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A RPL Configuration Option for the 6LoWPAN Routing Header

Abstract

This document complements RFC 8138 and dedicates a bit in the RPL configuration option defined in RFC 6550 to indicate whether RFC 8138 compression is used within the RPL Instance.

Status of This Memo

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1. Introduction

The transition of a RPL [RFC6550] network to activate the compression defined in [RFC8138] can only be done when all routers in the network support it. Otherwise, a non-capable node acting as a router would drop the compressed packets and black-hole its subDAG. In a mixed case with both RFC8138-capable and non-capable nodes, the compression may be turned on only if all the non-capable nodes act as Hosts and their RPL parents handle the compression/decompression for them.

This document complements [RFC8138] and dedicates a flag in the RPL configuration option to indicate whether [RFC8138] compression

should be used within the RPL Instance. The setting of this new flag is controlled by the Root and propagates as is in the whole network. When the bit is not set, source nodes that support [RFC8138] should refrain from using the compression unless the information is superseded by configuration.

With RPL, a leaf is an IPv6 Host, which implies that leaves do not forward packets. This specification provides scenarios that force a non-capable RPL-Aware Node (RAN) to become a leaf. The parent router must know, e.g., by configuration, or leveraging "RPL Capabilities" [CAPABILITIES], when a leaf does not support the compression defined in [RFC8138]. This is implicitly the case for a RPL-Unaware Leaf (RUL) but is not known for a RPL-Aware Leaf (RAL). The parent router must uncompress the packets before delivering them to a non-capable leaf and it must compress the traffic from the leaf.

2. Terminology

2.1. References

The Terminology used in this document is consistent with and incorporates that described in "Terms Used in Routing for Low-Power and Lossy Networks (LLNs)" [RFC7102]. Other terms in use in LLNs are found in "Terminology for Constrained-Node Networks" [RFC7228].

"RPL", the "RPL Packet Information" (RPI), "RPL Instance" (indexed by a RPLInstanceID) are defined in "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks" [RFC6550]. The RPI is the abstract information that RPL defines to be placed in data packets, e.g., as the RPL Option [RFC6553] within the IPv6 Hop-By-Hop Header. By extension the term "RPI" is often used to refer to the RPL Option itself. The DODAG Information Solicitation (DIS), Destination Advertisement Object (DAO) and DODAG Information Object (DIO) messages are also specified in [RFC6550].

This document uses the terms RPL-Unaware Leaf (RUL) and RPL Aware Leaf (RAL) consistently with "Using RPI Option Type, Routing Header for Source Routes and IPv6-in-IPv6 encapsulation in the RPL Data Plane" [USEofRPLinfo]. The term RPL-Aware Node (RAN) refers to a node that is either a RAL or a RPL Router. A RAN manages the reachability of its addresses and prefixes by injecting them in RPL by itself. In contrast, a RUL leverages "Registration Extensions for IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) Neighbor Discovery" [RFC8505] to obtain reachability services from its parent router(s) as specified in "Routing for RPL Leaves" [UNAWARE-LEAVES].

2.2. Glossary

This document often uses the following acronyms:

6LoWPAN: IPv6 over Low-Power Wireless Personal Area Network
6LoRH: 6LoWPAN Routing Header
DIO: DODAG Information Object (a RPL message)
DODAG: Destination-Oriented Directed Acyclic Graph
LLN: Low-Power and Lossy Network
RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks
OF: RPL Objective Function
OCP: RPL Objective Code Point
MOP: RPL Mode of Operation
RPI: RPL Packet Information
RAL: RPL-Aware Leaf
RAN: RPL-Aware Node
RUL: RPL-Unaware Leaf
SRH: Source Routing Header

2.3. BCP 14

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119][RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Updating RFC 6550

This specification defines a new flag "Enable RFC8138 Compression" (T). The "T" flag is set to turn on the use of the compression of RPL artifacts with [RFC8138] within a RPL Instance. If a RPL Instance has multiple Roots then they must be coordinated to use the same setting.

