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         Tuning the Behavior of IGMP and MLD for Routers in Mobile and Wireless
                                Networks
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Abstract

   IGMP and MLD are the protocols used by hosts and multicast routers to
   exchange their IP multicast group memberships with each other. This
   document describes the ways of IGMPv3 and MLDv2 protocol optimization
   for mobility, and aims to become a guideline for query and other
   timers and values tuning.

Status of this Memo

   This Internet-Draft is submitted in full conformance with the
   provisions of BCP 78 and BCP 79.

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   material or to cite them other than as "work in progress."

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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 multicast
routers or IGMP/MLD proxies [10] that maintain multicast membership
information on their downstream interfaces. Conceptually, IGMP and
MLD work on both wireless and mobile networks. However, wireless
access technologies operate on a shared medium or a point-to-point
link with limited spectrum 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. A mobile host
may cause disruption of a multicast service initiation and
termination in the new or previous network upon its movement. Slow
multicast service activation following a join may incur additional
delay in receiving multicast packets and 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.

When IGMP and MLD are used with mobile IP protocols, the proximity of
network entities should be considered. For example, when bi-
directional tunnel is used with the mobility entities described in
[11][14] in place, the mobile host experiences additional latency,
because the round-trip time using bi-directional tunnel between
mobility entities is larger comparing to the case that a host and an
upstream router attach to a LAN.

This document describes the ways of tuning the IGMPv3 and MLDv2
protocol behavior on multicast router and proxy side for wireless and
mobile networks, including query and other timers tuning. The
selective optimization that provides tangible benefits to the mobile
hosts and routers is given by keeping track of downstream hosts'
membership status and varying IGMP/MLD Query types and values to tune
the number of responses. The proposed behavior interoperates with
the IGMPv3 and MLDv2 protocols.

2. Terminology

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].

In this document, "router" means both multicast router and IGMP/MLD
proxy.

3. **Explicit Tracking of Membership Status**

   Mobile hosts use IGMP and MLD to request to join or leave multicast
   sessions. When an adjacent upstream router receives the IGMP/MLD
   Report messages, it recognizes the membership status on the link. To
   update the membership status reliably, the router sends IGMP/MLD
   Query messages periodically, and sends Group-Specific and/or Group-
   and-Source Specific Queries when a member host reports its leave.
   Then the other member hosts reply IGMP/MLD Report messages to notify
   their memberships. 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 cunsumption.

   The "explicit tracking function" [9] is the possible approach to
   reduce the transmitted number of IGMP/MLD messages and contribute to
   the efficiency of mobile communications. It enables the router to
   keep track of the membership status of the downstream IGMPv3 or MLDv2
   member hosts. That is, if a router enables the explicit tracking
   function, it does not always need to ask Current-State Report message
   transmission from the receiver hosts since the router implicitly
   recognizes the (potential) last member host when it receives the
   State-Change Report. The router can therefore send IGMP/MLD Group-
   Specific and Group-and-Source Specific Queries LMQC/LLQC times (see
   Section 4.3 for LMQC/LLQC) only when it recognizes the last member
   has left from the network. This reduces the transmitted number of
   Current-State Report messages.

   Enabling the explicit tracking function is advantageous for mobile
   multicast, but the function requires additional processing capability
   and a possibly large memory for routers to keep all membership
   status. Especially when a router needs to maintain a large number of
   receiver hosts, this resource requirement is potentially impacted.
   Therefore, this document recommends that adjacent upstream multicast
   routers enables the explicit tracking function for IP multicast
   communications on wireless and mobile networks, if they have enough
   resources. If operators think that their routers do not have enough
   resources, they may disable this function on their routers. Note
   that whether routers enable the explicit tracking function or not,
   they need to maintain downstream membership status by sending IGMPv3/
   MLDv2 General Query messages as some IGMPv3/MLDv2 messages may be
   lost during transmission.

