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IGMP and MLD Extensions for Mobile Hosts and Routers
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Abstract

This document describes IGMP and MLD protocol extensions for mobile hosts and routers. IGMP and MLD are necessary protocols for hosts to request join or leave multicast sessions. While the regular IGMP and MLD protocols support communication between mobile hosts and routers over wireless networks, this document discusses the conditions how mobile hosts and routers use IGMP and MLD in their communication more effectively. Aside from a modified protocol semantic, an optional "Listener Hold" function for the IGMP and MLD protocol is introduced, which requires an extended signaling.

Conventions 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 RFC 2119 [1].

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1. Introduction

The Internet Group Management Protocol (IGMP) [2] for IPv4 and the Multicast Listener Discovery Protocol (MLD) [3] for IPv6 are the standard protocols for hosts to initiate joining or leaving multicast sessions. These protocols must be also supported by the upstream multicast routers that serve multicast member hosts or IGMP/MLD proxy [7] on their downstream interfaces. Conceptually, IGMP and MLD work on wireless networks. However, wireless access technologies operate on a shared medium with limited frequency and bandwidth. In many wireless regimes, it is desirable to minimize multicast-related signaling to preserve the limited resources of battery powered mobile devices and the constrained transmission capacities of the networks (e.g., [12]). Additionally, a mobile host may cause initiation and termination of a multicast service in the new or the previous network. Slow multicast service activation following a join may degrade reception quality. Slow service termination triggered by IGMP/MLD querying or by a rapid departure of the mobile host without leaving the group in the previous network may waste network resources.

To create feasible condition for mobile hosts and routers communicating IGMP/MLD, it is required to "ease processing cost or battery power consumption by eliminating transmission of a large number of IGMP/MLD messages via flooding" and "realize fast state convergence by successive monitoring whether downstream members exist or not". One possible approach to support these requirements is explicit tracking. Upstream router traces all downstream members, thereby limiting the number of solicited membership reports (by periodical IGMP/MLD Query). The number of transmitted IGMP/MLD messages is effectively reduced, and the upstream router can immediately update the membership information and proceed the fast leave.

The explicit tracking function is supported by IGMPv3 [2] and MLDv2 [3]. In the previous version protocols, IGMPv1 [4], IGMPv2 [5], and MLDv1 [6], a host would cancel sending a pending membership reports requested by IGMP/MLD Query if a similar report was observed from another member on the network. This specification effectively reduced a possibility of network congestion or message flooding, but precluded the function for an upstream router to track membership status. On the other hand, in IGMPv3 and MLDv2, the membership report suppression mechanism has been removed, and therefore all downstream member hosts must send their membership reports to an upstream router and the router can keep track of membership status.

If the report suppression mechanism is removed from the host-side protocols, the upstream router supporting IGMPv3/MLDv2 receives all

membership reports from the downstream hosts. One may deduce that the router does not need to periodically send IGMPv3/MLDv2 Query messages to trace membership status. However, IGMPv3/MLDv2 capable routers usually configure to send periodical IGMP/MLD Query messages to seek membership information to the downstream hosts, and disable the function that keeps track of membership status. One of the reasons is that IGMP/MLD message is non-reliable and may be lost in the transmission, and therefore the router would need to confirm the membership by sending query messages. The other reason is that, for keeping track of membership status, the router needs additional processing cost and a possibly large size of the memory to record all member information. The requirement to keep the compatibility mode with older version IGMP/MLD is also the reason, because the router needs to support the downstream hosts that are not upgraded to the latest versions of IGMP/MLD and run the report suppression mechanism.

IGMPv3 and MLDv2 provide the ability for hosts to report source-specific subscriptions. With IGMPv3/MLDv2, a mobile host can specify a channel of interest, using multicast group and source addresses with INCLUDE filter mode in its join request. Upon reception, the upstream router establishes the shortest path tree toward the source without coordinating a shared tree. This function is called the source filtering function and required to support Source-Specific Multicast (SSM) [8].

