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Multicast Context Transfer in mobile IPv6
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Abstract

Protocol mechanisms for fast mobile multicast in IPv6 based on multicast listening context transfer are proposed.
The focus is the context transfer for mobile multicast listeners using Multicast Listener Discovery protocol Version 2 (MLDv2).
Multicast context transfer block and operational considerations for optimised multicast context transfer based on Fast Handovers for Mobile IPv6 and Candidate Access Router Discovery are described.
The requirements for MLDv2 context extension and operation at access

routers to support multicast context transfer for mobile IPv6 are specified.
Interactions of MLDv2 with Protocol Independent Multicast Sparse Mode (PIM-SM) for multicast routing state update based on multicast listening context transfer are overviewed.
Operational considerations for MLDv2 and PIM-SM to support multicast receiver and source mobility based on context transfer are discussed.
Comparison with other multicast protocol proposals for Mobile IPv6 (MIPv6) is given.

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1. Introduction

Context transfer is proposed for mobile nodes for quickly re-establishment of their services when the nodes move and change their access routers [13].

The Context Transfer protocol (CTP) [6] designed by the IETF Seamoby WG as Experimental protocol for usage in Mobile IPv4 and MIPv6 environment is aimed to provide general mechanisms for exchange of context data for moving mobile nodes between access routers.
In the Appendix B of CTP specification [6], an example for multicast listener context transfer in IPv6 considering MLD [RFC2710] is given.
In this example, for each active multicast group at the access router MLD context is established.
Because the access routers does not distinguish between MLD contexts of individual nodes, all MLD contexts established for subscribed multicast group addresses, which are attached to a given link at the previous

access router, are transferred to the next router during the handover.

This causes additional network overhead and processing for creation of multicast contexts and route trees at the next access routers for multicast groups, which are not needed for the particular moving node.

The focus of the current draft is the efficient multicast context transfer considering the Multicast Listener Discovery Protocol (MLDv2) in mobile IPv6 (MIPv6) environment.
It is aimed to support seamless handover for mobile receivers using MLDv2 in case of Any Source [21] and Source Specific Multicast [24].

The work is based on the European project DAIDALOS [14], which goal is heterogeneous mobile networking including DVB-T and unidirectional links [15].

The multicast context transfer in DAIDALOS is designed to support applications, such as:
- Multicast file and streaming distribution
- Multiparty conference scenarios
- Multicast audio and video transmission
- DVB-T.

Mobile multicast in this framework is based on MLDv2 context transfer for mobile multicast receivers [17].

This Draft defines the multicast context transfer operations and data structures required for MLDv2 service re-establishment in Mobile IPv6. Facilities for optimised multicast context transfer based on the Fast Handovers proposal for MIPv6 [5] and Candidate Access Router Discovery (CARD) protocol [7] are overviewed.

Requirements for MLDv2 operation in case of context transfer and extension of MLDv2 protocol context at access routers to track information per individual nodes and their multicast groups are descried.
The interaction of MLDv2 and PIM-SM to support context transfer is specified.

The fast mobile multicast using context transfer is compared with other multicast solutions for IPv6 based on Fast Handovers for Mobile IPv6 [8] and Hierarchical Ipv6 Environment [9].

2. Terminology used in this document

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [9].
Mobility related terminology is defined in [10].

The Internet Protocol (IP) multicast service model for any source multicast (ASM) is defined in RFC 1112 [21]. Source specific multicast (SSM)

provides network-layer support for one-to-many delivery only and is defined in [19], [24], [23], [22].
Multicast Listener Discovery Version (MLDv2) for IPv6 is defined in [1] as extension of MLD [2]. PIM-SM is specified in [3], [4].
Abbreviations used in the following text:

AR	Access Router
MN	Mobile Node
CTP	Context Transfer Protocol
M-CTB	Multicast Context Transfer Block
ASM	Any Source Multicast
SSM	Source Specific Multicast
FBU	Fast Binding Update

3. Multicast context transfer

3.1. Protocol overview

The multicast context transfer is used in case of mobile node movement (handover) to provide and install the listening and routing control data for the multicast groups required for the active multicast services of the mobile node.
Considering the Context Transfer Protocol's messages and signalling flows [6], the context transfer for mobile multicast in IPv6 is defined.