4. **Tuning IGMP/MLD Timers and Values**

4.1. **Tuning IGMP/MLD General Query Interval**

   IGMP and MLD are non-reliable protocols; to cover the possibility of
   a State-Change Report being missed by one or more multicast routers,
   "hosts retransmit the same State-Change Report messages [Robustness
   Variable] - 1 more times", at intervals chosen at random from the
   range (0, [Unsolicited Report Interval]) [2][3]. Although this
   behavior increases the protocol robustness, it does not guarantee
   that the State-Change Report reaches the routers. Therefore, routers
   still need to refresh the downstream membership information by
   receiving Current-State Report periodically solicited by IGMP/MLD
   General Query sent in the [Query Interval] period, in order to
   enhance robustness of the host in case of link failures and packet
   loss. It also supports the situation that mobile hosts turn off or
   move from a network to other network managed by a different router
   without any notification (e.g., leave request).

   The [Query Interval] is the interval between General Queries sent by
   the regular IGMPv3/MLDv2 querier, and the default value is 125
   seconds [2][3]. By varying the [Query Interval], multicast routers
   can tune the number of IGMP/MLD messages on the network; larger
   values cause IGMP/MLD Queries to be sent less often.

   This document proposes 150 seconds for the [Query Interval] value by
   changing the Querier's Query Interval Code (QQIC) field specified in
   the IGMP/MLD Query message, for the case that a router enabling the
   explicit tracking function sends General Query and potentially
   operates a large number of member hosts such as more than 200 hosts
   on the wireless link. This longer interval value contributes to
   minimizing traffic of Report messages and battery power consumption
   for mobile hosts.

   On the other hand, this document also proposes 60 to 90 seconds for
   the [Query Interval] value for the case that a router enabling the
   explicit tracking function attaches to a wireless link having higher
   capacity of the resource. This shorter interval contributes to quick
   synchronization of the membership information tracked by the router
   but may consume battery power of mobile hosts.

   If a router does not enable the explicit tracking function, the
   [Query Interval] value would be its default value, 125 seconds.

   In situations where Mobile IPv6 [14] is used, when the home agent
   implements multicast router functionality and multicast data packets
   are tunneled to and from the home agent, the home agent may want to
   slow down Query periodicity, especially when network congestion is

detected. This can be done by the home agent starting forwarding
queries with the default [Query Interval] value and increasing it in
a gradual manner until it exceeds the mobile host's lifetime.

4.2. Tuning IGMP/MLD Query Response Interval

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. Its default value is 10 seconds expressed
by "Max Resp Code=100" for IGMPv3 [2] and "Maximum Response
Code=10000" for MLDv2 [3]. By varying the [Query Response Interval],
multicast routers can tune the burstiness of IGMP/MLD messages on the
network; larger values make the traffic less bursty as host responses
are spread out over a larger interval, but will increase join latency
when State-Change Report is missing.

According to our experimental analysis, this document proposes two
tuning scenarios for tuning the [Query Response Interval] value in
different wireless link conditions; one scenario is for a wireless
link with a lower capacity of network resource or a lossy link, and
the other scenario is for a wireless link with enough capacity or
reliable condition for IGMP/MLD message transmission.

Regarding the first scenario, for instance, when a multicast router
attaches to a bursty IEEE 802.11b link, the router configures the
longer [Query Response Interval] value, such as 10 to 20 (sec). This
configuration will reduce congestion of the Current-State Report
messages on a link but may increase join latency and leave latency
when the unsolicited messages (State-Change Record) are lost on the
router.

The second scenario may happen for a multicast router attaching to a
wireless link having higher capacity of the resource or a point-to-
(multi-)point link such as an IEEE 802.16e link, because IGMP/MLD
messages do not seriously affect the link condition. The router can
seek Current-State Report messages with the shorter [Query Response
Interval] value, such as 5 to 10 (sec). This configuration will
contribute to quickly (at some level) discovering non-tracked member
hosts and synchronizing the membership information.

4.3. Tuning Last Member Query Timer (LMQT) and Last Listener Query
         Timer (LLQT)

Shortening the Last Member Query Timer (LMQT) for IGMPv3 and the Last
Listener Query Timer (LLQT) for MLDv2 contributes to minimizing leave
latency. LMQT is represented by the Last Member Query Interval
(LMQI), multiplied by the Last Member Query Count (LMQC), and LLQT is
represented by the Last Listener Query Interval (LLQI), multiplied by

the Last Listener Query Count (LLQC).

