ROLL
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RPL Capabilities
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Abstract

This draft enables the discovery, advertisement and query of capabilities for RPL nodes.

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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This Internet-Draft will expire on September 10, 2020.

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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.

This document 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: As defined in [I-D.jadhav-roll-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.

Upstream path/direction: Path or direction from the node to the Root in a DAG.

Downstream path/direction: Path or direction to the node from the Root in a DAG.

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

1.2. What are 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. This document defines Capabilities 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.

2. Requirements for this document

Following are the requirements considered for this documents:

REQ1: 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.

REQ2: Optional capabilities handshake. Capabilities are features, possibly optional, which could be handshaked between the nodes and the root within an RPL Instance.

REQ3: 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.

REQ4: Capabilities could be explicitly queried.

2.1. How are Capabilities different from MOP or DIO Configuration Option?

The Mode of Operation (MOP) field in RPL mandates the operational requirement for the nodes joining as routers. MOP and DIO Configuration Option is strictly controlled by the Root node in RPL. Intermediate 6LRs could not modify the values. Also, the MOP never changes for the lifetime of the RPL Instance. Changes in DIO Configuration Option are possible but are very rare. Capabilities, on the other hand, might change more dynamically.

RPL DIO message also carries routing metrics and constraints as specified in [RFC6551]. Metrics and constraints are used as part of objective function which aids in node's rank calculation. A router may use capabilities carried in DIO message as additional metrics/ constraints. However, capabilities have a larger scope and may be carried in other messages other than DIO and can flow in both the directions (upstream and downstream).

3. Capabilities

Handling of Capabilities MUST be supported if the network uses MOPex [I-D.jadhav-roll-mopex].

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

3.1. Capability Catagories

Capabilities can be divided into two broad categories:

Global Capabilities: It will include the features and capability supported across an RPL instance. These capabilities can be advertised by the Root or 6LRs of the DODAG. If a Node in the LLN doesn't support a paticular global capability it may have to join the RPL instance as a leaf node, as indicated by that individual capability option. Example of such capabilities are Compression Methods Supported, Support for TE paths (P-DAO).

Local Capabilities: It will include the cpabilities very specific to a Node in the LLN. Example of such capabilities are NBR Cache information, Routing Table Information.

Note that some capabilities can be either global or local depending upon the context they are used ex.P-DAO [TODO: This is not clear]

3.2. Capability Control Message Option

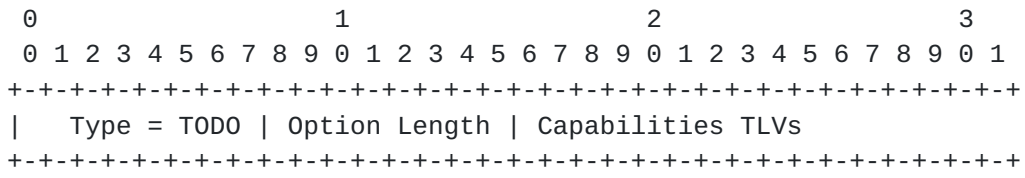


Figure 1: Capabilities Option

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

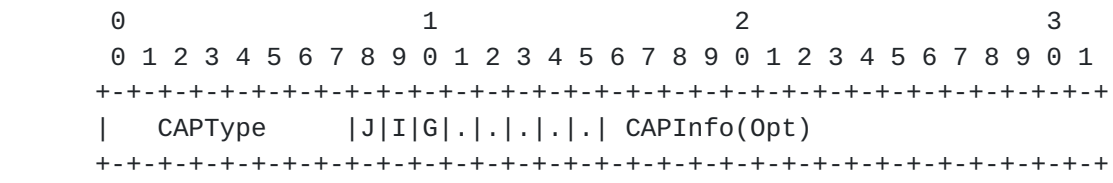


Figure 2: Capabilities TLV

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 diseminated with additional information depending on the scope of the capability indicated by the I bit.

