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Loop Free RPL
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Abstract

The IETF has developed the IPv6 based standards for Low-power and Lossy Networks (LLNs) to meet requirements of constrained applications, such as field monitoring, inventory control and so on. The IPv6 Routing Protocol for LLNs (RPL) was published as [RFC6550] in March 2012. Based on routing metrics and constraints [RFC6551], RPL builds Directed Acyclic Graph (DAG) topology to establish bidirectional routes for LLNs for traffic types of multipoint-to-point, point-to-multipoint, and point-to-point. RPL routes are optimized for traffic to or from one or more roots that act as sinks. As a result, a DAG is partitioned into one or more Destination Oriented DAGs (DODAGs), one DODAG per sink. RPL is widely considered as a feasible routing protocol for LLNs. However, DODAG loops and lack of a loop free DODAG local repair mechanism are two open issues to be addressed. This draft introduces an alternative rank and an Objective Function to eliminate DODAG loops in RPL. Based on the proposed rank and Objective Function, this draft introduces a loop free RPL.

Status of this Memo

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1. Introduction

Low-power and Lossy Networks (LLNs) are a class of networks in which nodes and their communication links are constrained. LLN nodes typically operate with constrains on processing power, physical size, memory, power consumption, lifetime, and rate of activity. Their communication links are characterized by high loss rate, low data rate, instability, low transmission power, and short transmission range. There can be from a few dozen up to thousands of nodes within a LLN. Routing in LLNs is different from routing in mobile ad-hoc networks. The IETF has developed an IPv6 Routing Protocol for LLNs (RPL) published in [RFC6550]. RPL supports multipoint-to-point traffic and point-to-multipoint traffic. The support for point-to-point traffic is also available.

RPL builds Directed Acyclic Graph (DAG) topology, which is partitioned into one or more Destination Oriented DAGs (DODAGs). DODAG is basic logical structure in RPL. RPL nodes construct and maintain DODAG through the DODAG Information Object (DIO) message which is transmitted via link-local multicasting by using the Trickle timer [RFC6206]. The sink in a DODAG is called the DODAG root. RPL defines rules to transmit the DIO messages within a DODAG. The DODAG root configures the DODAG parameters including RPLInstanceID, DODAGVersionNumber, DODAGID, Rank, etc. and advertises the DODAG parameters in the DIO messages. To join a DODAG, a node selects a set of DODAG parents, on the routes towards the DODAG root, and a preferred DODAG parent as the preferred next hop node for upward traffic. Once a node joins a DODAG, it transmits DIO messages to advertise the DODAG parameters.

The traffic inside a LLN flows along the edges of the DODAG, either upward or downward. In RPL, upward routes, having the DODAG root as destination, are provided by the DODAG construction mechanism using DIO messages. Downward routes, from the DODAG root to any other destination, are provided by these destinations transmitting the Destination Advertisement Object (DAO) messages.

Three different modes of operation (MOP) for downward routes are specified in [RFC6550]:

1) No downward routes supported by RPL.
2) Storing mode of operation in which each router stores downward routing tables for its sub-DODAG. In Storing mode, the DAO message is sent to DAO parents. A node unicasts the DAO messages to the selected parent(s). Transmission of the DAO messages propagates from the nodes towards the DODAG root, where each intermediate router adds its downward routing stack to the DAO messages. In Storing mode, downward traffic is sent by using the downward

routing tables.

3) Non-Storing mode of operation in which only the DODAG root stores routes to all nodes in the network. In Non-Storing mode, the DAO message is sent to the DODAG root. A node unicasts the DAO messages to the DODAG root, which then calculates routes to all destinations by piecing together the information collected from the DAO messages. In Non-Storing mode, downward traffic is sent by way of source routing.

An RPL node may act as a leaf node or as a router. RPL defines operation rules for both leaf node and router. For example, a leaf node does not extend DODAG connectivity. An RPL router needs to implement Trickle timer algorithm [RFC6206]. An RPL router implementation needs to support the MOP in use by the DODAG, that is, support for upward routes only or support for upward routes and downward routes in Storing mode or support for upward routes and downward routes in Non-Storing mode.

