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M. Veillette, Ed.
Trilliant Networks Inc.
A. Pelov, Ed.
Acklio
A. Somaraju
Tridonic GmbH & Co KG
R. Turner
Landis+Gyr
A. Minaburo
Acklio

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CBOR Encoding of Data Modeled with YANG
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Abstract

This document defines encoding rules for serializing configuration data, state data, RPC input and RPC output, Action input, Action output and notifications defined within YANG modules using the Concise Binary Object Representation (CBOR) [RFC7049].

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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1. Introduction

The specification of the YANG 1.1 data modelling language [RFC7950] defines an XML encoding for data instances, i.e. contents of configuration datastores, state data, RPC inputs and outputs, action inputs and outputs, and event notifications.

A new set of encoding rules has been defined to allow the use of the same data models in environments based on the JavaScript Object Notation (JSON) Data Interchange Format [RFC7159]. This is accomplished in the JSON Encoding of Data Modeled with YANG specification [RFC7951].

The aim of this document is to define a set of encoding rules for the Concise Binary Object Representation (CBOR) [RFC7049]. The resulting encoding is more compact compared to XML and JSON and more suitable for Constrained Nodes and/or Constrained Networks as defined by [RFC7228].

2. Terminology and Notation

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 following terms are defined in [RFC7950]:

- action
- anydata
- anyxml
- data node
- data tree
- datastore
- feature

- identity
- module
- notification
- RPC
- schema node
- schema tree
- submodule

The following terms are defined in [RFC7951]:

- member name
- name of an identity
- namespace-qualified

The following terms are defined in [RFC8040]:

- yang-data (YANG extension)
- YANG data template

This specification also makes use of the following terminology:

- child: A schema node defined within a collection such as a container, a list, a case, a notification, an RPC input, an RPC output, an action input, an action output.
- delta: Difference between the current SID and a reference SID. A reference SID is defined for each context for which deltas are used.
- item: A schema node, an identity, a module, a submodule or a feature defined using the YANG modeling language.
- parent: The collection in which a schema node is defined.
- YANG Schema Item iDentifier (SID): Unsigned integer used to identify different YANG items.

2.1. YANG Schema Item iDentifier (SID)

Some of the items defined in YANG [RFC7950] require the use of a unique identifier. In both NETCONF [RFC6241] and RESTCONF [RFC8040], these identifiers are implemented using names. To allow the implementation of data models defined in YANG in constrained devices and constrained networks, a more compact method to identify YANG items is required. This compact identifier, called YANG Schema Item iDentifier (SID), is encoded using an unsigned integer. The following items are identified using SIDs:

- identities
- data nodes
- RPCs and associated input(s) and output(s)
- actions and associated input(s) and output(s)
- notifications and associated information
- YANG modules, submodules and features

To minimize its size, in certain positions, SIDs are represented using a (signed) delta from a reference SID and the current SID. Conversion from SIDs to deltas and back to SIDs are stateless processes solely based on the data serialized or deserialized.

Mechanisms and processes used to assign SIDs to YANG items and to guarantee their uniqueness is outside the scope of the present specification. If SIDs are to be used, the present specification is used in conjunction with a specification defining this management. One example for such a specification is under development as [I-D.ietf-core-sid].

2.2. CBOR diagnostic notation

Within this document, CBOR binary contents are represented using an equivalent textual form called CBOR diagnostic notation as defined in [RFC7049] section 6. This notation is used strictly for documentation purposes and is never used in the data serialization. Table 1 below provides a summary of this notation.

CBOR content	CBOR type	Diagnostic notation	Example	CBOR encoding
Unsigned integer	0	Decimal digits	123	18 7b
Negative integer	1	Decimal digits prefixed by a minus sign	-123	38 7a
Byte string	2	Hexadecimal value enclosed between single quotes and prefixed by an 'h'	h'f15c'	42 f15c
Text string	3	String of Unicode characters enclosed between double quotes	"txt"	63 747874
Array	4	Comma-separated list of values within square brackets	[1, 2]	82 01 02
Map	5	Comma-separated list of key : value pairs within curly braces	{ 1: 123, 2: 456 }	a2 01187b 021901c8
Boolean	7/20	false	false	f4
	7/21	true	true	f5
Null	7/22	null	null	f6
Not assigned	7/23	undefined	undefined	f7

Table 1: CBOR diagnostic notation summary

The following extensions to the CBOR diagnostic notation are supported:

- Any text within and including a pair of slashes is considered a comment.

