Implementing 6TiSCH Packet Replication and Elimination from / to the RPL root requires the ability to forward copies of packets over different paths via different RPL parents. Selecting the appropriate parents to achieve ultra-low latency and jitter requires information about a node’s parents. This document details what information needs to be transmitted and how it is encoded within a packet to enable this functionality.

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1. Introduction

Industrial network applications have stringent requirements on reliability and predictability, and typically leverage 1+1 redundancy, aka Packet Replication and Elimination (PRE) [I-D.papadopoulos-6tisch-pre-reqs] to achieve their goal. In order for wireless networks to be able to be used in such applications, the principles of Deterministic Networking [I-D.ietf-detnet-architecture] lead to designs that aim at maximizing packet delivery rate and minimizing latency and jitter. Additionally, given that the network nodes often do not have an unlimited power supply, energy consumption needs to be minimized as well.

To meet this goal, IEEE Std. 802.15.4 [IEEE802154-2015] provides Time-Slotted Channel Hopping (TSCH), a mode of operation which uses a fixed communication schedule to allow deterministic medium access as well as channel hopping to work around radio interference. However, since TSCH uses retransmissions in the event of a failed transmission, end-to-end delay and jitter performance can deteriorate.

The 6TiSCH working group, focusing on IPv6 over IEEE Std. 802.15.4-TSCH, has worked on the issues previously highlighted and produced the "6TiSCH Architecture" [I-D.ietf-6tisch-architecture] to address that case. Building on this architecture, "Exploiting Packet Replication and Elimination in Complex Tracks in 6TiSCH LLNs"
Internet-Draft      RPL MC NSA object type extension        October 2018

[I-D.papadopoulos-6tisch-pre-reqs] leverages PRE to improve the Packet Delivery Ratio (PDR), provide a hard bound to the end-to-end latency, and limit jitter.

PRE achieves a controlled redundancy by laying multiple forwarding paths through the network and using them in parallel for different copies of a same packet. PRE can follow the Destination-Oriented Directed Acyclic Graph (DODAG) formed by RPL from a node to the root. Building a multi-path DODAG can be achieved based on the RPL capability of having multiple parents for each node in a network, a subset of which is used to forward packets. In order for this subset to be defined, a RPL parent subset selection mechanism, which falls within the remit of the RPL Objective Function (OF), needs to have specific path information. The specification of the transmission of this information is the focus of this document.

More concretely, this specification focuses on the extensions to the DAG Metric Container [RFC6551] required for providing the PRE mechanism a part of the information it needs to operate. This information is the RPL [RFC6550] parent address set of a node and it must be sent to potential children nodes of the node. The RPL DIO Control Message is the canonical way of broadcasting this kind of information and therefore its DAG Metric Container [RFC6551] field is used to append a Node State and Attribute (NSA) object. The node’s parent address set is stored as an optional TLV within the NSA object. This specification defines the type value and structure for this TLV.

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].

The draft uses the following Terminology:

Track A sequence of 6TiSCH schedule resources to support a single-path multi-hop transmission of a packet. See "6TiSCH Architecture" [I-D.ietf-6tisch-architecture] for more.

Complex Track A Track which supports a multi-path multi-hop transmission of a packet. See "6TiSCH Architecture" [I-D.ietf-6tisch-architecture] for more.

Packet Replication and Elimination (PRE) The sending of multiple copies of a packet using multi-path forwarding over a multi-hop network and the consolidation of multiple received packet copies to control flooding. See "Exploiting Packet Replication and
Alternative Parent (AP) Selection The problem of how to select the next hop target node for a packet copy to be forwarded to when performing packet replication. See "Exploiting Packet Replication and Elimination in Complex Tracks in 6TiSCH LLNs" [I-D.papadopoulos-6tisch-pre-reqs] for more.

3. Node State and Attribute (NSA) object type extension

For supporting PRE, nodes need to report their parent set to their potential children. DIO messages can carry multiple options, out of which the DAG Metric Container option [RFC6551] is the most suitable structurally and semantically for the purpose of carrying the parent set. The DAG Metric Container option itself can carry different nested objects, out of which the Node State and Attribute (NSA) [RFC6551] is appropriate for transferring generic node state data. Within the Node State and Attribute it is possible to store optional TLVs representing various node characteristics. As per the Node State and Attribute (NSA) [RFC6551] description, no TLV has been defined for use. This document defines one TLV for the purpose of transmitting a node’s parent set.

```
0                   1                   2                   3
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| RPLInstanceID | Version Number |             Rank              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|G|0| MOP | Prf |     DTSN      |     Flags     |   Reserved    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                                                               |
|                                                               |
|                                                               |
|                            DODAGID                            |
|                                                               |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| DAGMC Type (2) | DAGMC Length  |                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+                               |
|                                                               |
|                                                               |
|                                                               |
|                                                               |
//                   DAG Metric Container data                 //
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 1: Example DIO Message with a DAG Metric Container option
Figure 1 shows the structure of the DIO Control Message when a DAG Metric Container option is included. The DAG Metric Container option type (DAGMC Type in Figure 1) has the value 0x02 as per the IANA registry for the RPL Control Message Options, and is defined in [RFC6550]. The DAG Metric Container option length (DAGMC Length in Figure 1) expresses the DAG Metric Container length in bytes. DAG Metric Container data holds the actual data and is shown expanded in Figure 2.