Multicast listening in IPv6 is based on MLDv2 [1], which extends the MLD protocol [2] for Source Specific Multicast [19].
For multicast routing, MLDv2 provides the information on the active listeners of a particular multicast group to the multicast routing protocol. In this draft, PIM-SM [3], [4] is considered.

Dependent on the time of the context transfer activation, the context transfer could be based on:
- predictive signalling: context transfer starts before the handover, when the mobile node is connected to the previous access network.
- reactive: context transfer starts after the connection of the mobile node to the next access network.

The predictive and reactive strategies for usage of context transfer protocol are described in [6].

In the predictive scenario for multicast context transfer described in figure 1, the mobile node sends a message to the previous access router to activate the context transfer.

Context transfer is started with the context activation by the mobile node sending a message to the previous access router.
According [6], the context transfer initiation could also be based on internally generated (link layer 2 triggers).

```
                  +-----------------+        +------------------+
                  |access network   |        |access network    |
                  +-----------------+        +------------------+
                           |                        |
                           |                        |
               previous AR v                        v  next AR
                   +----------------+          +-----------------+
                   | MLDv2 context | M-CTB     | MLDv2 context   |
                   | per node and  | data      | update          |
   context         | aggregated    | --------->|                 |
   activate        |               |<--------- |                 |
              +--> +---------------+ CT reply  +-----------------+
              |            |                         |
              |            |multicast                | multicast
              |            |                         |
              | MN         v                   MN  v
          +--------------------+          +--------------------+
          |MLDv2 socket state |   handover  |MLDv2 socket state |
          |-------------------|   ------>   |-------------------|
          |                   |             |                   |
          +--------------------+          +--------------------+
```

Figure 1: Predictive scenario for multicast context transfer

After the context activation, the multicast context transfer block (M-CTB) is built at the previous access router in interaction with MLDv2.

The M-CTB includes the multicast addresses required for the multicast services of the moving mobile node. M-CTB is sent from the previous to the next access router in the Context Data message.

Receiving the context data message with the M-CTB, the next access router provides it to the MLDv2 protocol for updating the multicast aggregated context and establishement of an individual node MLDv2 context.
MLDv2 supplies the information from the M-CTB to the multicast routing protocol to build the routing context for the multicast addresses.

This document focusses mainly on the fast multicast and the above predictive scenario, when the context transfer is activated at the previous access router.

Further strategies for proactive context transfer could be based on sending a context activitate message to the next access router, which uses a CTP's Request message to obtain the context for the particular mobile node's multicast groups from the previous access router.

Due additional message exchange, this kind of proactive context transfer is not efficient for Fast Mobile Multicast.

Reactive scenarios are also slow for fast multicast and include additional overhead.
In these scenarios, the mobile node sends context transfer activation to the next access router after the handover [6].
To optimise context transfer of multicast services, this document studies in section 3.3. further strategies for context activation based on MIPv6 and its enhancements for Fast Handovers and Candidate Access Router Discovery.

3.2. Multicast context transfer block

The multicast context transfer block (M-CTB) includes the information required to re-establish the multicast listening and routing context for the moving mobile node at the next access router.
The multicast context transfer block is designed considering MLDv2 multicast address records [1]. It has the following structure:

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| NmbRec|       Access Point ID  (M_AP)                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| < ...... Multicast address records ........
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: Multicast Context Transfer Block

M-CTB includes following information:

- o NmbMrec - Number of following multicast address records for the access point ID
- o M_AP (48 Bit)û Access Point Identifier specifying the IEEE MAC address of layer 2 device at the next access router using which the mobile node will listen to the group.
- o List of multicast address records.