While LMQI and LLQI are changeable, it is reasonable to use the
default values (i.e., 1 second) for LMQI and LLQI in a wireless
network. LMQC and LLQC, whose default value is the [Robustness
Variable] value, are also tunable. Therefore, LMQC and LLQC MAY be
set to "1" for routers enabling the explicit tracking function, and
then LMQT and LLQT are set to 1 second. However, setting LMQC and
LLQC to 1 increases the risk of missing the last member; LMQC and
LLQC SHOULD be set to 1 only when network operators think that their
wireless link is stable enough.

On the other hand, if network operators think that their wireless
link is lossy (e.g., due to a large number of attached hosts or
limited resources), they MAY set LMQC and LLQC to "2" for their
routers enabling the explicit tracking function. Although bigger
LMQC and LLQC values may cause longer leave latency, the risk of
missing the last member will be reduced.

4.4. Tuning Startup Query Interval

The [Startup Query Interval] is the interval between General Queries
sent by a Querier on startup. The default value is 1/4 of [Query
Interval]; however, this document recommends the use of its shortened
value such as 1 second since the shorter value would contribute to
shortening handover delay for mobile hosts in, e.g., the base
solution with PMIPv6 [12]. Note that the [Startup Query Interval] is
a static value and cannot be changed by any external signal.
Therefore operators who maintain routers and wireless links must
properly configure this value.

4.5. Tuning Robustness Variable

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. The default [Robustness Variable] value defined in
IGMPv3 [2] and MLDv2 [3] is "2".

This document proposes "2" for the [Robustness Variable] value for
mobility, when a router attaches to a wireless link having lower
capacity of the resource or a large number of hosts. For a router
that attaches to a wireless link having higher capacity of the
resource or reliable condition, it is not required to retransmit the
same State-Change Report message; hence the router sets the
[Robustness Variable] to "1". Note that whether the explicit

tracking function is enabled or not, the [Robustness Variable] value
SHOULD NOT be bigger than "2".

4.6. Tuning Scenarios for Various Mobile IP Networks

In mobile IP networks, IGMP and MLD are used either with three
deployment scenarios; (1) running directly between host and access
router on a wireless network, (2) running between host and home
router through a tunnel link, and (3) running between home router and
foreign router through a tunnel link.

When a receiver host connects directly through a wireless link to a
foreign access router or a home router, the tuning of the IGMP/MLD
protocol parameters should be the same as suggested in the previous
sections. The example of this scenario occurs when route
optimization is adopted in MIPv6 [14] or Mobile IP [15], or when in
Proxy Mobile IPv6 (PMIPv6) [11], the mobile access gateway, whose
role is similar to the one of a foreign router, acts as a multicast
router as proposed in [13].

The second scenario occurs when bi-directional tunnel established
between host and home router is used to exchange IGMP/MLD messages
such as [14][15]. There are difficulties in tuning the parameters in
this situation, because the tunnel link condition is diverse and
changeable. When a host is far away from the home router, the
transmission delay between the two entities may be longer and the
packet delivery may be more unreliable. Thus the effects of the
IGMP/MLD message transmission through a tunnel link should be
considered during the parameter setting. For example, the [Query
Interval] and [Query Response Interval] could be set shorter to
compensate the transmission delay, and the [Robustness Variable]
could be increased for possible packet loss.

The third scenario occurs in [12], in which the mobile access gateway
(i.e., foreign router) acts as the IGMP/MLD Proxy [10] in PMIPv6
[11]. Through the bi-directional tunnel established with the local
mobility anchor (i.e., home router), the mobile access gateway sends
summary reports of its downstream member hosts to the local mobility
anchor. Apart from the distance factor that influences the parameter
setting, the [Query Response Interval] on the local mobility anchor
could be set to the smaller value since the number of foreign router
is much smaller compared to the that of the host and the chances of
packet burst is low for the same reason.

Ideally, the IGMP/MLD querier router adjusts its parameter setting
according to the actual mobile IP network conditions to benefit
service performance and resource utilization. It would be desirable
that a home router determines aforementioned timers and values

according to the delay between the initiating IGMP/MLD Query and the
responding IGMP/MLD Report, while describing such mechanism
dynamically adjusting these timers and values is out of scope of this
document.