- Deltas are visualized as numbers preceded by a '+' or '-' sign. The use of the '+' sign for positive deltas represents an extension to the CBOR diagnostic notation as defined by [RFC7049] section 6.

3. Properties of the CBOR Encoding

This document defines CBOR encoding rules for YANG schema trees and their subtrees.

Basic schema nodes such as leaf, leaf-list, list, anydata and anyxml can be encoded standalone. In this case, only the value of this

schema node is encoded in CBOR. Identification of this value needs to be provided by some external means when required.

A collection such as container, list instance, notification, RPC input, RPC output, action input and action output is serialized using a CBOR map in which each child schema node is encoded using a key and a value. This specification supports two type of CBOR keys; YANG Schema Item iDentifier (SID) as defined in Section 2.1 and member names as defined in [RFC7951]. Each of these key types is encoded using a specific CBOR type which allows their interpretation during the deserialization process. The end user of this mapping specification (e.g. RESTCONF [RFC8040], CoMI [I-D.ietf-core-comi]) can mandate the use of a specific key type.

In order to minimize the size of the encoded data, the proposed mapping avoids any unnecessary meta-information beyond those natively supported by CBOR. For instance, CBOR tags are used solely in the case of anyxml data nodes and the union datatype to distinguish explicitly the use of different YANG datatypes encoded using the same CBOR major type.

4. Encoding of YANG Data Node Instances

Schema node instances defined using the YANG modeling language are encoded using CBOR [RFC7049] based on the rules defined in this section. We assume that the reader is already familiar with both YANG [RFC7950] and CBOR [RFC7049].

4.1. The 'leaf' Data Node

Leafs MUST be encoded based on the encoding rules specified in Section 6.

4.2. The 'container' Data Node

Collections such as containers, list instances, notifications, RPC inputs, RPC outputs, action inputs and action outputs MUST be encoded using a CBOR map data item (major type 5). A map is comprised of pairs of data items, with each data item consisting of a key and a value. Each key within the CBOR map is set to a data node identifier, each value is set to the value of this data node instance according to the instance datatype.

This specification supports two type of CBOR keys; SID as defined in Section 2.1 encoded as deltas and member names as defined in [RFC7951] encoded using CBOR text strings. The use of CBOR byte strings for keys is reserved for future extensions.

4.2.1. SIDs as keys

Keys implemented using SIDs MUST be encoded using a CBOR unsigned integer (major type 0) or CBOR negative integer (major type 1), depending on the actual value. Keys are represented as the delta of the associated SID, delta values are computed as follows:

- The delta value is equal to the SID of the current schema node minus the SID of the parent schema node. When no parent exists in the context of use of this container, the delta is set to the SID of the current schema node (i.e., a parent with SID equal to zero is assumed).

- Delta values may result in a negative number, clients and servers MUST support both unsigned and negative deltas.

The following example shows the encoding of a 'system-state' container instance with a single child, a clock container. The clock container container has two children, a 'current-datetime' leaf and a 'boot-datetime' leaf.

Definition example from [RFC7317]:

```
typedef date-and-time {
  type string {
    pattern '\d{4}-\d{2}-\d{2}T\d{2}:\d{2}:\d{2}(\.\d+)?(Z|[\+\-]
             \d{2}:\d{2})';
  }
}

container system-state {

  container clock {
    leaf current-datetime {
      type date-and-time;
    }

    leaf boot-datetime {
      type date-and-time;
    }
  }
}
```

For this first representation, we assume that the SID of the parent container (i.e. 'system-state') is not available to the serializer. In this case, root data nodes are encoded using absolute SIDs.