IGMPv3 and MLDv2 support another operation with EXCLUDE filter mode. When a mobile host specifies multicast and source addresses with EXCLUDE filter mode in the join request, an upstream router forwards the multicast packets sent from all sources *except* the specified sources. In fact, this operation gives the complexity in the host-side procedure. If any application running on a host requests an EXCLUDE filter mode operation, the host sets the interface state to EXCLUDE mode for the requested multicast address, and the source address list of the interface record is the intersection of the source address lists requested by all applications in EXCLUDE mode, minus the source addresses that appear in any application in INCLUDE mode. The state transition that maintains the interface record is complex, and the implementation cost will be relatively high for mobile hosts.

Furthermore, specifying non-interesting source addresses with EXCLUDE filter mode reduces the advantage of scalable routing tree coordination produced by SSM. An upstream router needs to maintain a shared tree (e.g., RPT in PIM-SM) whenever the router receives join request with EXCLUDE filter mode from the downstream hosts. This increases the tree maintenance cost to the multicast routers on the routing paths. While the mobile multicast communication does not prohibit a traditional (*,G) join request (which is a join request

with EXCLUDE filter mode without specifying any source address), all other join requests with EXCLUDE filter mode should be eliminated from the mobile multicast communication.

This document describes the IGMP and MLD protocol extensions for mobile hosts and routers, and discusses the conditions how mobile hosts and routers use IGMP and MLD in their communication over wireless networks effectively. The selective solutions that provide tangible benefits to the mobile hosts and routers are given by "keeping track of membership status by eliminating a report suppression mechanism", "varying IGMP/MLD Query types and values to tune the number of responses", and "using a source filtering mechanism in a lightweight manner". The proposed solutions do not require changing the IGMP and MLD protocols. This condition is advantageous to the deployment.

2. Configurations

2.1. Tracking of Membership Status

Mobile hosts use IGMP and MLD to request to join or leave multicast sessions. When the upstream routers receive the IGMP/MLD reports, they recognize the membership status on the LAN. To update the membership status, the routers send IGMP/MLD Query messages periodically as a soft-state approach does, and the member hosts reply IGMP/MLD report messages upon reception.

IGMP/MLD Query is therefore necessary to obtain the up-to-date membership information, but a large number of the reply messages sent from all member hosts may cause network congestion or consume network bandwidth. To escape from the trouble, a membership report suppression mechanism was proposed in the traditional IGMP and MLD [4][5][6]. By the report suppression mechanism, a host would cancel sending a pending membership reports requested by IGMP/MLD Query if a similar report was observed from another member on the network. However, the report suppression mechanism precluded the function for an upstream router to track membership status. In IGMPv3 and MLDv2, it is hence decided that the membership report suppression mechanism has been removed, and all downstream member hosts must send their membership reports to an upstream router.

By eliminating membership report suppression, an IGMPv3 or MLDv2 capable upstream router could trace all downstream members and track per-host membership status on the interface. This reduces the number of solicited membership reports by periodical IGMP/MLD Query, and finally the total number of transmitted IGMP/MLD messages can be drastically reduced. This is beneficial especially to mobile hosts that do not have enough battery power, since flooding IGMP/MLD messages on a LAN makes all multicast members give significant attention and induces power consumption to the member hosts. This also allows the upstream router to proceed fast leaves, because the router can immediately converge and update the membership information, ideally.

2.2. IGMP/MLD Query Coordination

2.2.1. Unicasting IGMP/MLD General Query

IGMP and MLD are asymmetric and non-reliable protocols; multicast routers still need solicited membership reports by periodical IGMP/MLD Query, in order to be robust in front of host or link failures and packet loss. Moreover, it happens that mobile hosts may turn off or move from the wireless network to other wireless network managed by the different router without any notification (e.g., leave

request). Therefore, even though multicast routers keep track of the interests of downstream member hosts attached on the same LAN, IGMP/MLD Query must be sent periodically.

