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Lightweight IGMPv3 and MLDv2 Protocols
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Abstract

This document describes lightweight IGMPv3 and MLDv2 protocols (LW-IGMPv3 and LW-MLDv2), which simplify the standard (full) versions of IGMPv3 and MLDv2. The interoperability with the full versions and the previous versions of IGMP and MLD is also taken into account.

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].

Table of Contents

1. Introduction

IGMP version 3 [2] and MLD version 2 [3] implement source filtering capabilities that are not supported by their earlier versions, IGMPv1 [4], IGMPv2 [5] and MLDv1 [6]. 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 learn sources which are of interest or which are of not interested for a particular multicast address. This formation is used during forwarding of multicast data packets.

INCLUDE and EXCLUDE filter-modes are introduced to support the source filtering function. If a host wants to receive from specific sources, it sends an IGMPv3 or MLDv2 report with filter-mode set to INCLUDE. If the host does not want to receive from some sources, it sends a report with 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. Group timers and source timers are used to maintain the forwarding state of desired groups and sources under certain filter modes. When a group report arrives or a certain timer expires, a multicast router may update the desired or undesired source lists, reset related timer values, change filter mode, or trigger group queries. With all of the above factors correlating with each other, the determination rules become relatively complex, as the interface states could be frequently changed.

The multicast filter-mode improves the ability of the multicast receiver to express its desires. It is useful to support Source-Specific Multicast (SSM) [7] by specifying interesting source addresses with INCLUDE mode. 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. Even if a user wants to explicitly refuse traffic from some sources in a group, when other users in the same shared network have an interest in these sources, the corresponding multicast traffic is forwarded to the network. It is generally unnecessary to support the filtering function that blocks sources.

This document proposes simplified versions of IGMPv3 and MLDv2, named Lightweight IGMPv3 and Lightweight MLDv2 (or LW-IGMPv3 and LW-MLDv2). LW-IGMPv3 and LW-MLDv2 support both ASM and SSM communications

without a filtering function that blocks sources. Not only are they compatible with the standard IGMPv3 and MLDv2, but also the protocol operations made by hosts and routers or switches (performing IGMPv3/MLDv2 snooping) are simplified to reduce the complicated operations. Since LW-IGMPv3 and LW-MLDv2 are fully compatible with the full version of these protocols (i.e., the standard IGMPv3 and MLDv2), hosts or routers that have implemented the full version do not need to implement or modify anything to cooperate with LW-IGMPv3/LW-MLDv2 hosts or routers.

2. Terminology

Following notations are used in several places in this specification.

(*,G) join:
An operation triggered by a host that wants to join the group G. In this case, the host receives from all sources sending to group G. This is typical in the ASM communication.

(S,G) join:
An operation triggered by a host that wants to join the group G, with specifying desired source S. In this case, the host receives only from source S sending to group G.

INCLUDE (S,G) join:
An operation triggered by a host that wants to join a group G under INCLUDE filter-mode, with specifying desired source S. The same meaning of (S,G) join.

EXCLUDE (*,G) join:
An operation triggered by a host that wants to join a group G under EXCLUDE filter-mode. The same meaning of (*,G) join.

EXCLUDE (S,G) join:
An operation triggered by a host that wants to join a group G under EXCLUDE filter-mode, with specifying undesired source S. This operation is not supported by LW-IGMPv3/LW-MLDv2.

3. Simplification Method Overview

The principle is to simplify the host and router's behavior as much as possible to improve efficiency, while guaranteeing interoperability with the full versions, and introducing no side effects on applications.

For convenience, this document mainly discusses IGMPv3, since MLDv2 inherits the same source filtering mechanism, but this document additionally shows MLDv2's unique specifications when needed.

3.1. Behavior of Group Members

In LW-IGMPv3, the same service interface model as that of IGMPv3 is inherited:

```
IPMulticastListen ( socket, interface, multicast-address,
                    filter-mode, source-list )
```

In the lightweight protocol, INCLUDE mode on the host part has the same usage with the full version for INCLUDE (S,G) join, while EXCLUDE mode on the host part is preserved only for excluding null source-lists, which denotes a (*,G) join as used by IGMPv2/IGMPv1/ MLDv1. The detailed host operation of LW-IGMPv3/LW-MLDv2 is described in Section 4.

3.2. Behavior of Multicast Routers

Router filter-mode is defined to optimize the state description of a group membership [2][3]. As a rule, once a member report is in EXCLUDE mode, the router filter-mode for the group will be set to EXCLUDE. When all systems cease sending EXCLUDE mode reports, the filter-mode for that group may transit back to INCLUDE mode. Group timer is used to identify such transition.