CBOR diagnostic notation:

```
{
  1717 : {                              / clock  (SID 1717) /
    +2 : "2015-10-02T14:47:24Z-05:00", / current-datetime (SID 1719)/
    +1 : "2015-09-15T09:12:58Z-05:00"  / boot-datetime (SID 1718) /
  }
}
```

CBOR encoding:

```
a1                                    # map(1)
   19 06b5                            # unsigned(1717)
   a2                                 # map(2)
      02                              # unsigned(2)
      78 1a                           # text(26)
      323031352d31302d30325431343a34373a32345a2d30353a3030
      01                              # unsigned(1)
      78 1a                           # text(26)
      323031352d30392d31355430393a31323a35385a2d30353a3030
```

On the other hand, if the serializer is aware of the parent SID, 1716 in the case 'system-state' container, root data nodes are encoded using deltas.

CBOR diagnostic notation:

```
{
  +1 : {                              / clock  (SID 1717) /
    +2 : "2015-10-02T14:47:24Z-05:00", / current-datetime (SID 1719)/
    +1 : "2015-09-15T09:12:58Z-05:00"  / boot-datetime (SID 1718) /
  }
}
```

CBOR encoding:

```
a1                                    # map(1)
   01                                  # unsigned(1)
   a2                                 # map(2)
      02                              # unsigned(2)
      78 1a                           # text(26)
      323031352d31302d30325431343a34373a32345a2d30353a3030
      01                              # unsigned(1)
      78 1a                           # text(26)
      323031352d30392d31355430393a31323a35385a2d30353a3030
```

4.2.2. Member names as keys

Keys implemented using member names MUST be encoded using a CBOR text string data item (major type 3). A namespace-qualified member name MUST be used for all members of a top-level collection, and then also whenever the namespaces of the schema node and its parent are different. In all other cases, the simple form of the member name MUST be used. Names and namespaces are defined in [RFC7951] section 4.

The following example shows the encoding of a 'system' container instance using names. This example is described in Section 4.2.1.

CBOR diagnostic notation:

```
{
  "ietf-system:clock" : {
    "current-datetime" : "2015-10-02T14:47:24Z-05:00",
    "boot-datetime" : "2015-09-15T09:12:58Z-05:00"
  }
}
```

CBOR encoding:

```
a1                                      # map(1)
   71                                   # text(17)
      696574662d73797374656d3a636c6f636b    # "ietf-system:clock"
   a2                                   # map(2)
      70                                # text(16)
         63757272656e742d6461746574696d65   # "current-datetime"
      78 1a                             # text(26)
         323031352d31302d30325431343a34373a32345a2d30353a3030
      6d                                # text(13)
         626f6f742d6461746574696d65         # "boot-datetime"
      78 1a                             # text(26)
         323031352d30392d31355430393a31323a35385a2d30353a3030
```

4.3. The 'leaf-list' Data Node

A leaf-list MUST be encoded using a CBOR array data item (major type 4). Each entry of this array MUST be encoded using the rules defined by the YANG type specified.

The following example shows the encoding a 'search' leaf-list instance containing the two entries, "ietf.org" and "ieee.org".

Definition example [RFC7317]:

```
typedef domain-name {
  type string {
    length "1..253";
    pattern '((([a-zA-Z0-9_]([a-zA-Z0-9\-_]){0,61})?[a-zA-Z0-9].)
             *([a-zA-Z0-9_]([a-zA-Z0-9\-_]){0,61})?[a-zA-Z0-9]\.?
             )|\.';
  }
}

leaf-list search {
  type domain-name;
  ordered-by user;
}
```

CBOR diagnostic notation: ["ietf.org", "ieee.org"]

CBOR encoding: 82 68 696574662e6f7267 68 696565652e6f7267

4.4. The 'list' Data Node

A list MUST be encoded using a CBOR array data item (major type 4). Each list instance within this CBOR array is encoded using a CBOR map data item (major type 5) based on the same rules as a YANG container as defined in Section 4.2.

4.4.1. SIDs as keys

The following example show the encoding of a 'server' list instance using SIDs. It is important to note that the protocol or method using this mapping may carry a parent SID or may have the knowledge of this parent SID based on its context. In these cases, delta encoding can be performed based on this parent SID which minimizes the size of the encoded data.

