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A RPL DODAG Configuration Option for the 6LoWPAN Routing Header  
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## Abstract

This document updates [RFC 8138](#) by defining a bit in the RPL DODAG Configuration Option to indicate whether compression is used within the RPL Instance, and specify the behavior of [RFC 8138](#)-capable nodes when the bit is set and unset.

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## Table of Contents

<a href="#">1.</a>	Introduction . . . . .	<a href="#">2</a>
<a href="#">2.</a>	Terminology . . . . .	<a href="#">3</a>
<a href="#">2.1.</a>	References . . . . .	<a href="#">3</a>
<a href="#">2.2.</a>	Glossary . . . . .	<a href="#">3</a>
<a href="#">2.3.</a>	Requirements Language . . . . .	<a href="#">4</a>
<a href="#">3.</a>	Extending <a href="#">RFC 6550</a> . . . . .	<a href="#">4</a>
<a href="#">4.</a>	Updating <a href="#">RFC 8138</a> . . . . .	<a href="#">5</a>
<a href="#">5.</a>	Transition Scenarios . . . . .	<a href="#">5</a>
<a href="#">5.1.</a>	Coexistence . . . . .	<a href="#">6</a>
<a href="#">5.2.</a>	Inconsistent State While Migrating . . . . .	<a href="#">6</a>
<a href="#">5.3.</a>	Rolling Back . . . . .	<a href="#">6</a>
<a href="#">6.</a>	IANA Considerations . . . . .	<a href="#">7</a>
<a href="#">7.</a>	Security Considerations . . . . .	<a href="#">7</a>
<a href="#">8.</a>	Acknowledgments . . . . .	<a href="#">8</a>
<a href="#">9.</a>	Normative References . . . . .	<a href="#">8</a>
<a href="#">10.</a>	Informative References . . . . .	<a href="#">9</a>
	Authors' Addresses . . . . .	<a href="#">9</a>

[1.](#) Introduction

The design of Low Power and Lossy Networks (LLNs) is generally focused on saving energy, which is the most constrained resource of all. The routing optimizations in the "Routing Protocol for Low Power and Lossy Networks" [[RFC6550](#)] (RPL) such as routing along a Destination-Oriented Directed Acyclic Graph (DODAG) to a Root Node and the associated routing header compression and forwarding technique specified in [[RFC8138](#)] derive from that primary concern.

Enabling [[RFC8138](#)] on a running network requires a Flag Day where the network is upgraded and rebooted. Otherwise, if acting as a Leaf, a node that does not support the compression would fail to communicate; if acting as a router it would drop the compressed packets and black-hole a portion of the network. This specification enables a hot upgrade where a live network is migrated. During the migration, the compression remains inactive, until all nodes are upgraded.

This document complements [[RFC8138](#)] and signals whether it should be used within a RPL DODAG with a new flag in the RPL DODAG Configuration Option. The setting of this new flag is controlled by the Root and propagates as is in the whole network as part of the normal RPL signaling.

The flag is cleared to maintain the compression inactive during the migration phase. When the migration is complete (e.g., as known by network management and/or inventory), the flag is set and the compression is globally activated in the whole DODAG.

## [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), and "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  
 SubDAG: A DODAG rooted at a node which is a child of that node and a subset of a larger DAG  
 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. Requirements Language

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. Extending [RFC 6550](#)

The DODAG Configuration Option is defined in [Section 6.7.6 of \[RFC6550\]](#). Its purpose is extended to distribute configuration information affecting the construction and maintenance of the DODAG, as well as operational parameters for RPL on the DODAG, through the DODAG. As shown in Figure 1, the Option was originally designed with 4 bit positions reserved for future use as Flags.

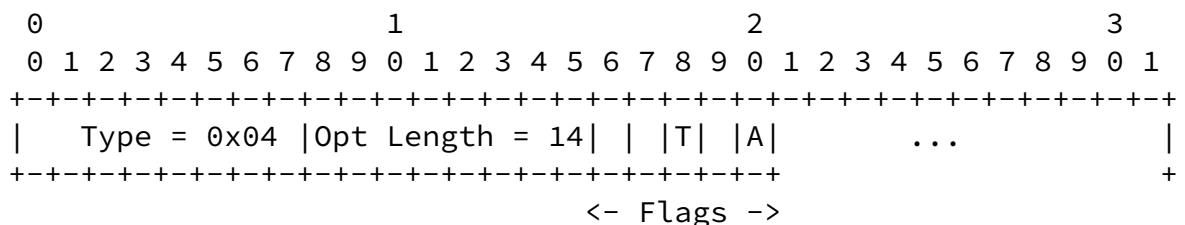


Figure 1: DODAG Configuration Option (Partial View)

This specification defines a new flag "Enable [RFC8138](#) Compression" (T). The "T" flag is set to turn-on the use of [\[RFC8138\]](#) within the DODAG. The "T" flag is encoded in position 2 of the reserved Flags

in the DODAG Configuration Option (counting from bit 0 as the most significant bit) and set to 0 in legacy implementations as specified respectively in Sections [20.14](#) and [6.7.6](#) of [\[RFC6550\]](#).

Section 4.3 of [\[USEofRPLinfo\]](#) updates [\[RFC6550\]](#) to indicate that the definition of the Flags applies to Mode of Operation (MOP) values zero (0) to six (6) only. For a MOP value of 7, [\[RFC8138\]](#) MUST be used on Links where 6LoWPAN Header Compression [\[RFC6282\]](#) applies and MUST NOT be used otherwise.

