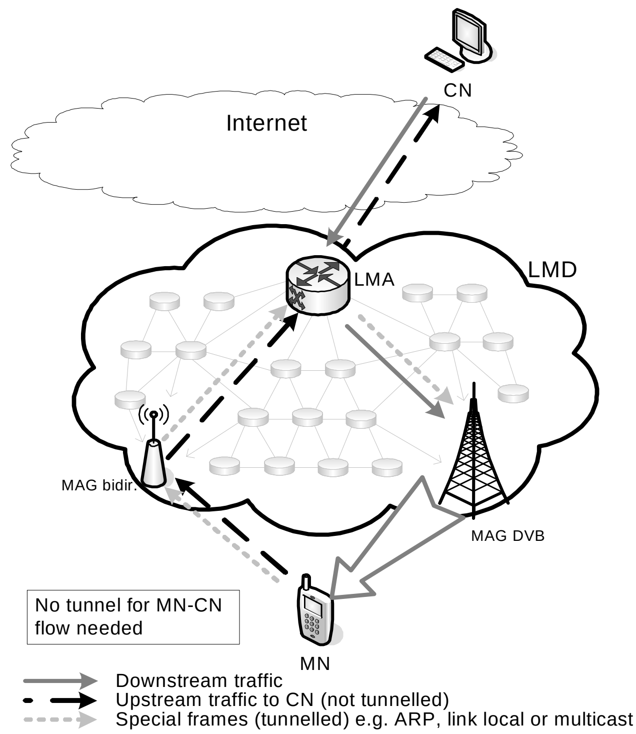

Figure 5: MN based approach

5. Review of the presented approaches

In the following the advantages and limitations of these three approaches as well as deployment scenarios shall be discussed.

One big advantage of the LMA based approach is that there are no necessary changes on the MNs or the MAG-DVB and the bidirectional interface used for the tunnelling may be connected to a network outside of the LMD or even to a network of another operator. Therefore this approach will allow more and more flexible business models than others. However, a drawback of this approach is the bandwidth consumption in the bidirectional access networks due to the link layer tunnelling. It also imposes additional load on the LMA because it has to manage the tunnels of all unidirectionally connected MNs. Please note that the transparency of this approach allows the LMA to switch to the usual LLTM at any point of time and even only for some flows / packets by simply forwarding all tunnelled packets to the MAG-DVB.

The MAG based approach does not put additional load on the LMA but its deployment scenarios are more limited: on one hand this approach limits the usage of the unidirectional link to MNs which are connected to bidirectional networks belonging to the same LMD. On the other hand all MAGs whose coverage overlaps with the unidirectional cell have to be equipped with appropriate software and resources to cope with the tunnel termination.

The MN based approach has the huge advantage that tunnelling is required only for very few packets. Therefore this is the only approach which saves bandwidth on the air interface in comparison to the common LLTM mechanism. Moreover there is no need to provide additional resources in the network for tunnel termination. The drawbacks are higher requirements to the MN: it has to be able to manage unidirectional flow routing and for return traffic it can only use bidirectional access networks of the same LMD. Compared to the other approaches the MN based approach is the most efficient solution for integration of unidirectional networks into LMDs but it can be deployed in a very limited range of scenarios because of its high requirements to the LMD and the MN.

Since broadcast networks usually cover thousands of nodes and users it is expected that they will be mainly used for very popular services and content common to many users at the same time. A good example would be the transmission of sports events including some kind of interactive elements e.g. polls or advertisements. In such a scenario there would be very limited packets sent from each listener node e.g. IGMP / MLD reports, RTCP messages and the packets for the interactive parts of the service invoked by the user. Since bidirectional networks like WLAN or UMTS are much smaller the nodes connected to the broadcast cell are distributed among many bidirectional access networks so the load for return traffic in each of these networks will be low. Having such scenarios in mind the difference in bandwidth consumption of the presented approaches may be negligible but issues like load on central components, latency and privacy may be more important.

All in all the value of each approach may differ for each MN because it depends on the exact scenario and situation of the MN.