Definition example from [RFC7317]:

```
   list server {
     key name;

     leaf name {
       type string;
     }
     choice transport {
       case udp {
         container udp {
           leaf address {
             type host;
             mandatory true;
           }
           leaf port {
             type port-number;
           }
         }
       }
     }
     leaf association-type {
       type enumeration {
         enum server;
         enum peer;
         enum pool;
       }
       default server;
     }
     leaf iburst {
       type boolean;
       default false;
     }
     leaf prefer {
       type boolean;
       default false;
     }
   }
```

CBOR diagnostic notation:

```
[
  {
    1755 : "NRC TIC server",          / name (SID 1755) /
    1757 : {                          / udp (SID 1757) /
      +1 : "tic.nrc.ca",              / address (SID 1758) /
      +2 : 123                        / port (SID 1759) /
    },
    1753 : 0,                         / association-type (SID 1753) /
    1754 : false,                     / iburst (SID 1754) /
    1756 : true                       / prefer (SID 1756) /
  },
  {
    1755 : "NRC TAC server",          / name (SID 1755) /
    1757 : {                          / udp (SID 1757) /
      +1 : "tac.nrc.ca"               / address (SID 1758) /
    }
  }
]
```

CBOR encoding:

```
82                                  # array(2)
   a5                               # map(5)
      19 06db                       # unsigned(1755)
      6e                            # text(14)
         4e524320544943207365726572 # "NRC TIC server"
      19 06dd                       # unsigned(1757)
      a2                            # map(2)
         01                         # unsigned(1)
         6a                         # text(10)
            7469632e6e72632e6361    # "tic.nrc.ca"
         02                         # unsigned(2)
         18 7b                      # unsigned(123)
      19 06d9                       # unsigned(1753)
      00                            # unsigned(0)
      19 06da                       # unsigned(1754)
      f4                            # primitive(20)
      19 06dc                       # unsigned(1756)
      f5                            # primitive(21)
   a2                               # map(2)
      19 06db                       # unsigned(1755)
      6e                            # text(14)
         4e524320544143207365726572 # "NRC TAC server"
      19 06dd                       # unsigned(1757)
      a1                            # map(1)
         01                         # unsigned(1)
         6a                         # text(10)
            7461632e6e72632e6361    # "tac.nrc.ca"
```

4.4.2. Member names as keys

The following example shows the encoding of a 'server' list instance using names. This example is described in Section 4.4.1.

CBOR diagnostic notation:

```
[
  {
    "ietf-system:name" : "NRC TIC server",
    "ietf-system:udp" : {
      "address" : "tic.nrc.ca",
      "port" : 123
    },
    "ietf-system:association-type" : 0,
    "ietf-system:iburst" : false,
    "ietf-system:prefer" : true
  },
  {
    "ietf-system:name" : "NRC TAC server",
    "ietf-system:udp" : {
      "address" : "tac.nrc.ca"
    }
  }
]
```

CBOR encoding:

```
82                                          # array(2)
   a5                                       # map(5)
      70                                    # text(16)
         696574662d73797374656d3a6e616d65   # "ietf-system:name"
      6e                                    # text(14)
         4e5243205449432073657766572        # "NRC TIC server"
      6f                                    # text(15)
         696574662d73797374656d3a756470     # "ietf-system:udp"
      a2                                    # map(2)
         67                                 # text(7)
            61646472657373                  # "address"
         6a                                 # text(10)
            7469632e6e72632e6361            # "tic.nrc.ca"
         64                                 # text(4)
            706f7274                        # "port"
         18 7b                              # unsigned(123)
      78 1c                                 # text(28)
         696574662d73797374656d3a6173736f636961746f6e2d74797065
      00                                    # unsigned(0)
      72                                    # text(18)
         696574662d73797374656d3a696275727374 # "ietf-system:iburst"
      f4                                    # primitive(20)
      72                                    # text(18)
         696574662d73797374656d3a707265666572 # "ietf-system:prefer"
      f5                                    # primitive(21)
   a2                                       # map(2)
      70                                    # text(16)
         696574662d73797374656d3a6e616d65   # "ietf-system:name"
      6e                                    # text(14)
         4e5243205441432073657766572        # "NRC TAC server"
      6f                                    # text(15)
         696574662d73797374656d3a756470     # "ietf-system:udp"
      a1                                    # map(1)
         67                                 # text(7)
            61646472657373                  # "address"
         6a                                 # text(10)
            7461632e6e72632e6361            # "tac.nrc.ca"
```

4.5. The 'anydata' Data Node

An anydata serves as a container for an arbitrary set of schema nodes that otherwise appear as normal YANG-modeled data. An anydata instance is encoded using the same rules as a container, i.e., CBOR map. The requirement that anydata content can be modeled by YANG implies the following:

- Keys of any inner data nodes MUST be set to valid deltas or member names.