```
0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Routing-MC-Type|Res Flags|P|C|O|R|A   |  Prec | Length (bytes) | =>MC
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Res       |  Flags    |A|O|    PS  type   |   PS  Length  | =>NSA
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| PS IPv6 address(es) ...                                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 2: DAG Metric Container (MC) data with Node State and Attribute (NSA) object body and a TLV

The structure of the DAG Metric Container data in the form of a Node State and Attribute (NSA) object with a TLV in the NSA Optional TLVs field is shown in Figure 2. The first 32 bits comprise the DAG Metric Container header and all the following bits are part of the Node State and Attribute object body, as defined in [RFC6551]. This document defines a new TLV, which CAN be carried in the Node State and Attribute (NSA) object Optional TLVs field. The TLV is named Parent Set and is abbreviated as PS in Figure 2.

PS type: The type of the Parent Set TLV. The value is TBD1.

PS Length: The total length of the TLV value field (PS IPv6 address(es)) in bytes.

PS IPv6 address(es): A sequence of zero or more IPv6 addresses belonging to a node’s parent set. Each address requires 16 bytes. The order of the parents in the parent set is in decreasing preference based on the Objective Function [RFC6550] used by the node.

3.1. Usage

The PS SHOULD be used in the process of parent selection, and especially in alternative parent selection, since it can help the alternative path from significantly deviating from the preferred
path. The Parent Set is information local to the node that broadcasts it.

3.1.1. DAG Metric Container fields

Given the intended usage, when using the PS, the NSA object it is contained in MUST be used as a constraint in the DAG Metric Container. More specifically, using the PS places the following requirements on the DAG Metric Container header fields:

- ‘P’ flag: MUST be cleared, since PS is used only with constraints.
- ‘C’ flag: MUST be set, since PS is used only with constraints.
- ‘O’ flag: Used as per [RFC6550], to indicated optionality.
- ‘R’ flag: MUST be cleared, since PS is used only with constraints.
- ‘A’ Field: MUST be set to 0 and ignored, since PS is used only with constraints.
- ‘Prec’ Field: Used as per [RFC6550].

3.1.2. Node State and Attribute fields

For clarity reasons, the usage of the PS places no additional restrictions on the NSA flags (‘A’ and ‘O’), which can be used as normally defined in [RFC6550].

3.2. Compression

The PS IPv6 address(es) field in the Parent Set TLV add overhead due to their size. Therefore, compression is highly desirable in order for this extension to be usable. To meet this goal, a good compression method candidate is [RFC8138] 6LoWPAN Routing Header (6LoRH). Furthermore, the PS IPv6 address(es) belong by definition to nodes in the same RPL DODAG and are stored in the form of a list of addresses. This makes this field a good candidate for the use of the same compression as in Source Routing Header 6LoRH (SRH-6LoRH), achieving efficiency and implementation reuse. Therefore, the PS IPv6 address(es) field SHOULD be compressed using the compression method for Source Routing Header 6LoRH (SRH-6LoRH) [RFC8138].

4. Security Considerations

The structure of the DIO control message is extended, within the pre-defined DIO options. Therefore, the security mechanisms defined in RPL [RFC6550] apply to this proposed extension.
5. IANA Considerations

This proposal requests the allocation of a new value TBD1 for the
"Parent Set" TLV in the Routing Metric/Constraint TLVs sub-registry
from IANA.

6. References

6.1. Informative references

[I-D.ietf-6tisch-architecture]
Thubert, P., "An Architecture for IPv6 over the TSCH mode
of IEEE 802.15.4", draft-ietf-6tisch-architecture-15 (work
in progress), October 2018.

[I-D.ietf-detnet-architecture]
Finn, N., Thubert, P., Varga, B., and J. Farkas,
"Deterministic Networking Architecture", draft-ietf-
detnet-architecture-08 (work in progress), September 2018.

[I-D.papadopoulos-6tisch-pre-reqs]
Papadopoulos, G., Montavont, N., and P. Thubert,
"Exploiting Packet Replication and Elimination in Complex
Tracks in 6TiSCH LLNs", draft-papadopoulos-6tisch-pre-
reqs-02 (work in progress), July 2018.

[RFC2119]  Bradner, S., "Key words for use in RFCs to Indicate
Requirement Levels", BCP 14, RFC 2119,
DOI 10.17487/RFC2119, March 1997,

Kelsey, R., Levis, P., Pister, K., Struik, R., Vasseur,
Low-Power and Lossy Networks", RFC 6550,
DOI 10.17487/RFC6550, March 2012,

and D. Barthel, "Routing Metrics Used for Path Calculation
in Low-Power and Lossy Networks", RFC 6551,
DOI 10.17487/RFC6551, March 2012,

[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,
6.2. Other Informative References

[IEEE802154-2015]
IEEE standard for Information Technology, "IEEE Std 802.15.4-2015 Standard for Low-Rate Wireless Personal Area Networks (WPANs)", December 2015.

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