RPL has been implemented and tested [draft-clausen-lln-rpl-experiences-04]. A snapshot of the DODAG was made every ten seconds. In 74.14% of the 4114 snapshots, at least one loop was observed. In RPL, the cause of DODAG loops comes from rank increase. This draft introduces an alternative rank and an Objective Function to eliminate DODAG loops in RPL. In this draft, a node's rank never increases, even if a parent becomes unreachable. As a result, the introduced rank and Objective Function prevent DODAG loops from occurring. This draft also introduces a method for repairing DODAG locally without causing any DODAG loop. The DODAG local repair method applies to both Storing and Non-Storing modes of operation in RPL.

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 [RFC2119].

Additionally, this draft employs terminologies defined in [RFC6550], and extends following terminologies:

DIO: DODAG Information Object in which the rank is represented by two integers.

Up: Up refers to the direction from leaf node or router towards the DODAG root.

Down: Down refers to the direction from the DODAG root towards leaf node or router.

This draft introduces the following new terminologies:

DRQ: DODAG Repair Request

DRP: DODAG Repair Reply

Rank_DRQ: The rank of the node generating the DRQ message.

Rank_DRP: The rank of the node transmitting the DRP message.

DRQID: IPv6 address of the node generating DRQ message.

DRSN: Sequence number of the DRQ message of the node generating DRQ message.

3. Alternative Rank

In RPL, the rank plays very important role in the DODAG construction and maintenance. The rank of a node defines a position of the node relative to other nodes with respect to the DODAG root. Each node maintains its own rank. The DODAG root has the lowest rank. Nodes maintain their ranks based on parent-child relationship such that a child must have a rank strictly greater than ranks of all its DODAG parents. The DODAG root has no parent. The acyclic structure of the DODAG is guaranteed as long as the rank of any node is strictly greater than ranks of its DODAG parents. It is safe for a node to decrease its rank, as long as its rank remains greater than the ranks of its DODAG parents. However, the rank increase can cause DODAG loops. RPL allows rank increase, which is the source of DODAG loops in RPL. A node's rank increase may also cause all nodes in sub-DODAG to increase their ranks, which may lead to instability in the rank values.

3.1. Alternative Rank Definition

DODAG loops in RPL can be avoided if nodes do not increase their ranks. In order to meet this restriction, this draft defines the rank of a node as a proper fraction:

$$Rank = m/n \quad (1)$$

where m and n are integers such that $0 <= m < n$.

The principle of this alternative rank definition comes from the fact that there are an infinite number of proper fractions between any two proper fractions. This guarantees that a node can decrease its rank for any number of times and still keep its rank greater than ranks of its DODAG parents.

In this draft, a node maintains its rank as two integers, that is, numerator and denominator. The fractional value is used in rank operations, such as rank comparison.

The ROOT_RANK is defined as 0/1 and maintained as 0 and 1. The DODAG root sets its rank to ROOT_RANK. The INFINITE_RANK is defined as 1/1 and maintained as 1 and 1. The INFINITE_RANK can not be advertised in the DIO messages by any node.

3.2. Rank Split Operation

For any two ranks R1 = m/n and R2 = p/q, the rank split operation is defined as:

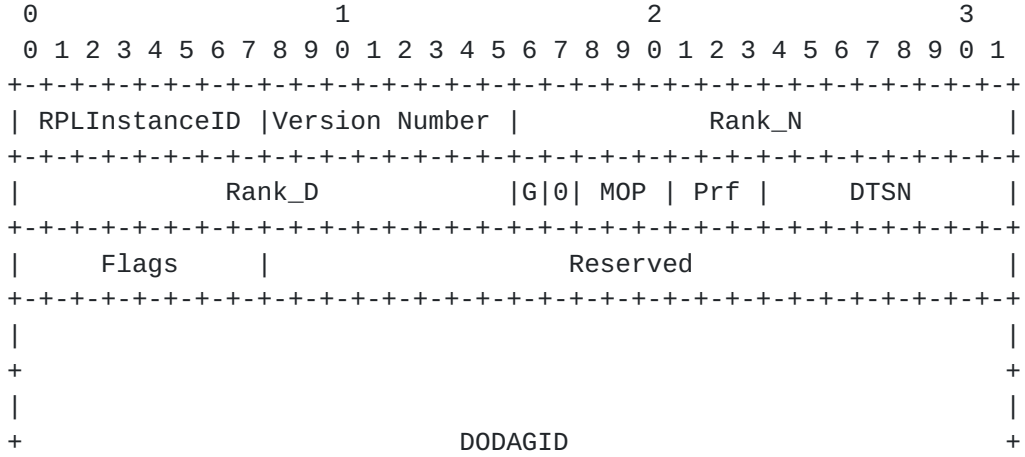
$$sp(R1, R2) = (m+p)/(n+q) \quad (2)$$

It can be shown that if R1 < R2, then R1 < sp(R1,R2) < R2. That is, the split operation splits two ranks R1 and R2 and generates a new rank sp(R1,R2) that is in between R1 and R2.