However, periodical message flooding using the all-hosts multicast address (i.e. 224.0.0.1 or ff02::1) as its IP destination address gives the unwilling situation to the mobile hosts. When the mobile hosts are operating in dormant mode and not communicating with others, they should not be woken up by IGMP/MLD General Query and keep sleeping for saving the battery power. In this case, only the hosts that are receiving multicast contents should make the response to the router.

IGMPv3 and MLDv2 specifications [2][3] say that a host MUST accept and procss any Query whose IP Destination Address field contains any of the addresses (unicast or multicast) assigned to the interface on which the Query arrives. According to the scenario, a router may want to unicast the message to tracked member hosts in the [Unicast Query Interval], especially when a multicast router has a small number of mobile hosts that are listening different multicast sessions. In this situation, the router multicasts IGMP/MLD General Query with longer [Query Interval] (described in Section 2.2.3).

[TODO: Define [Unicast Query Interval] value. The value could be same of the default [Query Interval]?]

2.2.2. Multicasting IGMP/MLD Group-Specific Query

In the standard protocols [2][3], an IGMP/MLD Group-Specific Query is sent to verify there are no hosts that desire reception of the specified group or to rebuild the desired reception state for a particular group. The Group-Specific Query is sent when a router receives State-Change Records indicating a host is leaving a group, and never in response to Current-State Records.

In a dormant mode operation, a Group-Specific Query can be used to build and refresh the group membership state of hosts on attached networks. When more than one mobile host join the multicast contents whose multicast address is same, a Group-Specific Query can be sent to maintain the group membership state of mobile hosts on attached networks. Since a Group-Specific Query specifies the corresponding multicast address (not the all-hosts multicast address) as its IP destination address, dormant mode hosts that do not join any multicast session are not woken up by these specific Queries and only active group member hosts that have been receiving multicast contents would reply IGMP/MLD reports.

However, sending many Group-Specific Queries for all corresponding

groups may increase the total number of transmitted IGMP/MLD messages. [TODO: Therefore, it is necessary to know the condition in which a Group-Specific Query is used for maintaining the group membership state of all hosts on a link, instead of a General Query.]

The [Multicast Group-Query Interval] is the interval between Group-Specific Queries sent by the querier, i.e., the router that sends the Group-Specific Query. [TODO: Define [Multicast Group-Query Interval]. We currently think this value is same of the default [Query Interval] value the regular IGMP and MLD define [2][3].]

2.2.3. Values in IGMP/MLD Query

A multicast router operating in dormant mode keeps track of the membership status and checks the membership status by transmitting unicast IGMP/MLD General Query or multicast IGMP/MLD Group-Specific Query. Cooperating with these scenarios, the message interval between IGMP/MLD General Queries is set to longer than the default [Query Interval] value.

The Query Interval is the interval between General Queries sent by the querier, and the default value is 125 seconds [2][3]. By varying the [Query Interval], multicast routers can tune the number of IGMP messages on the network; larger values cause IGMP Queries to be sent less often.

[TODO: We will provide the appropriate [Query Interval] value that would fit in the mobile communication environment based on some experimental results. In our current sense, this value should be larger than the default value the regular IGMP and MLD define.]

The Query Response Interval is the Max Response Time (or Max Response Delay) used to calculate the Max Resp Code inserted into the periodic General Queries, and the default value is 10 seconds [2][3]. By varying the [Query Response Interval], multicast routers can tune the burstiness of IGMP messages on the network; larger values make the traffic less bursty, as host responses are spread out over a larger interval.

[TODO: We will provide the appropriate [Query Response Interval] value that would fit in the mobile communication environment based on some experimental results. In our current sense, this value should be less than the default value the regular IGMP and MLD define, because, while the larger Query Interval does not reduce the number of transmitted IGMP/MLD messages, it may cause slow leave latency.]

Mobile hosts may receive a variety of Queries on different interfaces and of different kinds (e.g., General Queries, Group-Specific

Queries, and Group-and-Source-Specific Queries), each of which may require its own delayed response.