J = Join only as leaf if capability not understood

I = Capability Info present

G = If set indicates a Global Capability else its a local. For a capability if it's mandatory and global bit is set then node those either doesn't understand the capability or doesn't have this capability should not join the DODAG as a router. All the global capablities MUST be diseminated across the network. 6LRs in the network MUST copy the global capabilities in their DIOs.

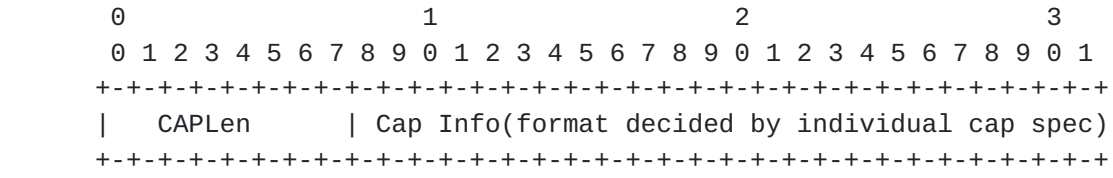


Figure 3: Capabilities Info

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.

3.3. 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 because of the DAO-Aggregation. The targets of the capabilities option are indicated by one or more Target options that precede the Capabilties Option. This handling is similar to the Transit Information Option as supported in Section 6.7.8. of [RFC6550].

4. Guidelines for defining new capabilities

This section provides guidelines/recommendations towards defining new capabilities. Note that the capabilities might be carried as part of the multicast messaging such as DIO and hence the set should be used in restrictive manner as far as possible.

4.1. Handling Capability flags

The 'G' (global) flag indicating global capability should be set only by the root. However, it is not mandatory for the root to set this flag for all capabilities it indicates. It should set this flag only for those capabilities which the 6LRs downstream must propagate further downstream.

The 'I' (information) flag is set only when there is additional information to be set in context to the capability.

The 'J' (join) flag can be set in context to a capability either by a 6LR or the root. The 'J' flag indicates that if the capability is not supported by a node then it can join the instance only as a 6LN (or do not join as 6LR).

The 'C' (copy) flag is set by the node indicating that the capabilities MUST be copied downstream by the node.

4.1.1. Rules to handle capabilities flag

On receiving a capability it does not support, the node MUST check the 'J' flag of the capability before joining the Instance. If the 'J' flag is set then it can only join as a 6LN.
If the node is operating as 6LR and subsequently it receives a capability which it doesn't understand with 'J' flag set, then the node has to switch itself to 6LN mode. During switching the node needs to inform its downstream peers of its changed status by sending a DIO with infinite rank as mentioned in [RFC6550].

5. ROLL Capabilities

5.1. Projected Route Capability (PRC)

[I-D.ietf-roll-dao-projection] proposes mechanisms to compute and install traffic engineered paths in the RPL network. It enables an RPL Root to install and maintain Projected Routes based on requested path metric, within its DODAG, along with a selected set of nodes that may or may not include self, for a chosen duration. Projected Route Capability will be used to enable this TE path calculation. PRC will be an optional global capability. Any node that does not understand or support the projected route functions can still act as an LR.

The DODAG root will use projected routes capability to advertise the support of projected routes with the possible mode of operations and set of path metrics it can use to calculate a projected route. DODAG root will add the PRC to DIO message so that it can disseminate the information in entire DODAG. Router nodes in the LLN receiving DIOs with PRC MUST forward the same into their sub-DODAG without any change even though they don't understand or support the projected route feature.LR will use the path metric information advertised by the DODAG root to learn these metrics from the network and neighbors. The same information they will use to advertise in the sibling information option. LR will also use these path metrics information to request traffic-engineered routes optimizing a or set of specific network metric(s).

LRs in the network will use this capability to inform the PCE if they can be part of a storing or non-storing or both mode of projected routes. Here the PRC will be part of the DAO message.

The capability will convey the below information. The PRC MUST have either of the information or both depending upon the node type.If originator is BR, then both the information MUST be there.

I: Supports projected route for both storing and non-storing mode.

II: List of supported path metrics that can be used to compute projected routes.

III: [To Decide] Can we add the PCE address information to this?