4. ICMPv6 RPL Control Message Extension

This draft uses RPL control messages defined in [RFC6550] except the DIO message. The rank is advertised in the RPL control message using two integers, numerator and denominator, instead of the fractional value. As a result, the format of DIO Base Object is modified. In addition, to repair a DODAG locally, two new RPL control messages, DODAG Repair Request (DRQ) message and DODAG Repair Reply (DRP) message, are introduced. RPL control message format is defined in Figure 6 and Figure 7 of [RFC6550]. The code field for the DRQ and DRP messages needs to be assigned by IANA. The message base for DRQ and DRP are defined as follows.

4.1. Format of the Modified DIO Base Object



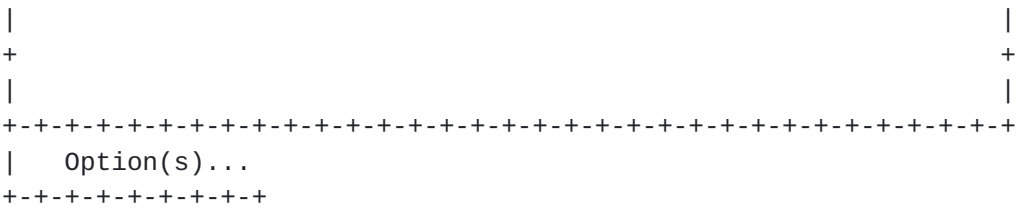


Figure 1: The Modified DIO Base Object

Rank_N: 16-bit unsigned integer indicating the numerator of fractional rank of the node generating DIO message.

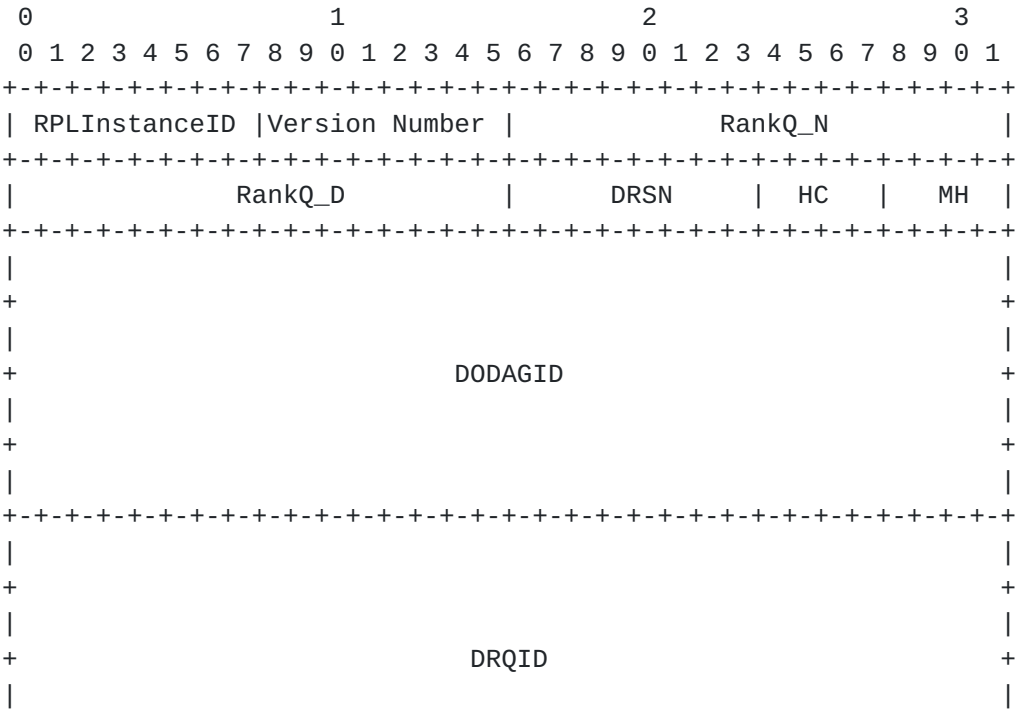
Rank_D: 16-bit unsigned integer indicating the denominator of fractional rank of the node generating DIO message.