[TODO: The timer management for each queries may or should be independent. E.g. the timer value for General Query should be longer than the one of other queries. We will investigate this issue.]

To cover the possibility of unsolicited reports being missed by multicast routers, unsolicited reports are retransmitted [Robustness Variable] - 1 more times, at intervals chosen at random from the defined range [2][3]. The QRV (Querier's Robustness Variable) field in IGMP/MLD Query contains the [Robustness Variable] value used by the querier. Routers adopt the QRV value from the most recently received Query as their own [Robustness Variable] value, whose range should be set between "1" to "7". While the default [Robustness Variable] value defined in IGMPv3 [2] and MLDv2 [3] is "2", the [Robustness Variable] value announced by the querier must not be "0" and should not be "1".

[TODO: We will propose the robustness values that would be adjusted according to the number of receivers. In our current sense, this value should not be bigger than "2" especially when the [Query Response Interval] is set to less than its default value.]

2.3. IGMP/MLD Querier Selection

[TODO: Is there any condition or assumption in which multiple multicast routers exist in a single wireless link? If there is the case, do we need to consider IGMP/MLD querier selection mechanism and the corresponding timer values or intervals? The Querier's Query Interval Code (QQIC) field specifies the [Query Interval] used by the querier may be tuned. The actual interval, called the Querier's Query Interval (QQI), is derived from QQIC. Multicast routers that are not the current querier adopt the QQI value from the most recently received Query as their own [Query Interval] value.]

3. Protocol Extensions

3.1. IGMP/MLD Hold and Release Operations

A mobile host sends a join/leave request for particular multicast session to its upstream router (i.e., a proxy router or an adjacent router), and the router will maintain IGMP/MLD state of the host and serve multicast data to the host. According to a fast handover scenario (e.g., using FMIPv6 [10]), a mobile host wants to accelerate multicast service termination in the previous network before handoff and immediately rejoin the session after the movement. As the router's behavior, when the router remains part of the multicast delivery tree, it keeps the session active without leaving from the session, while the data transmission is paused until the host completes the movement and resumed after the movement.

This document describes an IGMP/MLD Hold operation that enables to keep the membership state for fast packet forwarding, and an IGMP/MLD Release operation that ressumes forwarding the multicast session after the host movement. Originally, an idea of MLD Hold was proposed in [13].

Note that discussing the procedure of context transfer (CT) for each mobility protocol (e.g., FMIPv6, PMIPv6 [11]) and the message format for CT will be defined in other documents. And also, discussing how a mobile host or a router detects the movement and triggers to send an IGMP/MLD Hold message is depend on the mobility protocol, and hence out of scope of this document.

3.1.1. Action of Mobile Host and Router for IGMP/MLD Hold

An IGMP/MLD Hold operation is used to notify an upstream multicast router (e.g., HA in case of bidirectional tunneling, adjacent router in case of remote subscription) to stop forwarding data of the specified multicast sessions if there is no member joining the same sessions, but maintain the multicast membership on the router's interface the message was received.

When a mobile host starts moving from a network to a new network, the host or the gateway that detects the movement sends an IGMP/MLD Hold message (mentioned in Section 3.1.3) to its upstream router to make a fast handover for the specified multicast sessions.

When the multicast router receives an IGMP/MLD Hold message from a mobile host, it records the host's address and specified group and source address records and filter-mode, and stops the corresponding group or source timer until the IGMP/MLD Hold Timer (described in Section 3.1.4) is expired. The router does not send any Group-

Specific or Group-and-Source Specific Query upon reception of an IGMP/MLD Hold message.

After the router recognizes the IGMP/MLD Hold message, the router decides whether it stops forwarding the data or not. The decision is dependent on whether the router has been keeping track of membership status. If the router has been tracking all the members, it can recognize whether the message sender host is the last member joining the notified session on the interface or not. If the router has not been tracking, the router waits for receiving the next Current-State Report and recognizes whether the host is the last member joining the notified session on the interface or not. And if the message sender host is the last member, the router stops forwarding data by disabling the outgoing interface for that session, whereas it keeps the host's membership state. If the host is not the last member of the session, the router does not stop forwarding the data even with reception of this message.