5.1.1. Format of Projected Route Capability

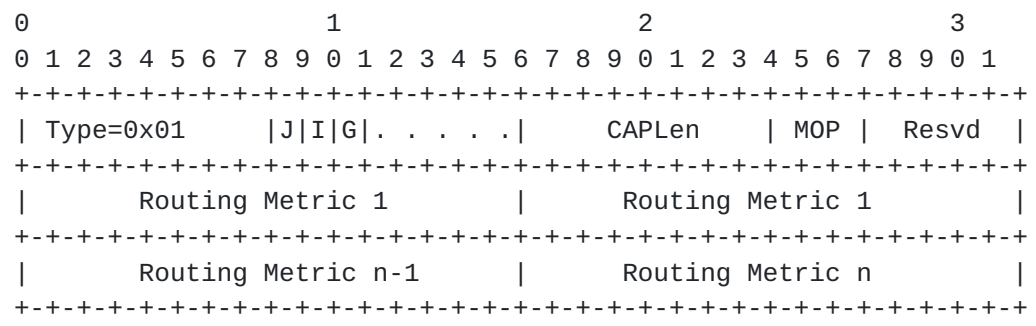


Figure 4: Projected Route Capability TLV

Type: 0x01.

Flags: DODAG root MUST set G bit to 1 plus LRs MUST set it to 0. I bit will always be set to 1.

CAPLen: 8-bit unsigned integer, representing the length in octets of the option, not including the Option Type and Length fields.

MOP: 3-bit field indicating the mode of operation of projected route capability.

Resvd: 5-bit unused fields.They MUST be initialized to zero by the sender and MUST be ignored by the receiver.

Routing Metric: 16 bit unsigned integer represetning the routing metric to be used for TE path calculation. There can be n number of such routing metric fields. These fileds are alowed with the PRC sent by the DODAG ROOT. LRs MUST not send routing metric information with PRC.

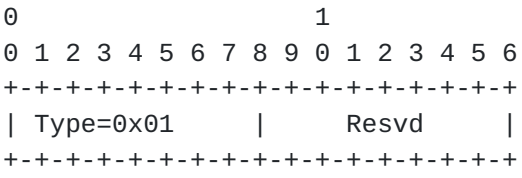


Figure 5: Routing Metric Information

5.2. 6LoRH Capability

[RFC8138] introduces a new 6LoWPAN Routing Header (6LoRH) to carry IPv6 routing information. The 6LoRH may contain source routing information such as a compressed form of SRH, and other sorts of routing information such as the RPI and IP-in-IP encapsulation

The transition to [RFC8138] in a network can only be done when all nodes support the specification. In a mixed case with both RFC8138-capable and non-capable nodes it would not be posssible to take advantage of 6LoRH.[I-D.thubert-roll-turnon-rfc8138] defines a mechanism to control the use of 6LoRH in a DODAG by using "T" flag bit in RPL configuration option. To assist DODAG root to decide if it has to set "T" flag bit in RPL Configuration Option to enable 6LoRH within its DODAG, all LRs in DODAG MUST inform their support of [RFC8138] by adding 6LoRH capability TLV to their advertised capability control message option.

DODAG root MUST use 6LoRH capability TLV to inform all the nodes in the DODAG, that DODAG is [RFC8138] compliance. 6LoRH is an optional local capability.

Any LR joining the DODAG MUST add 6LoRH capability TLV to the capability control message option in its DAO message to inform BR that it supports RFC8138.If received DAO message doesn't have 6LoRH capability TLV, DODAG Root MUST conclude the target node doesn't support RFC 8138.So if DODAG is still not using 6LoRH, it MUST refrain from using the compression and if it is already using it, it MUST deny the LR from joining the DODAG with proper error code. [TODO- Need to add new Error code].

6LoRH capability is an optional capability any node that doesn't understand or support the 6LoRH can join the DODAG if the "T" flag in the RPL Configuration option is not set otherwise it MUST join the network as a leaf node.