In LW-IGMPv3, hosts primarily send INCLUDE requests, and also can request an EXLUDE (*,G) join, which can be interpreted by the router as a request to include all sources. Without the more general form of EXCLUDE requests, it is unnecessary for the router to maintain the EXCLUDE filter-mode, and the state model for multicast router can be simplified as:

```
(multicast address, group timer, (source records))
```

Here a group timer is kept to represent a (*,G) join. Its basic behavior is: when a router receives a (*,G) join, it will set its group timer and keep the source list for sources specified in the previously received source records. When the group timer expires,

the router may change to the reception for the listed sources. The definition of the source record is the same as that of full version.

The elimination of the filter-mode will greatly simplify the router behavior. The detailed operation of router operation is described in Section 5.

4. LW-IGMPv3 Protocol for Group Members

4.1. Query and Report Messages

LW-IGMPv3 uses two sets of messages, i.e., Query and Report messages, being the same as the full version protocols. There is no difference between the definition and usage of the Query message. But the report types in lightweight protocols are reduced because an operation that triggers EXCLUDE (S,G) join is omitted.

There are three Group Record Types defined in the full IGMPv3: Current-State Record noted by MODE_IS_INCLUDE (referred to as IS_IN) or MODE_IS_EXCLUDE (IS_EX), Filter-Mode-Change Record noted by CHANGE_TO_INCLUDE_MODE (TO_IN) or CHANGE_TO_EXCLUDE_MODE (TO_EX), and Source-List-Change Record noted by ALLOW_NEW_SOURCES (ALLOW) or BLOCK_OLD_SOURCES (BLOCK). LW-IGMPv3 inherits the action on change of interface state and reception of a Query, but IS_IN and IS_EX record types are eliminated and Current-State Records are noted by other records. The following sections explain the details.

4.2. Action on Change of Interface State

When the state of an interface of a group member host is changed, a State-Change Report for that interface is immediately transmitted from that interface. The type and contents of the Group Record(s) in that Report are determined by comparing the filter mode and source list for the affected multicast address before and after the change. While the requirements are the same as the full version for the computation, in the lightweight version host, the interface state change rules are simplified due to the reduction of message types. The contents of the new transmitted report are calculated as follows (Group Record Types are described in Section 4.4):

Old State	New State	State-Change Record Sent
INCLUDE (A)	INCLUDE (B)	ALLOW(B-A), BLOCK(A-B)
INCLUDE (A)	EXCLUDE ({})	TO_EX({})
INCLUDE ({})	EXCLUDE ({})	TO_EX({})
EXCLUDE ({})	INCLUDE (B)	TO_IN(B)

To cover the possibility of the State-Change Report being missed by one or more multicast routers, it is retransmitted [Robustness Variable]-1 more times, at intervals chosen at random from the range (0, [Unsolicited Report Interval]). (These values are defined in

[2][3].)

4.3. Action on Reception of a Query

When a lightweight version host receives a Query, it does not respond immediately. Instead, it delays its response by a random amount of time, bounded by the Max Resp Time value derived from the Max Resp Code in the received Query message [2][3]. The system 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.

Before scheduling a response to a Query, the system must first consider previously scheduled pending responses and in many cases schedule a combined response. Therefore, the lightweight version host must be able to maintain the following state:

- A timer per interface for scheduling responses to General Queries.
- A per-group and interface timer for scheduling responses to Group-Specific and Group-and-Source-Specific Queries.
- A per-group and interface list of sources to be reported in the response to a Group-and-Source-Specific Query.

LW-IGMPv3 inherits the full version's rules that are used to determine if a Report needs to be scheduled. The difference is regarding the simplification of EXCLUDE filter-mode and the type of Report as detailed in Section 4.4.

4.4. LW-IGMPv3 Group Record Types

Among Group Record Types defined in the full IGMPv3, several record types are not used in LW-IGMPv3 as some of the processes related to the filter mode change to the EXCLUDE mode are eliminated and some of the report messages are converged with a record having null source address list. All of the record types of report messages used by the full and lightweight version protocols are shown as follows:

IGMPv3	LW-IGMPv3	Comments
IS_EX({})	TO_EX({})	Query response for (*,G) join
IS_EX(x)	N/A	Query response for EXCLUDE (x,G) join
IS_IN(x)	ALLOW(x)	Query response for INCLUDE (x,G) join
ALLOW(x)	ALLOW(x)	INCLUDE (x,G) join
BLOCK(x)	BLOCK(x)	INCLUDE (x,G) leave
TO_IN(x)	TO_IN(x)	Change to INCLUDE (x,G) join
TO_IN({})	TO_IN({})	(*,G) leave
TO_EX(x)	N/A	Change to EXCLUDE (x,G) join
TO_EX({})	TO_EX({})	(*,G) join

where "x" represents a non-null source address list and "({})" represents null source address list. For instance, IS_EX({}) means a report whose record type is IS_EX with null source address list. "N/A" represents not applicable (or no use) because the corresponding operation should not occur in the lightweight version protocols.