RPL defines a Configuration Option that is registered to IANA in section 20.14. of [RFC6550]. The "T" flag is encoded in one of the reserved control bits in the RPL Configuration Option. The bit position of the "T" flag is indicated in Section 6.

Section 6.3.1. of [RFC6550] defines a 3-bit Mode of Operation (MOP) in the DIO Base Object. The new "T" flag is defined only for MOP value between 0 to 6. For a MOP value of 7 or above, the flag MAY indicate something different and MUST NOT be interpreted as "Enable RFC8138 Compression" unless the specification of the MOP indicates to do so.

4. Updating RFC 8138

A node that supports this specification MUST source packets in the compressed form using [RFC8138] if and only if the "T" flag is set. This behaviour can be overridden by the configuration of the node in order to cope with intermediate implementations of the Root that

support [RFC8138] but not this specification and cannot set the "T" flag.

The decision of using [RFC8138] is made by the originator of the packet depending on its capabilities and its knowledge of the state of the "T" flag. A router that encapsulates a packet is the originator of the resulting packet and decides whether to compress the outer headers as indicated above. An external target [USEofRPLinfo] is not expected to support [RFC8138]. An intermediate router MUST forward the packet in the form that the source used, either compressed or uncompressed, unless it is forwarding to an external target or delivering to a leaf that is not known to support [RFC8138], in which cases it MUST uncompress the packet.

5. Transition Scenarios

A node that supports [RFC8138] but not this specification can only be used in an homogeneous network. Enabling the [RFC8138] compression requires a "flag day"; all nodes must be upgraded, and then the network can be rebooted with the [RFC8138] compression turned on.

A node that supports this specification can work in a network with [RFC8138] compression turned on or off with the "T" flag set accordingly and in a network in transition from off to on or on to off (see Section 5.1).

A node that does not support [RFC8138] can interoperate with nodes that do in a network with [RFC8138] compression turned off. If the compression is turned on, the node cannot forward compressed packets and therefore it cannot act as a router. It may remain connected to that network as a leaf, generates uncompressed packets, and can receive packets if they are delivered by the parent router in the uncompressed form. Unless this is known by other means, the node SHOULD join as a RUL as an indication that its parent router needs to uncompress the packets before delivering.

[RFC6550] states that "Nodes other than the DODAG Root MUST NOT modify this information when propagating the DODAG Configuration option". Therefore, even a legacy parent propagates the "T" flag as set by the Root whether it supports this specification or not. So when the "T" flag is set, it is transparently flooded to all the nodes in the RPL Instance.

Sections 8.5 and 9.2 of [RFC6550] also suggests that a RAN may only attach to a DODAG as a leaf when it does not support the Mode of Operation of a RPL Instance, the Objective Function (OF) as indicated by the Objective Code Point (OCP) or some other parameters in the configuration option.

This specification reiterates that a RAN that is configured to operate in a RPL Instance but does not support a value for a known parameter that is mandatory for routing, such as the OCP, MUST NOT operate as a router but MAY still join as a leaf. Note that a legacy RAN will not recognize when a reserved field is used and will not turn to a leaf when the "T" flag is set.

The intent for this specification is to perform a migration once and for all without the need for a flag day. In particular it is not the intention to undo the setting of the "T" flag, and though it is possible to roll back (see Section 5.4), adding nodes that do not support [RFC8138] after a roll back may be problematic if the roll back is not fully complete (see caveats in Section 5.2).

5.1. Inconsistent State While Migrating

When the "T" flag is turned on in the configuration option by the Root, the information slowly percolates through the DODAG as the DIO gets propagated.

Some nodes will see the flag and start sourcing packets in the compressed form while other nodes in the same RPL Instance are still not aware of it. Conversely, in non-storing mode, the Root will start using [RFC8138] with a Source Routing Header 6LoRH (SRH-6LoRH) that routes all the way to the parent router or to the leaf.

