

ROLL
Internet-Draft
Intended status: Standards Track
Expires: May 4, 2020

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November 1, 2019

**Mode of Operation extension and Capabilities
draft-ietf-roll-mopex-cap-01**

Abstract

RPL allows different mode of operations which allows nodes to have a consensus on the basic primitives that must be supported to join the network. The MOP field in [RFC6550](#) is of 3 bits and is fast depleting. This document extends the MOP field specification and adds a notion of capabilities using which the nodes can further advertise their support for, possibly optional, capabilities.

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[1.](#) Introduction

RPL [[RFC6550](#)] specifies a proactive distance-vector based routing scheme. The protocol creates a DAG-like structure which operates with a given "Mode of Operation" (MOP) determining the minimal and mandatory set of primitives to be supported by all the participating nodes.

MOP as per [[RFC6550](#)] is a 3-bit value carried in DIO messages and is specific to the RPL Instance. The recipient of the DIO message can join the specified network as a router only when it can support the primitives as required by the mode of operation value. For example, in case of MOP=3 (Storing MOP with multicast support) the nodes can join the network as routers only when they can handle the DAO advertisements from the peers and manage routing tables. The 3-bit value is already exhausted and requires replenishment. This document introduces a mechanism to extend mode of operation values.

This document further adds a notion of capabilities using which the nodes in the network could inform its peers about its additional capabilities/features. This document highlights the differences of capabilities from that of Mode of operation and explains the necessity of it.

1.1. Requirements Language and 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](#) [[RFC2119](#)].

MOP: Mode of Operation. Identifies the mode of operation of the RPL Instance as administratively provisioned at and distributed by the DODAG root.

MOPex: Extended MOP: This document extends the MOP values over a bigger range. This extension of MOP is called MOPex.

Capabilities: Additional features or capabilities which might possibly be optional that are supported by the node.

DAO: DODAG Advertisement Object. An RPL message used to advertise the target information in order to establish routing adjacencies.

DIO: DODAG Information Object. An RPL message initiated by the root and is used to advertise the network configuration information.

Current parent: Parent 6LR node before switching to the new path.

NPDAO: No-Path DAO. A DAO message which has target with lifetime 0.

MOPex: MOP extension as defined in this document.

This document uses terminology described in [[RFC6550](#)]. For the sake of readability all the known relevant terms are repeated in this section.

2. Requirements for this document

Following are the requirements considered for this documents:

REQ1: MOP extension. Current MOP of 3-bit is fast depleting. An MOP extension needs to extend the possibility of adding new MOPs in the future.

REQ2: Backwards compatibility. The new options and new fields in the DIO message should be backward compatible i.e. if there

are nodes which support old MOPs they could still operate in their own instances.

REQ3: Optional capabilities handshake. Capabilities are features, possibly optional, which could be handshaked between the nodes and the root within an RPL Instance.

REQ4: Capabilities handshake could be optionally added with existing MOPs. Capabilities been optional in nature could be put to use with existing MOPs. Capabilities and MOP-extension is mutually independent i.e. a DIO can have a capabilities option, MOP-extension option or both in the same message.

3. Extended MOP Control Message Option

This document reserves existing MOP value 7 to be used as an extender. DIO messages with MOP value of 7 may refer to the Extended MOP (MOPex) option in the DIO message.

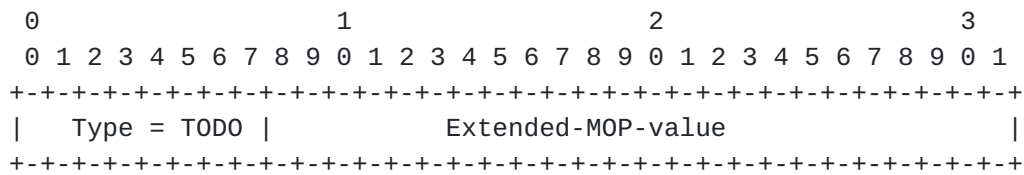


Figure 1: Extended MOP Option

3.1. Final MOP

An implementation supporting this document MUST calculate the final MOP value as the sum of base MOP (as supported in [Section 6.3.1. of \[RFC6550\]](#)) plus the MOPex value. Thus if the MOPex value is 0, it means the final MOP is 7 since the base MOP in this case will be set to 7.