LW-IGMPv3 does not use EXCLUDE filter-mode with a non-null source address list. A multicast router creates the same state when it receives a report message containing either IS_EX({}) or TO_EX({}) record types. Therefore, LW-IGMPv3 integrates the IS_EX({}) operation with the TO_EX({}) operation.

When a LW-IGMPv3 host needs to make a query response for the state of INCLUDE (x,G) join, it makes a response whose message type is expressed with ALLOW(x), instead of using the IS_IN record type. Because the router's processing of the two messages is completely same, the IS_IN(x) type is eliminated for simplification.

A LW-IGMPv3 host does not use EXCLUDE mode, while TO_IN record is used the following situation: the host first launches an application (AP1) that requests INCLUDE (x,G) join, and sends ALLOW(x). Then the host launches another application (AP2) that joins (*,G), and it sends TO_EX(). In this condition, when AP2 terminates but AP1 keeps working on the lightweight version host, the host sends a report with TO_IN(x) record type for [Robustness Variable] times.

5. LW-IGMPv3 Protocol for Multicast Routers

The major difference between the full and lightweight version protocols on the router part is that for the lightweight version filter-mode is discarded and the function of the group timer is redefined. The states maintained by the lightweight router are reduced and the protocol operation is greatly simplified.

5.1. Group Timers and Source Timers in the Lightweight Version

A source timer is kept for each source record and it is updated when the source is present in a received report. It indicates the validity of the sources and needs to be referred when the router takes its forwarding decision.

The group timer being used in the full version of IGMPv3 for transitioning the router's filter-mode from EXCLUDE to INCLUDE, is redefined in the lightweight protocols to identify the non-source-specific receiving states maintaining for (*,G) join. Once a group record of TO_EX() is received, the group timer is set to represent this (*,G) group join. The expiration of the group timer indicates that there are no more listeners on the attached network for this (*,G) group. Then if at this moment there are unexpired sources (whose source timers are greater than zero), the router will change to receiving traffic for those sources. The role of the group timer can be summarized as follows:

Group Timer Value	Actions/Comments
G_Timer > 0	All members in this group.
G_Timer == 0	No more listeners to this (*,G) group. If all source timers have expired then delete group record. If there are still source record timers running, use those source records with running timers as the source record state.

The operation related to the group and source timers has some difference compared with the full IGMPv3. In the full version, if a source timer expires under the EXCLUDE router filter-mode, its corresponding source record is not deleted until the group timer expires for indicating undesired sources. In the lightweight version, since there is no need to keep such records for blocking specific sources, if a source timer expires, its source record should be deleted immediately, not waiting for the time-out of the group timer.

5.2. Source-Specific Forwarding Rules

A full version multicast router needs to consult IGMPv3 state information when it makes decisions on forwarding a datagram from a source or its upstream router to its attached network, based on the router filter-mode and source timer. In LW-IGMPv3, because of the absence of the router filter-mode, the group timer and source timer could be used for such decisions. The forwarding suggestion made by LW-IGMPv3 to the routing protocols is summarized as follows:

Group Timer	Source Timer	Action
G_Timer == 0	S_TIMER > 0	Suggest forwarding traffic from source
G_Timer == 0	S_TIMER == 0	Suggest stopping forwarding traffic from source and remove source record. If there are no more source records for the group, delete group record
G_Timer == 0	No Source Elements	Suggest not to forward traffic from the source
G_Timer > 0	S_TIMER >= 0	Suggest forwarding traffic from source
G_Timer > 0	No Source Elements	Suggest forwarding traffic from source

5.3. Reception of LW-IGMPv3 Group Records

On receiving LW-IGMPv3 group records, the LW-IGMPv3 router must act upon these records and possible change their own states to reflect the new desired membership state of the network.

Lightweight routers query sources that are requested to be no longer forwarded to a group. When a router queries or receives a query for a specific set of sources, it lowers its source timers for those sources to a small interval of Last Member Query Time seconds. If group records are received in response to the queries which express interest in receiving traffic from the queried sources, the corresponding timers are updated.

Similarly, when a router queries a specific group, it lowers its

group timer for that group to a small interval of Last Member Query Time seconds. If TO_EX({}) group records are received within the interval, the group timer for the group is updated and the suggestion to the routing protocol to forward the group stands without any interruption.

