A Compression Format for RPL Control Messages draft-goyal-roll-rpl-compression-00

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DIO Size: Example 1

- Consider a multicast DIO consisting of
  - a Configuration Option
  - a Route Information Option
  - a Metric Container with one ETX metric object and one ETX constraint object.
- This message consists of :
  - 5 bytes for a typical IPv6 header, compressed as per [I-D.ietf-6lowpan-hc] :
    - 2 byte LOWPAN_IPHC Base Encoding
    - 1 byte Context Identifier Extension
    - 1 byte Next Header
    - 1 byte Group ID to identify all-RPL-nodes multicast address.
  - 4 bytes for ICMP Type, Code and Checksum fields;
  - 24 bytes for DIO Base Object;
  - 16 bytes for DODAG Configuration Option;
  - 24 byte Route Information Option;
  - 14 bytes for Metric Container consisting of:
    - 2 bytes for Type and Option Length fields;
    - 6 bytes for ETX metric object (4 bytes header + 2 bytes body);
    - 6 bytes for ETX constraint object (4 bytes header + 2 bytes body).
- Thus, the total length of such a DIO is 87 bytes.

DIO Size: Example 2

- Consider a multicast DIO consisting of
  - A Configuration Option
  - A Route Discovery Option
  - A Metric Container with one ETX metric object and one ETX constraint object
- This message consists of
  - 5 bytes of compressed IPv6 header
  - 4 bytes for ICMP Type, Code and Checksum fields
  - 24 bytes for DIO Base Object
  - 16 bytes for DODAG Configuration Option
  - 26 bytes for Route Discovery Option consisting of:
    - 4 bytes for Type, Option Length and other fixed length fields;
    - 2 bytes for the Target address field;
    - 20 bytes for the Address vector (assuming ten 2-byte long elements).
  - 14 bytes for Metric Container consisting of:
    - 2 bytes for Type and Option Length fields
    - 6 bytes for ETX metric object (4 bytes header + 2 bytes body)
    - 6 bytes for ETX constraint object (4 bytes header + 2 bytes body).
- The total length of such a DIO is 89 bytes.

Need for Compression

- With IEEE 802.15.4 as the link layer, the link layer payload can be as small as 81 bytes.
- RPL DIO messages are susceptible to fragmentation.
- This document specifies a compression format for ICMPv6 RPL control messages
  - The document currently defines the compression format for
    - DIO base object
    - DODAG Configuration Option
    - Some of the Routing Metric/Constraint objects.

RPL ICMPv6 Message Compression

- Various fields of a compressed ICMPv6 messages are:
  - Type: 155
  - Code: Set the 7th bit in the Code of the corresponding uncompressed message.
  - Checksum: calculated in the same manner as for the uncompressed message.
  - Base: The Base object must be compressed in the manner specified in the document.
  - Option(s): Both compressed and uncompressed versions are allowed.

DIO Base Object

```
 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 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
| RPLInstanceID |Version Number |             Rank              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|G|0| MOP | Prf |      DTSN     |     Flags     |   Reserved    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
+                                                               +
|                                                               |
+                            DODAGID                            +
|                                                               |
+                                                               +
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Option(s)...
+-+-+-+-+-+-+-+-+
```

Compression Format for DIO Base Object

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+- - - - - - - - - - - - - -
|C|I|L|V|R|G|T|F|  Ra   | Compr | Inline Fields
+---+---+---+---+---+---+---+---+- - - - - - - - - - - - -
```

- C: This flag is set to 1 if the 3rd byte contains an 8-bit identifier of the "context" that provides values of all elided fields in the base object and the options.
- I: This flag is set to 1 if the RPLInstanceID field is present inline. Otherwise, the implicit value of the RPLInstanceID depends on the context if present. In the absence of the context, the implicit value of the RPLInstanceID depends on the value of the L flag.
- L: Meaningful only when the RPLInstanceID field is elided but no context is identified, the L flag is set to 1 if the elided RPLInstanceID is local and has implicit value 128. The L flag is set to 0 if the elided RPLInstanceID field is global and has implicit value 0.
- V: This flag is set to 1 if the Version Number is carried inline. Otherwise, the implicit value of the Version Number depends on the context if present. If no context is present, the implicit value is assumed to be zero.

Compression Format for DIO Base Object

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+- - - - - - - - - - - - - - -
|C|I|L|V|R|G|T|F|  Ra   | Compr | Inline Fields
+---+---+---+---+---+---+---+---+- - - - - - - - - - - - - -
```

- R: This flag indicates whether the Rank field in the DIO is shortened or not. This flag is set to 1 if the full 16-bit Rank is present inline in the compressed DIO. The flag is set to 0 if the 4-bit long Ra field contains the rank value.
- G: This flag indicates whether the byte containing the Grounded, Mode of Operation and DODAG Preference fields is elided or not.
- T: This flag is set to 1 if the DTSN field is carried inline.
- F: This flag indicates whether the Flags and Reserved fields in the DIO are elided or not.
- Ra: This field contains the 4-bit rank value if the R flag is set to 0.
- Compr: This field contains the number of prefix octets that are elided from the DODAGID field.
- Inline Fields: The context identifier, if present, occupies the 3rd byte. Any inline fields in the compressed DIO appear in the same order as in the uncompressed format.