Base MOP	MOPex	Final MOP
0	NA	0
1	NA	1
:	:	:
6	NA	6
7	0	7
7	1	8
7	2	9
:	:	:

Table 1: Final MOP calculation

3.2. Handling MOPex

If the MOPex option is absent in the DIO whose MOP is 7, then the MOPex value can be assumed to be zero (thus the final MOP in this case will be 7). The MOPex value should be referred only if the base MOP value is 7 and if the MOPex option is present. In case the base MOP is 7 and if the MOPex option is present, then the implementation MUST calculate the final MOP after considering the value in MOPex.

Note that [\[RFC6550\]](#) allows the node who does not support the received MOP to still join the network as a leaf node. This semantic continues to be true even in case of MOPex.

4. Capabilities

Currently RPL specification does not have a mechanism whereby a node can signal the set of features that are available on its end. Such a mechanism could help the root to advertise its capabilities and in response also determine some advanced information about the capabilities of the joining nodes. The Mode of Operation field in RPL mandates the operational requirement and does not allow loose coupling of additional capabilities. This document defines Capabilities as additional features which could be supported by the nodes and handshaked as part of RPL signaling. Capabilities are embedded as RPL control message option as defined [Section 6.7 of \[RFC6550\]](#) in the base messages of DIO, DAO and DAO-ACK signaling.

Note that capabilities and MOPex are mutually exclusive and it is possible for an implementation to support either or both of the options.

4.1. Capability Control Message Option

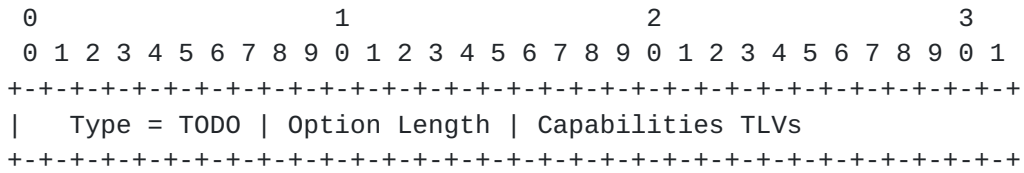


Figure 2: Capabilities Option

Multiple capabilities could be sent in the same message. The length field allows the message parser to skip the capability TLV parsing.

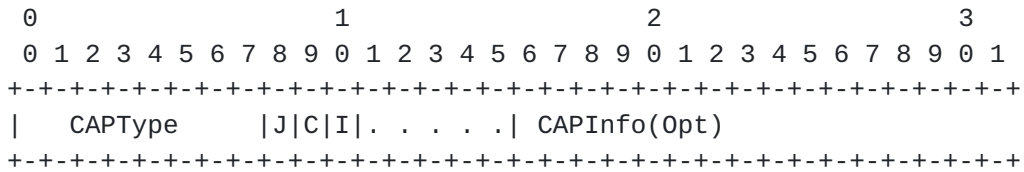


Figure 3: Capabilities TLV

Every capability is identified by its type and it may have an optional Capability Info. Note that a given capability may or may not be disseminated with additional information depending on the 'I' flag.

J = Join only as leaf if capability not understood

C = Copy capability to children

I = Cap Info present

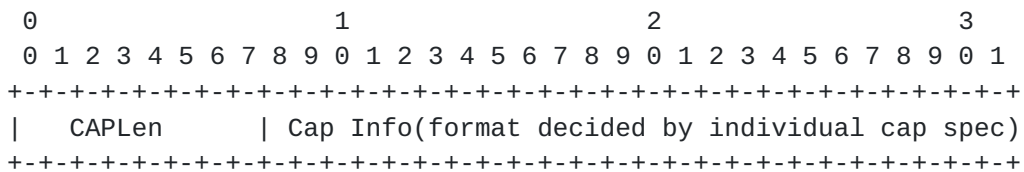


Figure 4: Capabilities Info

Capability Information provides additional information for the given capability. The format of this field should be defined as part the individual capability specification and is beyond the scope of this document. This document provides a container format for carrying the capability and its context information.