- The CBOR array MUST contain either unique scalar values (as a leaf-list, see Section 4.3), or maps (as a list, see Section 4.4).

- Values MUST follow the encoding rules of one of the datatypes listed in Section 6.

The following example shows a possible use of anydata. In this example, an anydata is used to define a data node containing a notification event, this data node can be part of a YANG list to create an event logger.

Definition example:

```
anydata event;
```

This example also assumes the assistance of the following notification.

```
module example-port {
  ...

  notification example-port-fault {  # SID 2600
    leaf port-name {                 # SID 2601
      type string;
    }
    leaf port-fault {                # SID 2601
      type string;
    }
  }
}
```

CBOR diagnostic notation:

```
{
  2601 : "0/4/21",       / port-name /
  2602 : "Open pin 2"    / port-fault /
}
```

CBOR encoding:

```
a2                        # map(2)
   19 0a29                # unsigned(2601)
   66                     # text(6)
      302f342f3231        # "0/4/21"
   19 0a2a                # unsigned(2602)
   6a                     # text(10)
      4f70656e2070696e2032 # "Open pin 2"
```

4.6. The 'anyxml' Data Node

An anyxml schema node is used to serialize an arbitrary CBOR content, i.e., its value can be any CBOR binary object. anyxml value may contain CBOR data items tagged with one of the tag listed in Section 8.1, these tags shall be supported.

The following example shows a valid CBOR encoded instance.

Definition example from [RFC7951]:

anyxml bar;

CBOR diagnostic notation: [true, null, true]

CBOR encoding: 83 f5 f6 f5

5. Encoding of YANG data templates

YANG data templates are data structures defined in YANG but not intended to be implemented as part of a datastore. YANG data templates are defined using the 'yang-data' extension as described by RFC 8040.

The encoding rules defined for YANG containers in section 4.2 may be used to serialize YANG data templates.

Definition example from [I-D.ietf-core-comi]:

```
import ietf-restconf {
  prefix rc;
}

rc:yang-data yang-errors {
  container error {
    leaf error-tag {
      type identityref {
        base error-tag;
      }
    }
    leaf error-app-tag {
      type identityref {
        base error-app-tag;
      }
    }
    leaf error-data-node {
      type instance-identifier;
    }
    leaf error-message {
      type string;
    }
  }
}
```

Just like YANG containers, YANG data templates can be encoded using either SIDs or names.

5.1. SIDs as keys

This example shows a serialization example of the yang-errors template using SIDs as CBOR map key.

CBOR diagnostic notation:

```
{
  1024 : {                    / error  (SID 1024) /
    +4 : 1011,                / error-tag (SID 1028) /
                              / = invalid-value (SID 1011) /
    +1 : 1018,                / error-app-tag (SID 1025) /
                              / = not-in-range (SID 1018) /
    +2 : 1740,                / error-data-node (SID 1026) /
                              / = timezone-utc-offset (SID 1740) /
    +3 : "max value exceeded" / error-message (SID 1027) /
  }
}
```

CBOR encoding:

```
A1                                      # map(1)
   19 0400                              # unsigned(1024)
   A4                                   # map(4)
      04                                # unsigned(4)
      19 03F3                           # unsigned(1011)
      01                                # unsigned(1)
      19 03FA                           # unsigned(1018)
      02                                # unsigned(2)
      19 06CC                           # unsigned(1740)
      03                                # unsigned(3)
      76                                # text(22)
         6D6178696D756D2076616C756520657863656565646564
```

5.2. Member names as keys

This example shows a serialization example of the yang-errors template using member names as CBOR map key.