The rest of fields are same as being described in [RFC6550].

4.2. DODAG Repair Request (DRQ)

The DRQ message is used by a node to repair a DODAG locally if a parent becomes unreachable. A node may also use the DRQ message to discover additional parents if it is necessary. Functionality of DRQ message is different from DIS message defined in [RFC6550]. A DRQ message can be relayed multiple hops.

4.2.1. Format of the DRQ Base Object



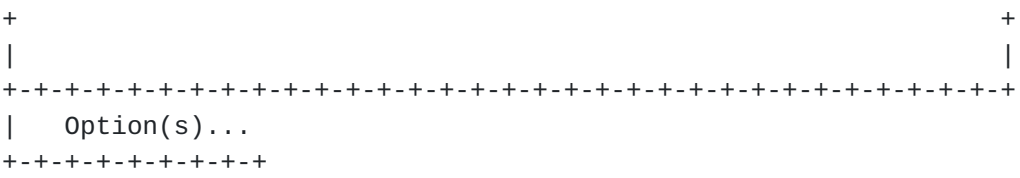


Figure 2: The DRQ Base Object

RPLInstanceID: 8-bit unsigned field as described in [RFC6550] to indicate which RPL Instance the DODAG is a part.

Version Number: 8-bit unsigned integer as described in [RFC6550] to indicate the DODAGVersionNumber.

RankQ_N: 16-bit unsigned integer indicating the numerator of fractional rank of the node generating the DRQ message.

RankQ_D: 16-bit unsigned integer indicating the denominator of fractional rank of the node generating the DRQ message.

DRSN: 8-bit field indicating sequence number of the DRQ message of the node generating the DRQ message.

HC: 4-bit field to indicate the number of hops traveled by a DRQ message.

MH: 4-bit field to indicate the maximum number of hops a DRQ message can travel. If a DRQ message reaches the maximum number of hops, it must be ignored.

DODAGID: 128-bit field as defined in [RFC6550]. A DODAGID is the identifier of a DODAG root. The DODAGID is unique within the scope of a RPL Instance in the LLN. The DODAGID must be a routable IPv6 address belonging to the DODAG root.

DRQID: 128-bit IPv6 address of the node generating the DRQ message.

4.2.2. Secure DRQ

A Secure DRQ message follows the format in Figure 7 of [RFC6550], where the base format is the DRQ message shown in Figure 2.

4.2.3. DRQ Options

The DRQ message may carry valid options.

This draft allows for the DRQ message to carry the following options:

0x00 Pad1
0x01 PadN
Path: This option field is present only if MOP is Non-Storing. The Path field contains IPv6 addresses of nodes traversed by the DRQ message along the path.

4.3. DODAG Repair Reply (DRP)

Upon receiving a DRQ message, a router with lower rank and non-empty DODAG parent set may generate a DRP message in responding to a received DRQ message.