3.1.2. Action of Mobile Host and Router for IGMP/MLD Release

An IGMP/MLD Release operation is used to restart forwarding data of the specified multicast sessions that are kept with the membership state at a router, or used to cancel the hold request previously notified by an IGMP/MLD Hold message.

When a mobile host moves to a new network, the host or the gateway that detects the movement operates IGMP/MLD Release by sending a standard IGMP/MLD Current-State Report message as mentioned in Section 3.1.3) to its upstream router to release the hold request previously sent.

When a multicast router receives an IGMP/MLD Current-State Report message, the router examines the message sender and an IGMP/MLD Hold Timer (Section 3.1.4). If the router has tracked the host's membership status, it compares the holding Multicast Address Records and notified Multicast Address Records specified in the IGMP/MLD Current-State Report message. Regarding the corresponding Multicast Address Records, the router will delete the host's membership state if it has, and restart the given group or source timer and forwarding the data again if the IGMP/MLD Hold Timer is not expired.

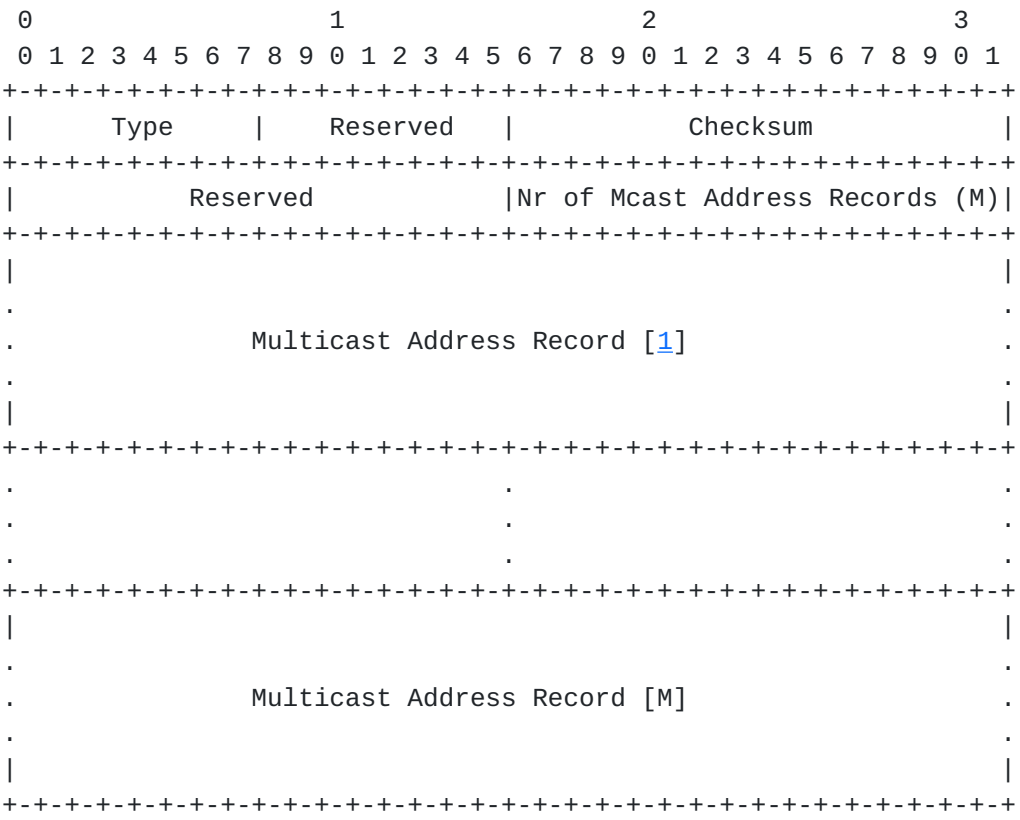
If either a multicast router has not tracked the corresponding membership status given by the host that sent the IGMP/MLD Current-State Report message, or if the IGMP/MLD Hold Timer has expired, then the router does not take any action.