To ensure that a packet is forwarded across the RPL Instance in the form in which it was generated, it is required that all the routers support [RFC8138] at the time of the switch, and that all nodes that do not support [RFC8138] only operate as leaves.

Setting the "T" flag is ultimately the responsibility of the network administrator. In a case of upgrading a network to turn the compression on, the network SHOULD be operated with the "T" flag reset until all targeted nodes are upgraded to support this specification. Section 5.2 and Section 5.3 provide possible transition scenarios where this can be enforced.

5.2. Single RPL Instance Scenario

In a Single RPL Instance Scenario, nodes that support [RFC8138] are configured with a new OCP, that may use the same OF operation or a variation of it, while nodes that do not support [RFC8138] are not, but are configured to join an unknown OCP.

The Root migrates to the new OCP before it sets the "T" flag, so that nodes that do not support [RFC8138] are all attached as leaves when the "T" flag is eventually set.

The parent router - which supports [RFC8138] - compresses the packets originated from the leaf and uncompresses the packets going to the leaf. This may be done on the fly by the parent of a non-capable RAL, or as part of the tunneling operation between the parent and the Root, if the leaf behaves as a RUL. This is described in section 7, 8, and 9 of [USEofRPLinfo].

Note that though tunneling from the Root to the parent is the generic case for RULs, on paper it is possible for the Root to avoid it for the traffic that it originates. The Root SHOULD always use tunneling to the parent of a RUL, even for its own packets, unless it knows that the leaf supports [RFC8138].

This scenario presents a number of caveats:

* The method consumes an extra OCP. It also forces nodes that do not support [RFC8138] to operate as RULs, unless there is a method to let the parent router know that it must uncompress the packet for this RAL.

* If the RPL implementation of a node does not turn it to a leaf when the OCP is changed to an unknown one, then the node may be stalled.

* If the only possible parents of a node are nodes that do not support [RFC8138], then that node will loose all its parent at the time of the migration and it will be stalled until a parent is deployed with the new capability.

5.3. Double RPL Instances Scenario

An alternative to the Single RPL Instance Scenario is to deploy an additional RPL Instance for the nodes that support [RFC8138].

The two RPL Instances operate independently as specified in [RFC6550]. The preexisting RPL Instance does not use [RFC8138], whereas the new RPL Instance does. This is signaled by the "T" flag which is only set in the configuration option in DIO messages in the new RPL Instance.

Nodes that support [RFC8138] participate in both Instances but favor the new RPL Instance for the traffic that they source. By contrast, nodes that only support the uncompressed format would either not be configured for the new RPL Instance, or would be configured to join it as leaves only.

This method eliminates the risks of nodes being stalled that are described in Section 5.2 but requires implementations to support at least two RPL Instances and demands management capabilities to introduce new RPL Instances and deprecate old ones.

5.4. Rolling Back

After downgrading a network to turn the [RFC8138] compression off, the administrator SHOULD make sure that all nodes have converged to the "T" flag reset before allowing nodes that do not support the compression in the network (see caveats in Section 5.2).

It is RECOMMENDED to only deploy nodes that support [RFC8138] in a network where the compression is turned on. A node that does not support [RFC8138] MUST only be used as a leaf.

6. IANA Considerations

This specification updates the Registry for the "DODAG Configuration Option Flags" that was created for [RFC6550] as follows:

Bit Number	Capability Description	Reference
2	Turn on RFC8138 Compression (T)	THIS RFC

Table 1: New DODAG Configuration Option Flag

7. Security Considerations

First of all, it is worth noting that with [RFC6550], every node in the LLN that is RPL-aware can inject any RPL-based attack in the network. A trust model MUST be put in place so that rogue nodes are excluded from participating to the RPL and the 6LowpAN signaling, and from the data packet exchange. This trust model could be at a minimum based on a Layer-2 Secure joining and the Link-Layer security. This is a generic RPL and 6LoWPAN requirement, see Req5.1 in Appendix of [RFC8505].