4.3.1. Format of the DRP Base Object

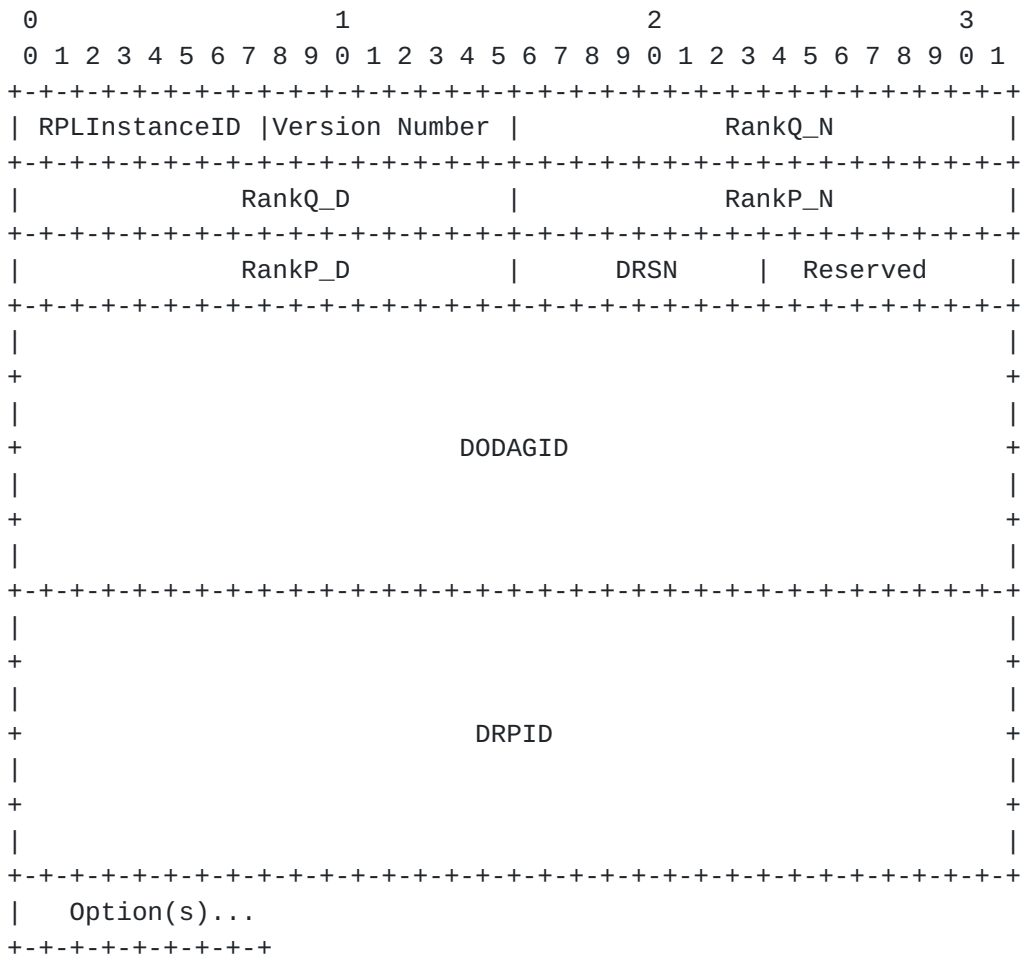


Figure 3: The DRP Base Object

RPLInstanceID: 8-bit unsigned field as described in [RFC6550] to indicate which RPL Instance the DODAG is a part.

Version Number: 8-bit unsigned integer as described in [RFC6550] to

indicate the DODAGVersionNumber.

RankQ_N: 16-bit unsigned integer indicating the numerator of fractional rank of the node generating the DRQ message.

RankQ_D: 16-bit unsigned integer indicating the denominator of fractional rank of the node generating the DRQ message.

RankP_N: 16-bit unsigned integer indicating the numerator of fractional rank of the node sending the DRP message.

RankP_D: 16-bit unsigned integer indicating the denominator of fractional rank of the node sending the DRP message.

DRSN: 8-bit field indicating the sequence number of DRQ message of the node generating the DRQ message.

Reserved: 8 unassigned bits of the DRP Base are reserved. They must be set to zero on transmission and must be ignored on reception.

DODAGID: 128-bit field as defined in [RFC6550]. A DODAGID is the identifier of a DODAG root. The DODAGID is unique within the scope of a RPL Instance in the LLN. The DODAGID MUST be a routable IPv6 address belonging to the DODAG root.

DRPID: 128-bit IPv6 address of the node that is destination of the DRP message.

4.3.2. Secure DRP

A Secure DRP message follows the format in Figure 7 of [RFC6550], where the base format is the DRP message shown in Figure 3.

4.3.3. DRP Options

The DRP message may carry valid options.

This draft allows for the DRP message to carry the following options:

0x00 Pad1
0x01 PadN
Path: This option is present only if MOP is Non-Storing and flag F is set. The Path field contains IPv6 addresses of traversed nodes by the DRQ message and the upward DRP message along the path.

4.4. RPL Control Message Options

The formats of option Pad1 and PadN are described in Figure 20 and Figure 21 of [RFC6550], respectively.

The format of the Path option is as follows:

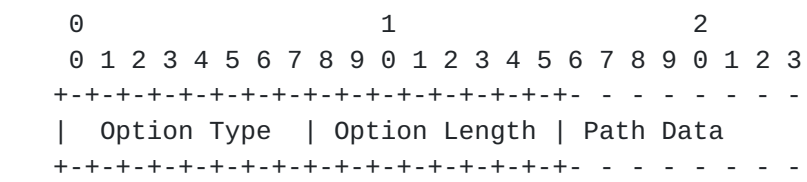


Figure 4: Format of the Path Option

Option Type: 8-bit identifier of the type of option. The Option Type value needs to be assigned by IANA.

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

Path Data: A variable length field that contains a list of IPv6 addresses.