Compressing the RPL Options

```
0                   1                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  Option Type  | Option Length | Option Data
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

- Option Type: The Option Type value for a compressed RPL option is same as that of the uncompressed option with the most significant bit (MSB) set to 1.
- Option Length: The Option Length is 8 bits long as in case of an uncompressed RPL option.

DODAG Configuration Option

```
 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 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Type = 4    |Opt Length = 14| Flags |A| PCS | DIOIntDoubl.  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|  DIOIntMin.   |   DIORedun.   |        MaxRankIncrease        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|      MinHopRankIncrease       |              OCP              |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   Reserved    | Def. Lifetime |      Lifetime Unit            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Compression Format for DODAG Configuration Option

```
0   1   2   3   4   5   6   7   8
+---+---+---+---+---+---+---+---+- - - - - - - -
| F | T1| T2| I1| I2| O | R | L | Inline Fields
+---+---+---+---+---+---+---+---+- - - - - - - -
```

- F: This flag indicates whether the byte consisting of the Flags, A and PCS fields, is elided or not.
- T1: This flag indicates whether the DIOIntervalDoublings and DIOIntervalMin fields are elided or not.
- T2: This flag indicates whether the DIORedundancyConstant field is elided or not.
- I1: This flag indicates whether the MaxRankIncrease field is elided or not.
- I2: This flag indicates whether the MinHopRankInc field is elided or not.
- O: This flag indicates whether the OCP field is elided or not.
- R: This flag indicates whether the Reserved byte is elided or not.
- L: This flag indicates whether the Default Lifetime and Lifetime Unit fields are elided or not.
- Inline fields: Any inline fields in the compressed DODAG Configuration option appear in the same order as in the uncompressed format.
- A compressed DODAG Configuration Option can be as small as 3 bytes, whereas an uncompressed DODAG Configuration Option is 16 bytes long.

Routing Metric/Constraint Object

```
 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 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Routing-MC-Type|Res Flags|P|C|O|R| A   |  Prec | Length (bytes)|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
//                        (object body)                        //
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Compression Format for Routing Metric/Constraint Object

```
0   1   2   3   4   5   6   7   8
+---+---+---+---+---+---+---+---+- - - - - - - -
|    Type   | C |O/P| P2|   A   | Object Body
+---+---+---+---+---+---+---+---+- - - - - - - -
```

- A compressed Metric Container Option MUST NOT contain uncompressed Routing Metric/ Constraint objects.
- A compressed Routing Metric/Constraint Object always has a fixed size. Thus, "recorded" metrics and sub-objects/TLV options within a metric object are not allowed.

Compression Format for Routing Metric/Constraint Object

```
0   1   2   3   4   5   6   7   8
+---+---+---+---+---+---+---+---+- - - - - - - -
|     Type    | C |O/P| P2|   A   | Object Body
+---+---+---+---+---+---+---+---+- - - - - - - -
```

- Type: The type of the routing metric/constraint object.
- C: This flag is set to one if the object represents a constraint.
- O/P: If the object represents a constraint, this flag is set to one if the constraint is optional. If the object represents a metric, this bit represents, along with P2 bit, a 2-bit "precedence" field.
- P2: This bit is relevant only when the object represents a metric. Along with the O/P bit, this bit forms a 2-bit "precendence" field to indicate the precedence of this metric relative to other metrics in the container. The precedence values range from 0 to 3, 0 being the highest precedence.
- A: This field is relevant only for metrics and indicates the manner in which the routing metric must be aggregated:
  - A=0x00: The routing metric is additive
  - A=0x01: The routing metric reports a maximum
  - A=0x02: The routing metric reports a minimum
  - A=0x03: The routing metric is multiplicative

Node State and Attributes Object

```
 0                   1                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
|      Res        |   Flags     |A|O|  Optional TLVs
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
```

Compressed Node State and Attributes Object

```
0   1   2   3   4   5   6   7   8
+---+---+---+---+---+---+---+---+
|         Reserved        | A | O |
+---+---+---+---+---+---+---+---+
```

Node Energy Object

```
 0                   1                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
|      NE Sub-objects
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
```

```
 0                   1                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
| Flags |I| T |E|       E-E       |   Optional TLVs
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
```

Figure 4: NE sub-object format

Compressed Node Energy Object

```
0   1   2   3   4   5   6   7   8
+---+---+---+---+---+---+---+---+
| I |   T   | E |     E-E       |
+---+---+---+---+---+---+---+---+
```

- Note that the E-E field has been reduced from 8 bits to 4 bits.

Hop Count Object

```
 0                   1                   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
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
|   Res   | Flags |    Hop Count    |  Optional TLVs
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+ ...
```

Compressed Hop Count Object

```
0    1    2    3    4    5    6    7    8
+---+---+---+---+---+---+---+---+---+
|             Hop Count             |
+---+---+---+---+---+---+---+---+---+
```

Throughput Object

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   (sub-object) .....
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
 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 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Throughput                           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Figure 7: Throughput sub-object format

The Throughput is encoded in 32 bits in unsigned integer format, expressed in bytes per second.

Compressed Throughput Object

```
 0                                                               1
 0   1   2   3   4   5   6   7   8   9   0   1   2   3   4   5   6
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                             Throughput                        |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

A 16-bit value expressed in units of kilo bytes per second.