The M-CTB is included in the Context Data Block of the CTP protocol [6] as it is shown in figure 3:

```
  0                   1                   2                   3
  0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |   Feature Profile Type (FTP)  |  Length       |P|  Reserved    |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 |                     Presence Vector (if P = 1)                 |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 ~                Multicast Context Transfer Block   (M-CTB)      ~
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 3: Integration of M-CTB in CTP message

Considering the CTP specification [6], the fields in figure 3 are defined:

- o FPT - Identifies the type given for the Multicast Context Transfer Block (M-CTB). The value is defined by IANA.

- o Length (8-bit unsigned integer) - Message length in units of 8 octet words.

- o 'P' bit   0 = No presence vector
  1 = Presence vector present.

- o Reserved - Reserved for future use.

- o M-CTB   - M-CTB as defined in this section with length defined by the Length Field. If the data is not 64-bit aligned, the data field is padded with zeros.

The M-CTB consists of number of multicast address records describing the multicast listening state of the mobile node before moving the previous access network.
Each multicast address record has the following structure:

```
 +-+-+-+-+-+-+-+-+
 |  NmbS |F-Type |
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 *                       Multicast Address                       *
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
 *                       Source Address [1]                      *
 |                                                               |
 *                       Source Address [2]                      *
 .                               .                               .
 *                       Source Address [N]                      *
 +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 4: Multicast address record

The multicast address record is similar to the address record used in the MLDv2 report messages [1]. It includes filter options (F-Types) for source addresses and allows on this way to support SSM [25].

The Multicast record is defined by following descriptions:

- o NmbS (4 bit unsigned integer) - Number of source addresses specified for the multicast group. If the number is 0, then the following FilterType is not checked.

- o F-Type (4 bit unsigned integer) - specifies the filter type of the source addresses specifed for the multicast grpup.

Value	Name and Meaning
1	MODE_IS_INCLUDE - defined in [1]. Indicates that the interface has a filter mode of INCLUDE for the specified multicast address and source lists.
2	MODE_IS_EXCLUDE - defined in [1], Indicates that the interface has a filter mode of EXCLUDE for the specified multicast address and source lists.

o M_ADR (128 bit)û L3 (IPv6) multicast group address, to which the mobile node will listen at the link attached to M_AP. Multicast addresses for IPv6 architecture are defined in [20].

o SourceList û List of IPv6 source addresses (128 bit) to listen on the multicast group. The addresses are used as information for the multicast routing protocol (PIM-SM) to perform source specific multicast and pruning.

3.3. Optimised multicast context transfer

The section describes optimised multicast context transfer based on Fast Handovers MIPv6 environment and optimal next router selection using the CARD protocol is described.

3.3.1 Multicast context transfer for IPv6 Fast Handovers

IPv6 Fast Handovers has been proposed [16] to minimize the interruption in services experienced by a Mobile IPv6 node as it changes its point of attachment to the Internet.

IPv6 Fast Handovers begins when a MN sends RtSolPr to its current access router to resolve one or more Access Point Identifiers (AP-IDs) to subnet-specific information. In response, the access router sends a PrRtAdv message, which contains one or more [AP-ID, AR-Info] tuples.

With the AR-Info information included in the PrRTAdv message, the mobile node formulates a prospective next Care-of address establishing and sends Fast Binding Updates.
IPv6 Fast Handovers protocol integrates predictive and reactive handover strategies for mobile node movement using FBUs.

The multicast context transfer could be triggered by reception of the FBU Messages either at the previous or at the next access router:

- In the case of predictive handover, the FBU is sent to the previous access router and triggers the context transfer activation.

- Using the reactive handover, the FBU message is sent to the next AR.

It triggers a request for context transfer sent from the next access router to the previous.
As result of this, the previous access router answers with the context transfer data.