5. DODAG Construction

In RPL, a DODAG is uniquely identified by the (RPLInstanceID, DODAGID) tuple and a DODAG Version is uniquely identified by the (RPLInstanceID, DODAGID, DODAGVersionNumber) tuple. The DODAGVersionNumber is monotonically incremented by the DODAG root.

To construct a new DODAG, the DODAG root configures DODAG parameters and transmits a DIO message with new (RPLInstanceID, DODAGID) tuple. To construct a new DODAG Version, the DODAG root transmits a DIO message with an increased DODAGVersionNumber. The DIO message is transmitted via link-local multicasting to all-RPL-nodes. Nodes obtain the DODAG parameters configured by the DODAG root in received DIO messages.

Upon receiving the DIO messages transmitted by the DODAG root or neighboring nodes containing new (RPLInstanceID, DODAGID, DODAGVersionNumber) tuple, the first hop neighboring nodes of the DODAG root may decide to join new DODAG advertised in received DIO messages. To do so, the first hop nodes add the DODAG root and selected neighboring nodes into their DODAG parent set and store the DODAG parameters advertised in received DIO messages. The first hop nodes keep all DODAG parameters unchanged except the rank. The first hop nodes use information carried in received DIO messages to calculate their ranks. To calculate its rank, a first hop node find

the maximum rank, Rank_Max, of the ranks of its DODAG parents. A first hop node set its rank such that its rank > Rank_max and its rank <= sp(Rank_Max, INFINITE_RANK). Upon joining a new DODAG, the first hop routers generate and transmit the DIO messages by following rules specified in [RFC6550] to advertise the DODAG parameters. A router must not transmit the DIO messages for DODAG Versions of which it is not a member. A router that is not the DODAG root must not change the DODAG parameters received in DIO messages except the rank and DTSN fields. All other DODAG parameters, such as the DODAGID and DODAGVersionNumber, must be propagated unchanged down the DODAG as nodes join new DODAG or new DODAG Version.

Upon receiving the DIO messages transmitted by the first hop neighboring routers, the second hop neighboring nodes of the DODAG root that want to join new DODAG or new DODAG Version perform same procedure as the first hop neighboring nodes do. The second hop routers then generate and transmit the DIO messages same as the first hop router do.

This DIO message propagation process continues until all nodes receive the DIO messages, select the DODAG parents and store their DODAG parameters, that is, the DODAG is completely constructed.

Among its DODAG parents, a node selects one preferred DODAG parent to be used as the preferred next hop node along upward routes to the DODAG root. A node also selects some of its DODAG parents as its DAO parents and schedules the DAO transmission.

6. DOADG Local Repair

When a DODAG parent becomes unreachable, a node may switch to another DODAG parent for upward traffic. DODAG may be locally repaired by the node transmitting a DRQ message. The DRQ message is transmitted by the DRQ message generator via link-local multicasting to all-RPL-nodes.

Upon receiving a DRQ message, a link-local neighboring router which is not the DODAG root discards the DRQ message if it does not have any DODAG parent. If the link-local neighboring router is the DODAG root, it accepts the DRQ message and generates a DRP message. If the link-local neighboring router is not the DODAG root and has a non-empty DODAG parent set and its rank is lower than Rank_DRQ (= RankQ_N/RankQ_D), it accepts the DRQ message and generates a DRP message. If the link-local neighboring router is not the DODAG root and has a non-empty DODAG parent set and its rank is greater than or equal to Rank_DRQ, it forwards the DRQ message to its preferred DODAG parent. This forwarding process continues until the DRQ message is discarded if HC of this DRQ message reaches MH or by a router that

has an empty DODAG parent set. Otherwise, the DRQ message reaches a router which is either the DODAG root or a router that has a non-empty DODAG parent set and a rank lower than Rank_DRQ, a DRP message is then generated.

The DRP message is unicasted. In Storing mode, the DRP message generator transmits the DRP message to the DRQ message generator by using a downward routing table. In Non-Storing mode, the DRP message is transmitted to the DRQ message generator by using Path option field.

6.1. DODAG Local Repair in Storing Mode

In Storing mode, if a DODAG parent becomes unreachable, a node removes that DODAG parent from its DODAG parent set.

If the updated DODAG parent set becomes empty, the node shall transmit a DRQ message to discover new DODAG parents.