5.2.1. Format of 6LoRH Capability

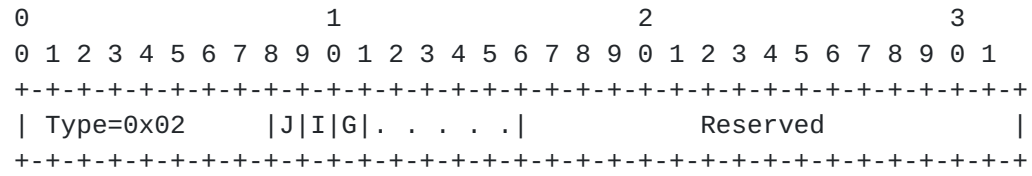


Figure 6: 6LoRH Capability TLV

Type: 0x02.

Flags: LRs MUST set it to 0. I bit will always be set to 0.

Reserved: 16-bit unsigned integer, they MUST be initialized to zero by the sender and MUST be ignored by the receiver..

5.3. Routing Resource Capability

Storing mode of operation requires each intermediate router in the LLN to maintain routing states' information in the routing table. LLN routers typically operate with constraints on processing power, memory, and energy (battery power). Memory limits the number of routing states an LR and BR can maintain. When the routing table of an LR or BR is full, it will either reject the new DAO messages received or will use some replacement policy to remove a routing entry and add the new one. Rejection of DAO messages will lead to an increase in DAO message transmission that impacts the energy and network convergence time. Routing state replacement leads to downward path downtime.

One possible way to solve problems due to routing table size constraint is to use this information to add neighbors to the DAO parent set.Routing resource capability can be used by LR and BR to advertise their current routing table usage details in the network. LR or LNs in LLN can use this information in the selection of the DAO parent set. PCE can use this information to select intermediate routers for the projected routes. Routing Resource is an optional local capability.

Routing reource capability TLV can occur multiple times in the capability control message option to advertise below possible routing table information.

I: Master Routing Table Storing

II: Storing mode P-DAO Table

III: Non-Storing mode P-DAO

Routing resource capabablity sent in DIO message has link local scope and it MUST not be forwarded.

5.3.1. Format of Routing Resource Capability

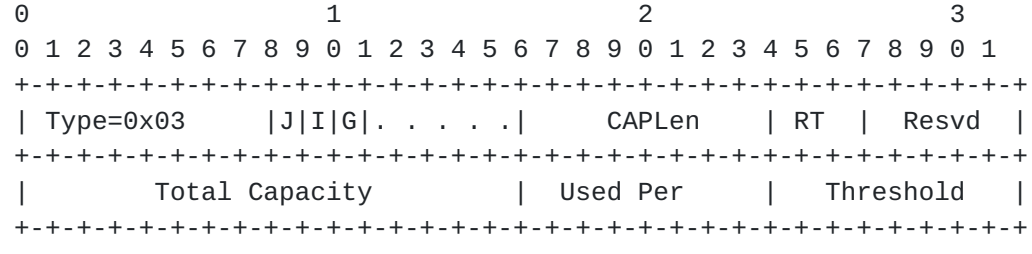


Figure 7: Routing Resource Capability TLV

Type: 0x03.

Flags: G bit MUST be set to 0. I bit will always be set to 1.

CAPLen: 8-bit unsigned integer, representing the length in octets of the option, not including the Option Type and Length fields.

RT: 3-bit field indicating the routing resource type. This document defines 3 routing resource type.

I: Master Routing Table Storing(RT = 1)

II: Storing mode P-DAO Table(RT = 2)

III: Non-Storing mode P-DAO(RT = 3)

Resvd: 5-bit unused field. It MUST be initialized to zero by the sender and MUST be ignored by the receiver.

Total Capacity: 16 bit unsigned integer representing the the routing table size.

Percentage used: 8 bit unsigned integer representing the the percentage of routing table space currently in use.

Threshold: 8 bit unsigned integer representing the maximum routing table space that can be used. If the routing resource type is RT1 and used Percentage is greater than or equal to a threshold, its siblings MUST stop using it as the preferred parent or remove it from the parent list. If the routing resource type is RT2 or RT3 and used Percentage is greater than or equal to a threshold, PCE MUST recompute some projected routes by excluding this node.