Latency Object

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   (sub-object) .....
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
 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 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            Latency                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The Latency is encoded in 32 bits in unsigned integer format, expressed in microseconds.

Compressed Latency Object

```
 0                                                               1
 0   1   2   3   4   5   6   7   8   9   0   1   2   3   4   5   6
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                              Latency                              |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

A 16-bit value expressed in units of milliseconds.

ETX Object

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|   (sub-object) .....
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|               ETX             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

The ETX * 128 is encoded using 16 bits in unsigned integer format, rounded off to the nearest whole number.

Compressed ETX Object

```
 0                                                               1
 0   1   2   3   4   5   6   7   8   9   0   1   2   3   4   5   6
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
|                               ETX                               |
+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+
```

DIO Size: Example 1

- Consider a multicast DIO consisting of
  - a Configuration Option
  - a Route Information Option
  - a Metric Container with one ETX metric object and one ETX constraint object.
- This message consists of :
  - 5 bytes for a typical IPv6 header, compressed as per [I-D.ietf-6lowpan-hc] :
    - 2 byte LOWPAN_IPHC Base Encoding
    - 1 byte Context Identifier Extension
    - 1 byte Next Header
    - 1 byte Group ID to identify all-RPL-nodes multicast address.
  - 4 bytes for ICMP Type, Code and Checksum fields;
  - 24 bytes for DIO Base Object;
  - 16 bytes for DODAG Configuration Option;
  - 24 byte Route Information Option;
  - 14 bytes for Metric Container consisting of:
    - 2 bytes for Type and Option Length fields;
    - 6 bytes for ETX metric object (4 bytes header + 2 bytes body);
    - 6 bytes for ETX constraint object (4 bytes header + 2 bytes body).
- Thus, the total length of such a DIO is 87 bytes.

DIO Size With Compression: Example 1

- The compressed message consists of :
  - 5 bytes of IPv6 header compressed as per [I-D.ietf-6lowpan-hc]
  - 4 bytes for ICMP Type, Code and Checksum fields
  - 4 bytes of compressed DIO Base Object consisting of 2 bytes of header and 2 bytes for DODAGID (the best case scenario)
  - 3 bytes of compressed DODAG Configuration Option, including 2 bytes for Type and Option Length fields
  - 24 bytes of Route Information Option
  - 8 bytes for Metric Container consisting of:
    - 2 bytes for Type and Option Length fields
    - 3 bytes for ETX metric object (1 byte header + 2 bytes body)
    - 3 bytes for ETX constraint object (1 byte header + 2 bytes body).
- Thus, the total length of the compressed DIO is 48 bytes.

DIO Size: Example 2

- Consider a multicast DIO consisting of
  - A Configuration Option
  - A Route Discovery Option
  - A Metric Container with one ETX metric object and one ETX constraint object
- This message consists of
  - 5 bytes of compressed IPv6 header
  - 4 bytes for ICMP Type, Code and Checksum fields
  - 24 bytes for DIO Base Object
  - 16 bytes for DODAG Configuration Option
  - 26 bytes for Route Discovery Option consisting of:
    - 4 bytes for Type, Option Length and other fixed length fields;
    - 2 bytes for the Target address field;
    - 20 bytes for the Address vector (assuming ten 2-byte long elements).
  - 14 bytes for Metric Container consisting of:
    - 2 bytes for Type and Option Length fields
    - 6 bytes for ETX metric object (4 bytes header + 2 bytes body)
    - 6 bytes for ETX constraint object (4 bytes header + 2 bytes body).
- The total length of such a DIO is 89 bytes.

DIO Size After Compression: Example 2

- The message, when compressed, consists of:
  - 5 bytes of IPv6 header compressed as per [I-D.ietf-6lowpan-hc]
  - 4 bytes for ICMP Type, Code and Checksum fields
  - 4 bytes of compressed DIO Base Object consisting of 2 bytes of header and 2 bytes for DODAGID (the best case scenario)
  - 3 bytes of compressed DODAG Configuration Option, including 2 bytes for Type and Option Length fields
  - 26 bytes of Route Discovery Option
  - 8 bytes for Metric Container consisting of:
    - 2 bytes for Type and Option Length fields
    - 3 bytes for ETX metric object (1 byte header + 2 bytes body)
    - 3 bytes for ETX constraint object (1 byte header + 2 bytes body).
- Thus, the total length of the compressed DIO is 50 bytes.