If the updated DODAG parent set is not empty, the node checks if the removed DODAG parent is its preferred DODAG parent. If yes, the node shall select a new preferred DODAG parent. Whether or not the removed DODAG parent is the preferred DODAG parent, the node may transmit a DRQ message to discover additional parents. The node may also schedule a No-Path DAO message transmission if the removed DODAG parent is its DAO parent.

To transmit a DRQ message in Storing mode, the node generates a DRQ message. It sets RPLInstanceID, DODAGVersionNumber and DODAGID by using the maintained DODAG parameters. It sets RankQ_N and RankQ_D to the numerator and denominator of its fractional rank, respectively. The node increases its DRSN by 1 and sets HC = 0 and MH to an appropriate value. There is no Path option field in Storing mode.

6.1.1. DRQ Message Processing

When a router receives a DRQ message, it discards the DRQ message if its DODAG parent set is empty. Otherwise, the router performs the following filtering process and discards the DRQ message if any of following conditions is true:

i) RPLInstanceID or DODAGVersionNumber or DODAGID in the DRQ message is not equal to the respective value maintained by the router.
ii) The DRQ message was received already by comparing DRQID and DRSN.
iii) HC is equal to MH.
iv) The DRQ message is transmitted by router's DODAG parent.

v) The DRQ message is generated by router itself or by its DODAG parent.

If the DRQ message passes filtering process, the receiving router processes the DRQ message further.

If the receiving router is the DODAG root, it accepts the DRQ message and generates a DRP message. To generate a DRP message, the DODAG root copies RPLInstanceID, DODAGVersionNumber, DRSN, and DODAGID from the DRQ message. It sets DRPID to DRQID, RankQ_N and RankQ_D to the RankQ_N and RankQ_D in DRQ message, respectively. It sets RankP_N and RankP_D to the numerator and denominator of its fractional rank, respectively. The DODAG root forwards the DRP message to the node from which it received the DRQ message.

If the receiving router is not the DODAG root and its rank is lower than Rank_DRQ, the router accepts the DRQ message and generates a DRP message as the root does. The router forwards the DRP message to the node from which it received the DRQ message.

If the receiving router is not the DODAG root and its rank is greater than or equal to Rank_DRQ, it adds a route entry to node DRQID into its downward routing table, increases value of HC field by 1 and forwards the DRQ message to its preferred DODAG parent.

6.1.2. DRP Message Processing

When a node receives a DRP message, it first performs filtering process and discards the DRP message if any of following conditions is true:

i) RPLInstanceID or DODAGVersionNumber or DODAGID in the DRP message is not equal to the respective value maintained by the receiving node.
ii) The DRP message was received already by comparing DRPID and DRSN.
iii) The receiving node is leaf node and is not the DRQ message generator.

If DRP message passes filtering process, the receiving node processes the DRP message further.

If the receiving node is the DRQ message generator and the DRP message sender is not in its DODAG parent set, it may add the DRP message sender into its DODAG parent set and select a new preferred DODAG parent. The receiving node may schedule a DAO message transmission if the DRP message sender is added into its DAO parent set.

If the receiving node is not the DRQ message generator, it must be a router.

If the receiving router has no route entry to node DRPID in its downward routing table, it discards the DRP message.

If the receiving router has a downward route entry to node DRPID and its rank is greater than or equal to Rank_DRQ (= RankQ_N/RankQ_D), it decreases its rank to sp(Rank_DRQ, Rank_DRP), where Rank_DRP = RankP_N/RankP_D. The receiving router updates its DODAG parent set caused by its rank decrease, that is, removing DODAG parents whose ranks are greater than or equal to sp(Rank_DRQ, Rank_DRP). If its preferred DODAG parent is removed, it selects a new preferred DODAG parent. The receiving router then updates the RankP_N and RankP_D fields of the DRP message to the numerator and denominator of its fractional rank, respectively, and forwards the DRP message to next hop node on the downward route. It may schedule a No-Path DAO message transmission if any of its DAO parents is removed due to its rank decrease.

If the receiving router has a downward route entry to node DRPID and its rank is lower than Rank_DRQ, it updates the RankP_N and RankP_D fields of DRP message to the numerator and denominator of its fractional rank, respectively, and forwards the DRP message to next hop node on the downward route. Noticed that the rank of receiving router is less than Rank_DRQ if the receiving router is on multiple DODAG repair downward routes. When the receiving router receives a DRP message, it may decrease its rank. Therefore, subsequent DRP messages may carry a Rank_DRQ greater than or equal to the rank of receiving router. If the receiving router is only on a single DODAG repair downward route, its rank must be greater than or equal to Rank_DRQ based on the DRQ message process procedure.