5.4. Neighbor Cache Capability

A neighbor cache maintains neighboring one-hop connected nodes information such as MAC address, link-local IP address and other reachability state information needed for layer two communication.Node density has direct implications on the neighbor cache. In the constrained network scenario the size of the neighbor cache will be limited. Thus there are chances that a node may not be able to store all the neighboring nodes in its cache and use replacement algorithms to evict some of the entries to accommodate the new one. If the replaced neighbor has installed a DAO route on it then it can lead to packet loss or additional address resolution message exchange. To avoid unnecessary replacement of neighbor cache entries neighbor cache management policy [I-D.ietf-lwig-nbr-mgmt-policy] proposes a solution that will put a

restriction on the connectivity to immediate neighbor depending upon the type of neighbor. But this won't solve the problem unless until the availability of neighbor cache is not taken into consideration while selecting the DAO parent set.

Neighbor Cache capability can be used by LR and BR to advertise their neighbor cache size information. This capablity information has only link scope and should not be advertised in the entire network. [TODO-- As neighbor cache entries category is not yet standardized i think we can't use it in capability. With categories format of the TLV is going to chnage.]

5.4.1. Format of Neighbor Cache Capability

6. Acknowledgements

Thanks to Georgios Papadopoulos, Li Zhao for the review and feedback.

7. IANA Considerations

7.1. New option: Capabilities

New entry is required for supporting new Capabilities option in the "RPL Control Message Options" space [RFC6550].

Value	Meaning	Reference
TBD1	Capabilities	This document

New options

7.2. New Registry for Capabilities Flags

IANA is requested to create a registry for the Capabilities flags as described in Section 2.1 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:

- Flag
- Description
- 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.

[TODO] implications of malicious attack involving setting the capability flags.

9. References

9.1. Normative References

[I-D.ietf-lwig-nbr-mgmt-policy]
Jadhav, R., Sahoo, R., Duquennoy, S., and J. Eriksson, "Neighbor Management Policy for 6LoWPAN", draft-ietf-lwig-nbr-mgmt-policy-03 (work in progress), February 2019.

[I-D.ietf-roll-dao-projection]
Thubert, P., Jadhav, R., and M. Gillmore, "Root initiated routing state in RPL", draft-ietf-roll-dao-projection-09 (work in progress), November 2019.

[I-D.thubert-roll-turnon-rfc8138]
Thubert, P. and L. Zhao, "Configuration option for RFC 8138", draft-thubert-roll-turnon-rfc8138-03 (work in progress), July 2019.

[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>.

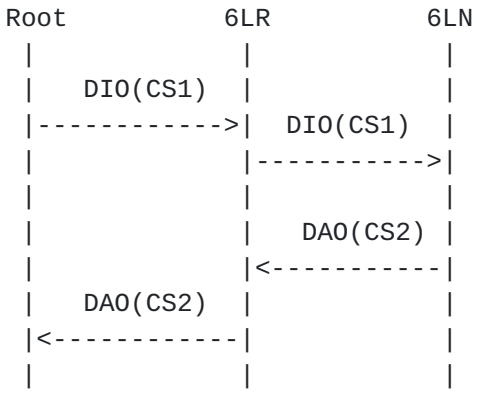
[RFC6550] Winter, T., Ed., Thubert, P., Ed., Brandt, A., Hui, J., Kelsey, R., Levis, P., Pister, K., Struik, R., Vasseur, JP., and R. Alexander, "RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks", RFC 6550, DOI 10.17487/RFC6550, March 2012, <https://www.rfc-editor.org/info/rfc6550>.

[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>.

9.2. Informative References

[RFC6551] Vasseur, JP., Ed., Kim, M., Ed., Pister, K., Dejean, N., and D. Barthel, "Routing Metrics Used for Path Calculation in Low-Power and Lossy Networks", RFC 6551, DOI 10.17487/RFC6551, March 2012, <https://www.rfc-editor.org/info/rfc6551>.

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 8: Capabilities Option

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