During a query period (i.e., Last Member Query Time seconds), the IGMP component in the router continues to suggest to the routing protocol that it forwards traffic from the groups or sources that it is querying. It is not until after Last Member Query Time seconds without receiving a record expressing interest in the queried group or sources that the router may prune the group or sources from the network.

The following table describes the changes in group state and the action(s) taken when receiving LW-IGMPV3 Group Record. This table also describes the queries which are sent by the Querier when a particular report is received. The notation in the table has the same meaning as the full version defines [2][3]:

Group Timer	Old Source List	Report Rec'd	New Source List	Actions
G_Timer >= 0	A	ALLOW(B)	A+B	(B)=GMI
G_Timer >= 0	A	BLOCK(B)	A	Send Q(G,A*B)
G_Timer == 0	A	TO_IN(B)	A+B	(B)=GMI Send Q(G,A-B)
G_Timer > 0	A	TO_IN(B)	A+B	(B)=GMI Send Q(G,A-B) Send Q(G)
G_Timer >= 0	A	TO_EX({})	A	(B)=GMI

In order to maintain protocol robustness, queries sent by actions in the table need to be transmitted [Last Member Query Count] times, once every [Last Member Query Interval] (These values are defined in [2][3]).

If while scheduling new queries, there are already pending queries to be retransmitted for the same group, the new and pending queries have to be merged. In addition, received host reports for a group with pending queries may affect the contents of those queries. The process of building and maintaining the state of pending queries is

described in [2][3].

The method which a lightweight router uses to build and send queries, and the actions the router should take on receiving Queries from other routers are completely the same as that of full version. The detailed description is described in [2][3].

6. Interoperability

LW-IGMPv3/LW-MLDv2 hosts and routers must interoperate with hosts and routers of the full version [2][3]. Also, LW-IGMPv3/LW-MLDv2 hosts and routers must interoperate gracefully with hosts and routers running IGMPv1/v2 or MLDv1.

6.1. Interoperation with the Full Version of IGMPv3/MLDv2

LW-IGMPv3/LW-MLDv2 do not introduce any change on the message format of the group query and report messages the full version protocols use. The LW-IGMPv3 group member sends a subset of IGMPv3 report messages, which can be recognized by a multicast router running the full or the lightweight IGMPv3 protocol on the same LAN.

A LW-IGMPv3 or LW-MLDv2 router does not process directly IS_IN(x), IS_EX(x) and TO_EX(x) (except for TO_EX({})) records that are used by the full version. When a LW-IGMPv3/LW-MLDv2 router receives these report messages from the full version host, it MUST translate them internally to the defined records and behaves accordingly. All possible record types are defined as follows:

IGMPv3/MLDv2 Report	LW-IGMPv3/LW-MLDv2 Equivalent
IS_IN(x)	ALLOW(x)
IS_EX(x)	TO_EX({})
TO_EX(x)	IS_EX()

6.2. Interoperation with IGMPv1/IGMPv2

6.2.1. Behavior of Group Members

A host's compatibility mode is determined from the Host Compatibility Mode variable which can be in one of three states: IGMPv1, IGMPv2 or IGMPv3. The Host Compatibility Mode of an interface is set to IGMPv2 and its IGMPv2 Querier Present timer is set to Older Version Querier Present Timeout seconds (defined in [2]) whenever an IGMPv2 General Query is received on that interface. The Host Compatibility Mode of an interface is set to IGMPv1 and its IGMPv1 Querier Present timer is set to Older Version Querier Present Timeout seconds whenever an IGMPv1 Membership Query is received on that interface. Based on the Host Compatibility Mode variable, a host acts using the IGMPv3, IGMPv2, or IGMPv1 protocol on that interface.

In the presence of older version group members, LW-IGMPv3 hosts may

allow its report message to be suppressed by either an IGMPv1 or IGMPv2 membership report. However, because the transmission of IGMPv1 or v2 packets reduces the capability of the LW-IGMPv3 system, as a potential protection mechanism, the choice to enable or disable the use of backward compatibility may be configurable.

6.2.2. Behavior of Multicast Routers

If a LW-IGMPv3 router is on a network where at least one router running IGMPv1 or IGMPv2 protocols, it is required that the lowest version of Querier must be used. This can be administratively assured by supporting IGMPv1, IGMPv2 or IGMPv3 compatibility mode.