The RPL DODAG Configuration Option is typically placed in a DODAG Information Object (DIO) message. The DIO message propagates down the DODAG to form and then maintain its structure. The DODAG Configuration Option is copied unmodified from parents to children. [\[RFC6550\]](#) states that "Nodes other than the DODAG Root MUST NOT modify this information when propagating the DODAG Configuration option". Therefore, a legacy parent propagates the "T" flag as set by the Root, and when the "T" flag is set, it is transparently flooded to all the nodes in the DODAG.

#### 4. Updating [RFC 8138](#)

A node SHOULD generate packets in the compressed form using [\[RFC8138\]](#) if and only if the "T" flag is set. This behavior can be overridden by configuration or network management. Overriding may be needed e.g., to turn on the compression in a network where all nodes support [\[RFC8138\]](#) but the Root does not support this specification and cannot set the "T" flag, or to disable it locally in case of a problem.

The decision to use [\[RFC8138\]](#) is made by the originator of the packet depending on its capabilities and its knowledge of the state of the "T" flag. A router encapsulating a packet is the originator of the resulting packet and is responsible for compressing the outer headers with [\[RFC8138\]](#), but it MUST leave the encapsulated packet as is.

An external target [\[USEofRPLinfo\]](#) is not expected to support [\[RFC8138\]](#). In most cases, packets to and from an external target are tunneled back and forth between the border router (referred to as 6LR) that serves the external target and the Root, regardless of the MOP used in the RPL DODAG. The inner packet is typically not compressed with [\[RFC8138\]](#), so for outgoing packets, the border router just needs to decapsulate the (compressed) outer header and forward

the (uncompressed) inner packet towards the external target.

A router MUST uncompress a packet that is to be forwarded to an external target. Otherwise, the router MUST forward the packet in the form that the source used, either compressed or uncompressed.

A RUL [[UNAWARE-LEAVES](#)] is both a leaf and an external target. A RUL does not participate in RPL and depends on the parent router to obtain connectivity. In the case of a RUL, forwarding towards an external target actually means delivering the packet.

## 5. Transition Scenarios

A node that supports [[RFC8138](#)] but not this specification can only be used in a homogeneous network. Enabling the [[RFC8138](#)] compression without a turn-on signaling method requires a "flag day"; by which time all nodes must be upgraded, and at which point the network can be rebooted with the [[RFC8138](#)] compression turned on.

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. Though it is possible to roll back (see [Section 5.3](#)), the roll back operation SHOULD be complete before the network operator adds nodes that do not support [[RFC8138](#)].

### 5.1. Coexistence

A node that supports this specification can operate in a network with the [[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 5.2](#)).

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, all the RPL-Aware Nodes are expected to be able to handle compressed packets in the compressed form. A node that cannot do so may remain connected to the network as a RUL as described in [[UNAWARE-LEAVES](#)].

### 5.2. Inconsistent State While Migrating

When the "T" flag is turned on 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 DODAG are still not aware of it. 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 DODAG in the form in which it was generated, it is required that all the RPL nodes support [RFC8138] at the time of the switch.

Setting the "T" flag is ultimately the responsibility of the Network Administrator. The expectation is that the network management or upgrading tools in place enable the Network Administrator to know when all the nodes that may join a DODAG were migrated. In the case of a RPL instance with multiple Roots, all nodes that participate to the RPL Instance may potentially join any DODAG. The network MUST be operated with the "T" flag unset until all nodes in the RPL Instance are upgraded to support this specification.

### 5.3. Rolling Back

When turning [RFC8138] compression off in the network, the Network Administrator MUST wait until all nodes have converged to the "T" flag unset before allowing nodes that do not support the compression in the network. To that effect, whether the compression is active in a node SHOULD be exposed the node's management interface.

Nodes that do not support [RFC8138] SHOULD NOT be deployed in a network where the compression is turned on. If that is done, the node can only operate as a RUL.

## 6. IANA Considerations

This specification updates the Registry that was created for [RFC6550] as the registry for "DODAG Configuration Option Flags" and updated as the registry for "DODAG Configuration Option Flags for MOP 0..6" by [USEofRPLinfo], by allocating one new Flag as follows:

+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+

Bit Number	Capability Description	Reference
2 (suggested)	Turn on <a href="#">RFC8138</a> Compression (T)	THIS RFC

Table 1: New DODAG Configuration Option Flag

IANA is requested to add [this document] as a reference for MOP 7 in the RPL Mode of Operation registry.

## 7. Security Considerations

It is worth noting that in RPL [[RFC6550](#)], every node in the LLN that is RPL-aware and has access to the RPL domain can inject any RPL-based attack in the network, more in [[RFC7416](#)]. This document applies typically to an existing deployment and does not change its security requirements and operations. It is assumed that the security mechanisms as defined for RPL are followed.

Setting the "T" flag before all 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 unsetting 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.

An attacker may unset the "T" flag to force additional energy



consumption of child or descendant nodes in its subDAG. Conversely it may set the "T" flag, so that nodes located downstream would compress when that it is not desired, potentially resulting in the loss of packets. In a tree structure, the attacker would be in position to drop the packets from and to the attacked nodes. So the attacks above would be more complex and more visible than simply dropping selected packets. The downstream node may have other parents and see both settings, which could raise attention.

## 8. Acknowledgments

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