6. Outlook on future work

Concerning the use of unidirectional networks there are two issues which will require further research: the tunnelling with the associated overhead and the broadcasting of frames from MNs. There will be further research into dynamic tunneling approaches as well as adopted broadcasting filters. Nevertheless these approaches should provide a seamless integration without the need to modify the TCP/IP stack

Concerning the integration of undirectional links into LMDs there is further research required, too. Since candidate technologies like DVB-T/-H / DMB / MediaFlow cover larger cells with diameters of several kilometers most likely some MNs in the unidirectional network will not be able to connect to a bidirectional network of the same operator. Therefore the support for the LMA based approach or the usual mechanism will be desirable. On the other hand an operator is expected to offer his clients the most efficient and flexible solution which is the MN based approach. The best answer to these contradicting requirements is a deployment which supports these two or even all approaches. This is possible if the LMA manages this state for each MN or even flow and configures the MAGs respectively. This management should be closely connected to the management of the assignment of flows to the active interfaces of the MNs. A special issue here is the selection of a unidirectional interface if several interfaces of one MN share the IP address.

So one aspect of future work will be development of a policy based architecture to define and store Service Level Agreements (SLAs), negotiate, store and enforce policies for a flow based network management in heterogeneous LMDs with multihoming support.

7. Conclusion

In this paper it was outlined how the LMD concept could provide a suitable environment to make efficient use of unidirectional networks like DVB-T/-H. The aptitude of the different approaches depends heavily on the concrete scenario and network situation. One interesting feature is that all presented approaches may be deployed in one LMD and even in one access network at the same time if necessary management information and filters can be provided to the respective network elements. For this purpose one can imagine a policy based network management system that suggests or even forces the application of a specific mechanism depending on the SLA of the specific identity and on the availability of resources.

References

[1] S. Sargento, T. Melia, A. Banchs, J. Moedeker, and L. Marchetti, "Mobility through heterogeneous networks in a 4g environment," in *Wireless World Research Forum (WWRF) 17th Meeting, Heidelberg, Germany*, 2006.

[2] T. Buburuzan, G. May, T. Melia, J. Moedeker, and M. Wetterwald, "Integration of broadcast technologies with heterogeneous networks - an ieee 802.21 centric approach," in *Proc. Digest of Technical Papers. International Conference on Consumer Electronics ICCE 2007*, pp. 1–2, 10–14 Jan. 2007.

[3] I. Miloucheva, J. Moedeker, and K. Jonas, "Seamless handover for unidirectional broadcast access networks in mobile ipv6," *Journal of communications*, vol. 2, no. 6, pp. 46–55, 2007.

[4] T. Ernst, N. Montavont, R. Wakikawa, C. Ng, and K. Kuladinithi, "Motivations and scenarios for using multiple interfaces and global addresses." internet-draft (work in progress), May 2008. INTERNET-DRAFT draft-ietf-monami6-multihoming-motivation-scenario-03.txt.

[5] R. Wakikawa, V. Devarapalli, T. Ernst, and K. Nagami, "Multiple care-of addresses registration." internet-draft (work in progress), Aug. 2008. INTERNET-DRAFT draft-ietf-monami6-multiplecoa-09.txt.

[6] J. Kempf, "Problem Statement for Network-Based Localized Mobility Management (NETLMM)." RFC 4830 (Informational), Apr. 2007.

[7] "Netlmm status page." http://tools.ietf.org/wg/netlmm/.

[8] M. Almeida, S. Sargento, and R. L. Aguiar, "Limitations of the integration of dvb technologies in a heterogeneous environment," in *Proc. IEEE Vehicular Technology Conference VTC Spring 2008*, pp. 2177–2181, 11–14 May 2008.

[9] "Ist project daidalos." http://www.ist-daidalos.org.

[10] E. Duros, W. Dabbous, H. Izumiyama, N. Fujii, and Y. Zhang, "A Link-Layer Tunneling Mechanism for Unidirectional Links." RFC 3077 (Proposed Standard), Mar. 2001.

[11] J. Kempf, "Goals for Network-Based Localized Mobility Management (NETLMM)." RFC 4831 (Informational), Apr. 2007.

[12] S. Gundavelli, K. Leung, V. Devarapalli, K. Chowdhury, and B. Patil, "Proxy Mobile IPv6." RFC 5213 (Proposed Standard), Aug. 2008.

[13] V. Devarapalli, N. Kant, H. Lim, and C. Vogt, "Multiple-interface support with proxy mobile ipv6." internet-draft (work in progress), Aug. 2008. INTERNET-DRAFT draft-devarapalli-netlmm-multihoming-03.txt.

[14] J. Korhonen, U. Nilsson, and V. Devarapalli, "Service Selection for Mobile IPv6." RFC 5149 (Informational), Feb. 2008.