Setting the "T" flag before some routers are upgraded may cause a loss of packets. The new bit is protected as the rest of the configuration so this is just one of the many attacks that can happen if an attacker manages to inject a corrupted configuration.

Setting and resetting the "T" flag may create inconsistencies in the network but as long as all nodes are upgraded to [RFC8138] support they will be able to forward both forms. The source is responsible for selecting whether the packet is compressed or not, and all routers must use the format that the source selected. So the result of an inconsistency is merely that both forms will be present in the network, at an additional cost of bandwidth for packets in the uncompressed form.

8. Acknowledgments

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9. Normative References

[RFC2119] Bradner, S., "Key words for use in RFCs to Indicate Requirement Levels", BCP 14, RFC 2119, DOI 10.17487/RFC2119, March 1997, <https://www.rfc-editor.org/info/rfc2119>.

[RFC8174] Leiba, B., "Ambiguity of Uppercase vs Lowercase in RFC 2119 Key Words", BCP 14, RFC 8174, DOI 10.17487/RFC8174, May 2017, <https://www.rfc-editor.org/info/rfc8174>.

[RFC6550] Winter, T., Ed., Thubert, P., Ed., Brandt, A., Hui, J., Kelsey, R., Levis, P., Pister, K., Struik, R., Vasseur, JP., and R. Alexander, "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks", RFC 6550, DOI 10.17487/RFC6550, March 2012, <https://www.rfc-editor.org/info/rfc6550>.

[RFC7102] Vasseur, JP., "Terms Used in Routing for Low-Power and Lossy Networks", RFC 7102, DOI 10.17487/RFC7102, January 2014, <https://www.rfc-editor.org/info/rfc7102>.

[RFC7228] Bormann, C., Ersue, M., and A. Keranen, "Terminology for Constrained-Node Networks", RFC 7228, DOI 10.17487/RFC7228, May 2014, <https://www.rfc-editor.org/info/rfc7228>.

[USEofRPLinfo] Robles, I., Richardson, M., and P. Thubert, "Using RPI Option Type, Routing Header for Source Routes and IPv6-in-IPv6 encapsulation in the RPL Data Plane", Work in Progress, Internet-Draft, draft-ietf-roll-useofrplinfo-38, 23 March 2020, <https://tools.ietf.org/html/draft-ietf-roll-useofrplinfo-38>.

[UNAWARE-LEAVES] Thubert, P. and M. Richardson, "Routing for RPL Leaves", Work in Progress, Internet-Draft, draft-ietf-roll-unaware-leaves-14, 11 April 2020, <https://tools.ietf.org/html/draft-ietf-roll-unaware-leaves-14>.

10. Informative References

[RFC6553] Hui, J. and JP. Vasseur, "The Routing Protocol for Low-Power and Lossy Networks (RPL) Option for Carrying RPL Information in Data-Plane Datagrams", RFC 6553, DOI 10.17487/RFC6553, March 2012, <https://www.rfc-editor.org/info/rfc6553>.

[RFC8138] Thubert, P., Ed., Bormann, C., Toutain, L., and R. Cragie, "IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) Routing Header", RFC 8138, DOI

10.17487/RFC8138, April 2017, <https://www.rfc-editor.org/info/rfc8138>.

[RFC8505] Thubert, P., Ed., Nordmark, E., Chakrabarti, S., and C. Perkins, "Registration Extensions for IPv6 over Low-Power Wireless Personal Area Network (6LoWPAN) Neighbor Discovery", RFC 8505, DOI 10.17487/RFC8505, November 2018, <https://www.rfc-editor.org/info/rfc8505>.

[CAPABILITIES] Jadhav, R., Thubert, P., Richardson, M., and R. Sahoo, "RPL Capabilities", Work in Progress, Internet-Draft, draft-ietf-roll-capabilities-02, 11 March 2020, <https://tools.ietf.org/html/draft-ietf-roll-capabilities-02>.

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