If a router that did not recognize an IGMP/MLD Hold message (e.g., due to packet loss or some troubles in its transmission) receives an

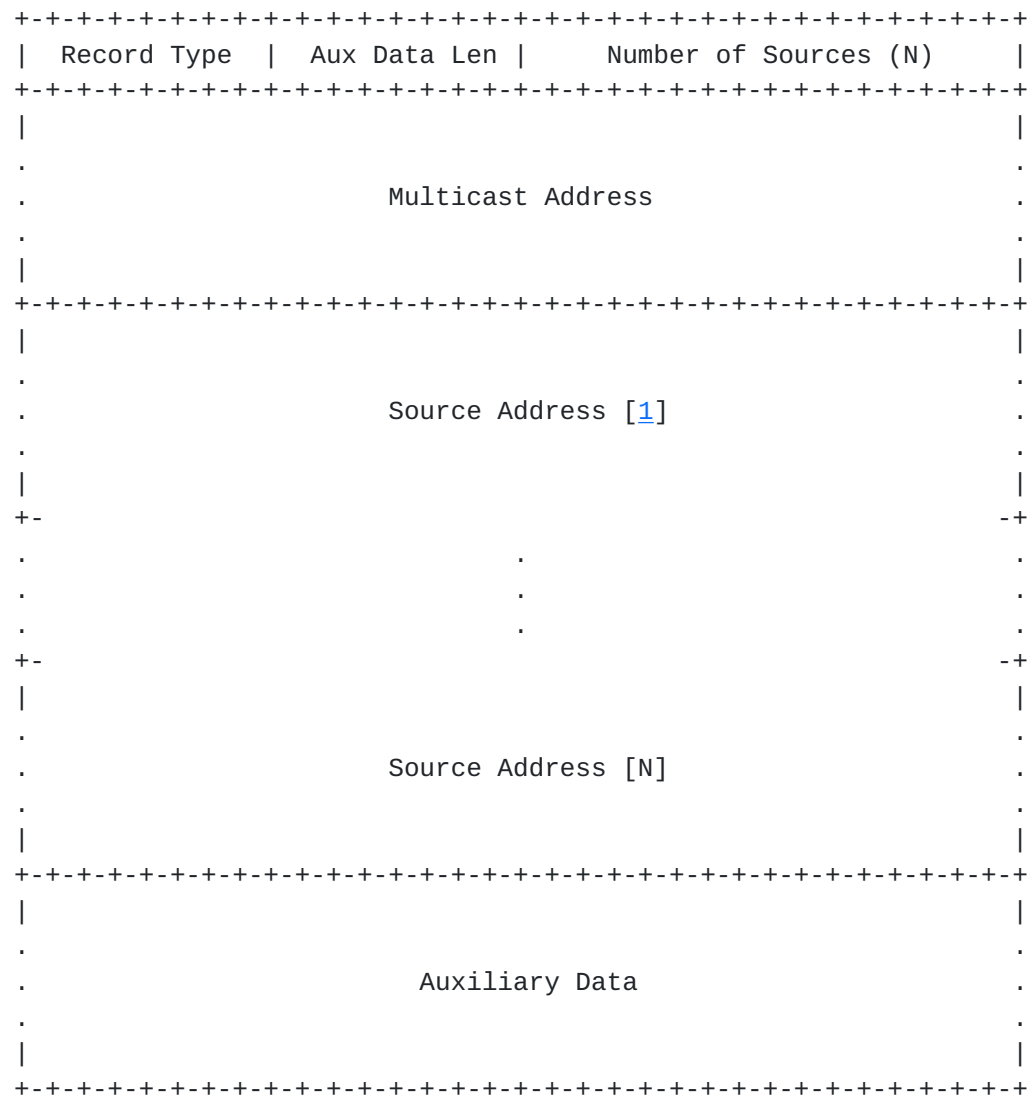
IGMP/MLD Current-State Report message, it will accept the message as a regular Current-State Report IGMP/MLD message as specified in Section 3.1.5.