Predictive multicast context transfer triggered by FBU in Fast Handovers MIPv6 is given in figure 5;

```
    Mobile Node                  Prev-AR                       Next-AR
    |                                   |           RtAdv          |
    |                                   |          <---------------|
    |RtSolPr                            |                           |
    |---------------->                  |                           |
    |                                   |                           |
    |                  PrRtAdv          |                           |
    |                 <----------------|                           |
    |                                   |                           |
    |FBU                                |                           |
    |----------------->                 |                           |
    |                     M-CTB trigger*| Context Transfer(M-CTB)   |
    |                                   | ----------------------->  |
    |                                   |                           |
```

Figure 5: Predictive multicast context transfer in Fast Handovers MIPv6

Because the multicast context transfer is based on triggering using the FBU message, it is similar to the proposal in [8]. The difference is that [8] includes in the FBU the mobile node's multicast context data.

3.3.2 Multicast support with CARD protocol

The Candidate Access Router Discovery (CARD) protocol was designed to support the acquisition of information about the possible next ARs that are candidates for the mobile node's handover [7].
CARD protocol is used in EU project DAIDALOS [14] together with the Context Transfer protocol [6] and IPv6 Fast Handovers [16] for efficient handover aimed at optimization of service re-establishment in case of MIPv6 node handover.

There are different issues for candidate access router discovery [13].
CARD could be used for the selection of a next router, which has already established multicast listening and routing states for the multicast groups, required by the mobile node.
For this purpose the multicast context as defined in section 3.2. should be included as sub-option in the CARD Reply Signalling message exchanged between access routers and mobile nodes.

The steps in usage of CARD for selection of optimal multicast router are shown in figure 6:

```
   Mobile Node                   Prev-AR                           Next-AR
   |                                  |                                  |
   |                                  |AR-AR CARD Request                |
   |                                  |------------------->              |
   |                                  |                                  |
   |                                  |          AR-AR CARD Reply(M-CTB)|
   |                                  |             <------------------ |
   |MN-AR CARD Request                |                                  |
   |------------------ >              |                                  |
   |                                  |                                  |
   |           MN-AR CARD Reply(M-CTB)|                                  |
   |          <------------------------|                                  |
   |*selection of optimal CAR         |                                  |
   |*based on multicast context       |                                  |
   |                                  |                                  |
```

Figure 6: Selection of optimal multicast router based on CARD

4. Operational requirements for IPv6 Multicast protocols

4.1 Requirements for MLDv2

4.1.1. MLDv2 context extension

The following requirements concerns the operation and context maintained at the "router" part of the MLDv2 protocol.
The "host" part of MLDv2 and its contexts per socket and interface remain the same.

For multicast context transfer, MLDv2 must keep per node (host) multicast group listener status on the interface.

Currently, the MLDv2 is designed to support the ASM [21] and SSM [19] models.
The MLDv2 context at the multicast router keeps the aggregated node information for multicast interfaces based on which the multicast router knows that "at least one" node multicast on the attached link is listening to packets for a particular multicast address.

Considerations for the MLDv2 routers to track per-host multicast listener status on an interface are discussed in Appendix A.2 of the MLDv2 specification.
To provide Multicast Context Transfer in MIPv6, it is a requirement for MLDv2 to build a multicast listener context per host (node) at the multicast access router in order to supply information for the building of the Multicast Control block.