5. **Destination Address of Specific Query**

   IGMP/MLD Group-Specific and Group-and-Source Specific Queries defined
   in [2][3] are sent to verify whether there are hosts that desire
   reception of the specified group or a set of sources or to rebuild
   the desired reception state for a particular group or a set of
   sources. These specific Queries build and refresh multicast
   membership state of hosts on an attached network. These specific
   Queries should be sent to all desired hosts with specific multicast
   address (not the all-hosts/all-nodes multicast address) as their IP
   destination addresses, because hosts that do not join the multicast
   session do not pay attention to these specific Queries, and only
   active member hosts that have been receiving multicast contents with
   the specified address reply IGMP/MLD reports.

6. Interoperability

IGMPv3 [2] and MLDv2 [3] 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 in its join request. Upon its reception, the upstream
router that supports IGMPv3/MLDv2 establishes the shortest path tree
toward the source without coordinating a shared tree. This function
is called the source filtering function and is required to support
Source-Specific Multicast (SSM) [8].

Recently, the Lightweight-IGMPv3 (LW-IGMPv3) and Lightweight-MLDv2
(LW-MLDv2) [4] protocols have been defined as the proposed standard
protocols in the IETF. These protocols provide protocol simplicity
for mobile hosts and routers, as they eliminate a complex state
machine from the full versions of IGMPv3 and MLDv2, and promote the
opportunity to implement SSM in mobile communications.

This document assumes that both multicast routers and mobile hosts
MUST be IGMPv3/MLDv2 capable, regardless whether the protocols are
the full or lightweight version. And this document does not consider
interoperability with older version protocols. The main reason not
being interoperable with older IGMP/MLD protocols is that the
explicit tracking function does not work properly with older IGMP/MLD
protocols.

7. Security Considerations

This document neither provides new functions or modifies the standard functions defined in [2][3][4]. Therefore there is no additional security consideration provided.

8. Acknowledgements

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Appendix A. Unicasting General Query

   IGMPv3 and MLDv2 specifications [2][3] describe that a host MUST
   accept and process any Query whose IP Destination Address field
   contains any of the addresses (unicast or multicast) assigned to the
   interface on which the Query arrives. In general, the all-hosts
   multicast address (224.0.0.1) or link-scope all-nodes multicast
   address (FF02::1) is used as the IP destination address of IGMP/MLD
   General Query. On the other hand, according to [2][3], a router MAY
   be able to unicast General Query to tracked member hosts in [Query
   Interval], if the router keeps track of membership information
   (Section 3).

   Unicasting IGMP/MLD General Query would reduce the drain on battery
   power of mobile hosts as only the active hosts that have been
   receiving multicast contents respond the unicast IGMP/MLD General
   Query messages and non-active hosts do not need to pay attention to
   the IGMP/MLD messages. This also allows the upstream router to
   proceed fast leaves (or shorten leave latency) by setting LMQC/LLQC
   smaller, because the router can immediately converge and update the
   membership information, ideally.

   However, there is a concern in unicast General Query. If a multicast
   router sends General Query "only" by unicast, it cannot discover
   potential member hosts whose join requests were lost. Since the
   hosts do not retransmit the same join requests (i.e., unsolicited
   Report messages), they loose the chance to join the channels unless
   the upstream router asks the membership information by sending
   General Query by multicast. It will be solved by using both unicast
   and multicast General Queries and configuring the [Query Interval]
   timer value for multicast General Query and the [Unicast Query
   Interval] timer value for unicast General Query. However, using two
   different timers for General Queries would require the protocol
   extension this document does not focus on. If a router does not
   distinguish the multicast and unicast General Query Intervals, the
   router should only use and enable multicast General Query.

   Also, unicasting General Query does not remove multicasting General
   Query. Multicast General Query is necessary to update membership
   information if it is not correctly synchronized due to missing
   Reports. Therefore, enabling unicast General Query SHOULD NOT be
   used for the implementation that does not allow to configure
   different query interval timers as [Query Interval] and [Unicast
   Query Interval]. If a router does not distinguish these multicast
   and unicast General Query Intervals, the router SHOULD only use and
   enable multicast General Query.

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