3.1.3. IGMP/MLD Hold Message Format

The following figure is the Report message format defined in IGMPv3 [2] and MLDv2 [3]. Type field is either IGMP Version 3 Membership Report (0x22) or Version 2 Multicast Listener Report (decimal 143); it is not necessary to change IGMP/MLD Report message format to support IGMP/MLD Hold messages.



The Multicast Address Record shown in the following figure defines new Record Types that express an IGMP/MLD Hold message. For an IGMP/MLD Release operation, the standard IGMP/MLD Current-State Report message is used.



Value	Name and Meaning
7	HOLD_INCLUDE - indicates that the interface has a filter mode of INCLUDE for the specified multicast address. The Source Address [i] fields in this Multicast Address Record contain the interface's source list for the specified multicast address. A HOLD_INCLUDE Record is never sent with an empty source list.
8	HOLD_EXCLUDE - indicates that the interface has a filter mode of EXCLUDE for the specified multicast address. The Source Address [i] fields in this Multicast Address Record contain the interface's source list for the specified multicast address, if it is non-empty. When a mobile host works with

LW-IGMPv3/LW-MLDv2 (Section 3.2), the Multicast Address Record does not contain the Source Address [i] field with HOLD_EXCLUDE type value.

3.1.4. IGMP/MLD Hold Timer

A router upon receiving an IGMP/MLD Hold message will identify the corresponding multicast sessions for which the message was received, and once it accepts the request will wait for IGMP/MLD Hold Timer period for the sessions for allowing the router on the new link to resume the sessions. However, if it does not receive any IGMP/MLD Current-State Record message for an IGMP/MLD Release operation within that given amount of time, it will delete the hold membership state given by the IGMP/MLD Hold message and proceed as it receives IGMP Leave or MLD Done request.

[TODO: We will provide the appropriate [IGMP/MLD Hold Timer] value that would fit in the mobile communication environment based on some experimental results. Does it depend on mobile protocols?]

3.1.5. Interoperability of IGMP/MLD Hold and Release

If a multicast router does not support an IGMP/MLD Hold operation, it will ignore the IGMP/MLD Hold message. In this case, an IGMP/MLD Current-State Report message sent by a mobile host that previously requested an IGMP/MLD Hold operation to stop forwarding data is dealt with as a new join request for the specified multicast sessions (when the corresponding group or source timer is expired) or simply updates the corresponding group and/or source timer (when these timers are not expired and the membership status has been still active).

3.2. Lightweight-IGMP/MLD

IGMPv3 and MLDv2 enable all member hosts to send membership reports to the upstream routers. Not only this function, IGMPv3 and MLDv2 support a source filtering function. An IGMPv3 or MLDv2 capable host can tell its upstream router which group it would like to join by specifying which sources it does (or does not) intend to receive multicast traffic from. IGMPv3 and MLDv2 add the capability for a multicast router to also learn which sources are (and are not) of interest to neighboring hosts, for packets sent to any particular multicast address. This source filtering function is required to invoke Source-Specific Multicast (SSM) [8].

IGMPv3 and MLDv2 introduce antithetic filter modes, INCLUDE and EXCLUDE filter modes, to expand the source filtering function. If a host wants to receive from specific sources, it sends an IGMPv3 or MLDv2 report with the filter mode set to INCLUDE. If the host does

not want to receive from some sources, it sends a report with the filter mode set to EXCLUDE. A source list for the given sources shall be included in the report message. INCLUDE and EXCLUDE filter modes are also defined in a multicast router to process the IGMPv3 or MLDv2 reports. When a multicast router receives the report messages from its downstream hosts, it forwards the corresponding multicast traffic by managing requested group and source addresses.