If a router is not explicitly configured to use IGMPv1 or IGMPv2 and hears an IGMPv1 Query or IGMPv2 General Query, it SHOULD log a warning. These warnings MUST be rate-limited. When in IGMPv1 mode, routers MUST send periodic IGMPv1 Queries and MUST ignore Leave Group messages. They SHOULD also warn about receiving an IGMPv2 or IGMPv3 query (such warnings MUST be rate-limited). When in IGMPv2 mode, routers MUST send periodic IGMPv2 Queries, and SHOULD also warn about receiving an IGMPv3 query (such warnings MUST be rate-limited).

If an LW-IGMPv3 router is placed on a network where there are hosts that have not been upgraded to IGMPv3, it MUST be able to operate in version 1 or version 2 compatibility mode. The router keeps a compatibility mode, an IGMPv1 Host Present Timer and an IGMPv2 Host Present Timer (as defined in [2][3]) for each group record. The IGMPv1 Host Present timer is set to Older Version Host Present Timeout seconds whenever an IGMPv1 Membership Report is received. The IGMPv2 Host Present timer is set to Older Version Host Present Timeout seconds whenever an IGMPv2 Membership Report is received.

The Group Compatibility Mode of a group record changes whenever an older version report (than the current compatibility mode) is heard or when certain timer conditions occur. When the IGMPv1 Host Present timer expires, the LW-IGMPv3 router switches to Group Compatibility mode of IGMPv2 if it has a running IGMPv2 Host Present timer. If it does not have a running IGMPv2 Host Present timer then it switches to Group Compatibility of IGMPv3. When the IGMPv2 Host Present timer expires and the IGMPv1 Host Present timer is not running, a router switches to Group Compatibility mode of IGMPv3. Note that when a group switches back to IGMPv3 mode, it takes some time to regain source-specific state information.

When Group Compatibility mode is IGMPv2, a LW-IGMPv3 router internally translates the following IGMPv2 messages for that group to their LW-IGMPv3 equivalents:

IGMPv2 Message	LW-IGMPv3 Equivalent
v2 Report	TO_EX({})
v2 Leave	TO_IN({})

When Group Compatibility mode is IGMPv1, a LW-IGMPv3 router internally translates the following IGMPv1 and IGMPv2 messages for that group to their IGMPv3 equivalents:

IGMPv1 Message	LW-IGMPv3 Equivalent
v1 Report	TO_EX({})

6.3. Interoperation with MLDv1

The MLDv2 hosts and routers MUST interoperate with the hosts and routers running MLDv1. The method is the same as described in Section 6.2. The difference is that when a MLDv2 router has a MLDv1 listener on its network, it translates the following MLDv1 messages to their MLDv2 equivalents:

MLDv1 Message	LW-MLDv2 Equivalent
Report	TO_EX({})
Done	TO_IN({})

7. Implementation Considerations

The lightweight protocols require no additional procedure on the implementation of the related protocols or systems, e.g. IGMP/MLD snooping, multicast routing protocol, and operation of application sockets, while the processing loads on the switches and routers that running IGMPv3/MLDv2 (snooping) and multicast routing protocols may be greatly decreased.

In the following sections, the implementation related aspects are described for the lightweight version protocols.

7.1. Implementation of Source-Specific Multicast

[8] illustrates the requirements of implementation of Source-Specific Multicast (SSM) on IGMPv3/MLDv2 hosts and routers. The lightweight protocol does not impose any bad influences on an SSM application. The requirements of LW-IGMPv3/LW-MLDv2 for supporting SSM are illustrated below.

A LW-IGMPv3/LW-MLDv2 host should not invoke a (*,G) join, i.e., TO_EX({}), and IGMPv2 Leave and MLDv1 Done messages for the application whose multicast address is in the SSM address range. The reception of a (*,G) join with an SSM group address should indicate an error to the application. The SSM-aware router will ignore TO_EX({}) reports with SSM addresses. Other types of Reports should be processed normally.

7.2. Implementation of Multicast Source Filter (MSF) APIs

Multicast Source Filter (MSF) APIs [9] defines (1) IPv4 Basic MSF API, (2) IPv4 Advanced MSF API, (3) Protocol-Independent Basic MSF API, and (4) Protocol-Independent Advanced MSF API.

According to the MSF APIs definition, a LW-IGMPv3 host should implement at least one of IPv4 Basic MSF API and Protocol-Independent Basic MSF API, and a LW-MLDv2 host should implement Protocol-Independent Basic MSF API. Other APIs, IPv4 Advanced MSF API and Protocol-Independent Advanced MSF API, are optional to implement in LW-IGMPv3/LW-MLDv2 host.

8. Security Considerations

The security considerations are the same as that of the full version of IGMPv3/MLDv2.

9. References

9.1. Normative References

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