4.2. Capabilities Handshake

The root node could advertise the set of capabilities it supports in the DIO message. A node could take advantage of the knowledge that the root supports a particular capability. Similarly a node could advertise its capabilities in the DAO message using the capability control message option defined in this document. Capabilities advertised by non-root nodes are strictly a subset of the capabilities advertised by the root.

In storing MOP, the DAO message from the 6LR could contain multiple target options. The targets of the capabilities option are indicated by one or more Target options that precede the Capabilities Option. This handling is similar to the Transit Information Option as supported in [Section 6.7.8. of \[RFC6550\]](#).

5. Implementations Consideration

The MOP-extension could cause 3-byte increase in memory in the RPL-Instance. The MOP field in the RPL-Instance needs to be upgraded to a 32 bit integer.

[[RFC6550](#)], it was possible to discard an unsupported DIO-MOP just by inspecting the base message. With this document, the MOPex is a different control message option and thus the discarding of the DIO message could happen after inspecting the message options.

A node in storing MOP could independently construct a DAO message with target options containing its child/sub-children. Thus with capabilities it needs to reconstruct the capabilities field as well. This may result in increase in the memory requirement on per routing-entry basis.

6. Acknowledgements

Thanks to Georgios Papadopoulos for the review and feedback.

7. IANA Considerations

7.1. Mode of operation: MOPex

IANA is requested to assign a new Mode of Operation, named "MOPex" for MOP extension under the RPL registry. The value of 7 is to be assigned from the "Mode of Operation" space [[RFC6550](#)]

Value	Description	Reference
7	MOPex	This document

Mode of Operation

7.2. New options: MOPex and Capabilities

Two new entries are required for new supporting new options "MOPex", "Capabilities" from the "RPL Control Message Options" space [RFC6550].

Value	Meaning	Reference
TBD1	MOPex	This document
TBD2	Capabilities	This document

New options

7.3. New Registry for Extended-MOP-value

IANA is requested to create a registry for the extended-MOP-value (MOPex). This registry should be located in TODO. New MOPex values may be allocated only by an IETF review. Currently no values are defined by this document. Each value is tracked with the following qualities:

- o MOPex value
- o Description
- o Defining RFC

7.4. New Registry for Capabilities Flags

IANA is requested to create a registry for the Capabilities flags as described in Section 4 of this document. This registry should be located in TODO. New Capabilities flags may be allocated only by an IETF review. Currently no flags are defined by this document. Each value is tracked with the following qualities:

- o Flag
- o Description

- o Defining RFC

8. Security Considerations

The options defined in this document are carried in the base message objects as defined in [RFC6550]. The RPL control message options are protected by the same security mechanisms that protect the base messages.

Capabilities flag can reveal that the node has been upgraded or is running a old feature set. This document assumes that the base messages that carry these options are protected by RPL security mechanisms and thus are not visible to a malicious node.

9. References

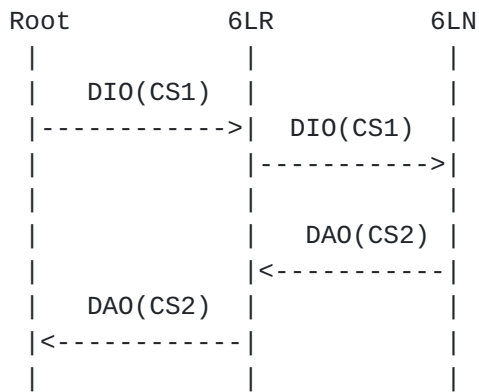
9.1. Normative References

[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>>.

9.2. Informative References

[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>>.

[Appendix A](#). Capability Handshake Example



CS: Capabilities Set
 CS1: Capabilities set advertised by root
 CS2: Capabilities set advertised by node. CS2 is a subset of CS1.

Figure 5: Capabilities Option

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