Figure 7 shows an entry of the context per mobile node extending the current aggregated MLDv2 context per given interface.

```
    +-+-+-+-+
    |       |
    |Nb-MRef|
    |       |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    *                      Mobile Node Address                      *
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
    |                                                               |
    *      MRef          |..........................................*
    |                                                               |
    +-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: MLDv2 context per node for a given link at the access router

The Multicast record is defined by following descriptions:

- o Nb-MRef (4 bit unsigned integer) - Number of references of the mobile node to entries in the aggregated MLDv2 context at AR. Each entry specifies a multicast group to which the mobile node is listening.
- o M-Adr (128 bit unsigned integer) - specifies the IPv6 address of the mobile node listening to the multicast groups and interfaces specified by MRef.
- o MRef - specifies the memory address of the entry in the aggregated MLDv2 context.

The proposed structures for extension of MLDv2 does not change the current aggregated context per interface and allow interoperation with existing MLDv2 implementations.

4.1.2 Operational considerations

Based on the multicast listener context per node, MLDv2 builds the M-CTB, as result of context transfer activation or triggering.
The M-CTB is supplied by MLDv2 to the Context transfer Protocol entity at the previous access router. It builds a valid context transfer data message and sends it to the next router.

Receiving the CTP message with the M-CTB, the CTP entity, the next AR supplies the M-CTB to the MLDv2 for further processing.
The processing of the M-CTB requires that MLDv2 changes the multicast context data at the next AR and invokes PIM-SM for building of multicast routing updates.

4.2 Requirements for multicast routing (PIM-SM)

Using the multicast context block, MLDv2 provides information to the

particular multicast routing protocol to build the routes and establish the routing context to the multicast addresses as required by the node. If routes already exist, nothing is done. Otherwise, the actions depend on the used multicast routing protocol.

In case of PIM-SM, there are different tasks for routing context establishment considering the M-CTB information.

- In case that in M-CTB a multicast group address (G) without sources is specified, the PIM-SM routing is required to perform (*, G) Join actions. This means a join to a route for all sources of the group.

- In case that M-CTB includes the option "INCLUDE" for a particular group address (G) and the source list (S), PIM-SM translates it in (S,G) join and uses the specification [4] to provide source-specific join.

- When M-CTB includes an multicast address record with the option "EXCLUDE" for the particular multicast group address (G) and source list (S), the (S,G,rpt) source-specific pruning actions should be performed as specified in [4].

5. Comparison with other IPv6 mobile multicast protocols

Mobility for IPv6 defines the multicast services for mobile nodes [5]. The proposed solution is slow, because it is based on the forwarding of the multicast packets by the Home Agents via the tunnel to the mobile nodes.

Multicast solutions extending mobile IPv6 multicast [5] are proposed for Fast Handover [16] and Hierarchical Mobile IPv6 environments [18].

The multicast protocol for Fast Handover MIPv6 [8] is based on integration of multicast flag in PrRtAdv message and multicast option in the Fast Binding Update. This option includes information describing the active multicast groups of the mobile node, for which the new access router should establish multicast listening and routing context.

The fast mobile multicast in the framework of Hierarchical Mobile IPv6 (H-MIPv6) and MIPv6 mechanisms is proposed in [9].
The multicast distribution is based on Mobility Anchor Points defined for the H-MIPv6 architectures. In M-HMIPv6, a mobile multicast node uses its local MAP as anchor point for multicast communication.
All multicast traffic is directed through this MAP using the Regional Care-of Address.
Traffic forwarding between MN and its MAP is done using a bi-directional tunnel. If a MN changes location within its MAP domain, it only registers its new Care-of Address with the MAP [D-HMIPv6], which does not affect multicast routing trees.

When entering a new MAP domain, a MN will be eager to sustain multicast connectivity via its previously established MAP.
Multicast handover procedures will occur, only if the MN changes into a new M-HMIPv6 enabled MAP domain, and will then shift multicast traffic from the previous to the current MAP.
In H-MIPv6, MLDv2 reports are extended with attendance code field to support multicast routing optimisation. The two approaches are based on extensions of specific protocols for seamless mobile handover in IPv6.

Compared with these approaches, multicast context transfer as proposed in the current Draft could be integrated in different mobile IP architectures as it is shown in section 3.1 and 3.3.
Because of the individual contexts at the ARs, a scalability problem dependent on the number of receiving mobile nodes arises.
In case of great number of mobile nodes using a particular access router for mobile multicast, performance degradation is possible, which should be considered in the design and implementation.

6. IANA considerations

IANA should record a value for identification of multicast context transfer block (M-CTB).

7. Further work

This draft specifies the multicast receiver mobility based on context transfer. It is intended for mobile nodes listening to multicast groups based on ASM model or subscribed to multicast channels using SSM.
Multicast source mobility in the context of SSM needs further work and specification.

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