However, practical applications do not use EXCLUDE mode to block sources very often, because a user or application usually wants to specify desired source addresses, not undesired source addresses. In addition, this scheme leads an implementation cost to mobile hosts and complex procedures to maintain coexisting situation of the interesting source address lists with INCLUDE filter mode or non-interesting source address lists with EXCLUDE filter mode.

Recently, Lightweight-IGMPv3 (LW-IGMPv3) and Lightweight-MLDv2 (LW-MLDv2) [9] are proposed in the IETF MBONED working group. These protocols are the simplified versions of IGMPv3 and MLDv2, and eliminate an EXCLUDE filter mode operation. Not only are LW-IGMPv3 and LW-MLDv2 fully compatible with the full version of these protocols (i.e., the standard IGMPv3 and MLDv2), but also the protocol operations made by hosts and routers are simplified in the lightweight manner, and complicated operations are effectively reduced. LW-IGMPv3 and LW-MLDv2 give the opportunity to grow SSM use.

In the lightweight protocols, EXCLUDE mode on the host part is preserved only for EXCLUDE (*,G) join/leave, which denotes a non-source-specific group report (known as the traditional (*,G) join/leave) and is equivalent to the group membership join/leave triggered by IGMPv2/IGMPv1/MLDv1.

The aim of LW-IGMPv3 and LW-MLDv2 is not only for contributing to the simpler implementation or reducing the memory size on a host. Another advantage is that it reduces the processing cost on upstream routers by eliminating the EXCLUDE filter mode operations. If both INCLUDE and EXCLUDE filter mode operations are supported in the networks, the routers need to maintain all source addresses joined from their downstream hosts. Even if a Shortest-Path Tree (SPT) is well coordinated, the routers need to refresh (and re-generate) some or all of the corresponding routing paths including the Rendezvous-Point Tree (RPT) whenever the downstream host requests EXLUDE filter mode join. LW-IGMPv3 and LW-MLDv2 preclude the unwilling situation. Since there is no side-effect, this document recommend to adopt LW-IGMPv3 and LW-MLDv2 to mobile hosts and routers, or eliminate EXCLUDE filter mode operation from mobile hosts if IGMPv3 and MLDv2 are adopted to hosts.

4. Implementations

4.1. Host-Side Implementation

Mobile hosts should implement IGMPv3 or LW-IGMPv3 for IPv4 multicast and MLDv2 or LW-MLDv2 for IPv6 multicast. All of these protocols eliminate a membership report suppression mechanism, and make hosts work with the function multicast routers use to trace downstream member hosts. These protocols also support SSM. According to the protocol requirement aforementioned, however, this document recommends to implement LW-IGMPv3 for IPv4 and LW-MLDv2 for IPv6 [9] rather than the full version protocols.

4.2. Router-Side Implementation

To keep track of multicast membership status and cooperate with SSM capable mobile hosts, multicast routers must implement IGMPv3/ LW-IGMPv3 or MLDv2/LW-MLDv2. Regarding the router-side implementation, the function to trace downstream members requires the hardware requirement that would cost the router additional hardware resources, especially CPU and memory resources.

[TODO: We assume that multicast routers are not tiny and non-powerful systems nor battery or power sensitive.]

As well as the host-side implementation, the elimination of the EXCLUDE filter mode will greatly simplify the router behavior, e.g. the action on reception of reports and the setting of the timers. This document therefore recommends to implement LW-IGMPv3 for IPv4 and LW-MLDv2 for IPv6 rather than their full version protocols. The detailed operation being simplified is described in [9].

5. Interoperability

TBD.

[TODO: We believe it would be currently feasible to assume the routers who take care of mobile hosts MUST be IGMPv3/MLDv2 capable (regardless whether the protocols are the full version or not). What we should understand is whether there is the case that mobile hosts may not be IGMPv3/MLDv2 capable or not.]

6. Security Considerations

TBD.

7. Acknowledgements

Dave Thaler, Matthias Waehlisch, and others provided many constructive and insightful comments.

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