6.2. DODAG Local Repair in Non-Storing Mode

The handling of parent unreachability in Non-Storing mode is similar to that in Storing mode. The first difference is that after removing a DAO parent from its DAO parent set, if its DODAG parent set is not empty, a node may schedule a DAO message transmission instead of the No-Path DAO message transmission. The second difference is that to generate a DRQ message in Non-Storing mode, a node adds a Path option field by inserting its IPv6 address into the Path option field. The third difference is that the DRP message is sent to destination node DRPID by source routing via Path option.

6.2.1. DRQ Message Processing

When a router receives a DRQ message, it performs same filtering

process as that in Storing mode. If the DRQ message passes filtering process, the receiving router processes the DRQ message further.

If the receiving router is the DODAG root, it accepts the DRQ message and generates a DRP message similarly as in Storing mode. The DODAG root copies Path option field from DRQ message to Path option field of DRP message. The DODAG root transmits the DRP message to destination node DRPID by using the route provided in Path option field, and on the downward route, intermediate routers obtain next hop node from the Path option field of DRP message.

If the receiving router is not the DODAG root and its rank is lower than Rank_DRQ, it accepts the DRQ message and generates a DRP message similarly as the DODAG root does. It copies the Path option field from DRQ message to the Path option field of DRP message. The receiving router forwards the DRP message to the node from which it received the DRQ message. The DRP message is sent to destination node DRPID via route provided in Path option field.

If the receiving router is not the DODAG root and its rank is greater than or equal to Rank_DRQ, It updates the DRQ message by inserting its own IPv6 address into the Path option field, increasing the value of HC field by 1 and forwards the DRQ message to its preferred DODAG parent.

6.2.2. DRP Message Processing

When a node receives a DRP message, it performs the same filtering process as in Storing mode. If the DRP message passes filtering process, the receiving node processes the DRP message further. The receiving node can be a leaf node or a router.

If the receiving node is the DRQ message generator and the DRP message sender is not in its DODAG parent set, it may add the DRP message sender into its DODAG parent set. The receiving node may select a new preferred DODAG parent. It may also schedule a DAO message transmission if the DRP message sender is added into its DAO parent set.

If the receiving node is not DRQ message generator, it must be a router.

If the receiving router is not on the downward route, it discards the DRP message. Otherwise, if its rank is lower than Rank_DRQ, the receiving router updates the RankP_N and RankP_D fields of the DRP message to the numerator and denominator of its fractional rank, respectively, and forwards the DRP message to destination node DRPID by obtaining route provided in the Path option field. Again, the rank

of receiving router is less than Rank_DRQ if the receiving router is on multiple DODAG repair downward routes. If its rank is greater than or equal to Rank_DRQ, the receiving router decreases its rank to sp(Rank_DRQ, Rank_DRP) and updates its DODAG parent set by removing any DODAG parent whose rank is greater than or equal to sp(Rank_DRQ, Rank_DRP). If its preferred DODAG parent is removed, it selects a new preferred DODAG parent. The receiving router updates the RankP_N and RankP_D fields of DRP message to the numerator and denominator of its fractional rank, respectively, and forwards the DRP message to the destination node DRPID by obtaining route provided in the Path option field. Furthermore, the receiving router may schedule a DAO message transmission if any of its DAO parents was removed due to its rank decrease.

7. Security Considerations

This draft introduces an alternative rank computation method and a DODAG local repair mechanism. In general, the security considerations for the DODAG construction and maintenance are similar to the ones for the operation of RPL as described in Section 19 of [RFC6550]. Section 10 of RPL specification [RFC6550] describes a variety of security mechanisms that provide data confidentiality, authentication, replay protection and delay protection services. Each RPL control message has a secure version that allows the specification of the level of security and the algorithms used to secure the message. New RPL control messages (DRQ and DRP) defined in this draft have secure versions as well.

8. IANA Considerations

This draft defines two new RPL Control Messages types and a new RPL Control Message Option.

Code field for the DODAG Repair Request (DRQ) message needs to be assigned by IANA.

Code field for the DODAG Repair Reply (DRP) message needs to be assigned by IANA.

Option Type field for Path option field needs to be assigned by IANA.

9. References

9.1. Normative References

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9.2. Informative References

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