CBOR diagnostic notation:

```
{
  "ietf-comi:error" : {
    "error-tag" : "invalid-value",
    "error-app-tag" : "not-in-range",
    "error-data-node" : "timezone-utc-offset",
    "error-message" : "max value exceeded"
  }
}
```

CBOR encoding:

```
A1                                      # map(1)
   6F                                   # text(15)
      696574662D636F6D693A6572726F72
   A4                                   # map(4)
      69                                # text(9)
         6572726F722D746167             # "error-tag"
      6D                                # text(13)
         696E76616C69642D76616C7565
      6D                                # text(13)
         6572726F722D6170702D746167
      6C                                # text(12)
         6E6F742D696E2D72616E6765
      6F                                # text(15)
         6572726F722D646174612D6E6F6465
      73                                # text(19)
         74696D657A6F6E652D7574632D6F6666736574
      6D                                # text(13)
         6572726F722D6D657373616765
      72                                # text(18)
         6D617820766C756520657836365646564
```

6. Representing YANG Data Types in CBOR

The CBOR encoding of an instance of a leaf or leaf-list data node depends on the built-in type of that data node. The following sub-section defined the CBOR encoding of each built-in type supported by YANG as listed in [RFC7950] section 4.2.4. Each subsection shows an example value assigned to a data node instance of the discussed built-in type.

6.1. The unsigned integer Types

Leafs of type uint8, uint16, uint32 and uint64 MUST be encoded using a CBOR unsigned integer data item (major type 0).

The following example shows the encoding of a 'mtu' leaf instance set to 1280 bytes.

Definition example from [RFC7277]:

```
leaf mtu {
  type uint16 {
    range "68..max";
  }
}
```

CBOR diagnostic notation: 1280

CBOR encoding: 19 0500

6.2. The integer Types

Leafs of type int8, int16, int32 and int64 MUST be encoded using either CBOR unsigned integer (major type 0) or CBOR negative integer (major type 1), depending on the actual value.

The following example shows the encoding of a 'timezone-utc-offset' leaf instance set to -300 minutes.

Definition example from [RFC7317]:

```
leaf timezone-utc-offset {
  type int16 {
    range "-1500 .. 1500";
  }
}
```

CBOR diagnostic notation: -300

CBOR encoding: 39 012b

6.3. The 'decimal64' Type

Leafs of type decimal64 MUST be encoded using a decimal fraction as defined in [RFC7049] section 2.4.3.

The following example shows the encoding of a 'my-decimal' leaf instance set to 2.57.

Definition example from [RFC7317]:

```
leaf my-decimal {
  type decimal64 {
    fraction-digits 2;
    range "1 .. 3.14 | 10 | 20..max";
  }
}
```

CBOR diagnostic notation: 4([-2, 257])

CBOR encoding: c4 82 21 19 0101

6.4. The 'string' Type

Leafs of type string MUST be encoded using a CBOR text string data item (major type 3).

The following example shows the encoding of a 'name' leaf instance set to "eth0".

Definition example from [RFC7223]:

```
leaf name {
  type string;
}
```

CBOR diagnostic notation: "eth0"

CBOR encoding: 64 65746830

6.5. The 'boolean' Type

Leafs of type boolean MUST be encoded using a CBOR true (major type 7, additional information 21) or false data item (major type 7, additional information 20).

The following example shows the encoding of an 'enabled' leaf instance set to 'true'.

Definition example from [RFC7317]:

```
leaf enabled {
  type boolean;
}
```

CBOR diagnostic notation: true

CBOR encoding: f5

6.6. The 'enumeration' Type

Leafs of type enumeration MUST be encoded using a CBOR unsigned integer (major type 0) or CBOR negative integer (major type 1), depending on the actual value. Enumeration values are either explicitly assigned using the YANG statement 'value' or automatically assigned based on the algorithm defined in [RFC7950] section 9.6.4.2.

The following example shows the encoding of an 'oper-status' leaf instance set to 'testing'.

Definition example from [RFC7317]:

```
leaf oper-status {
  type enumeration {
    enum up { value 1; }
    enum down { value 2; }
    enum testing { value 3; }
    enum unknown { value 4; }
    enum dormant { value 5; }
    enum not-present { value 6; }
    enum lower-layer-down { value 7; }
  }
}
```

CBOR diagnostic notation: 3

CBOR encoding: 03

6.7. The 'bits' Type

Leafs of type bits MUST be encoded using a CBOR byte string data item (major type 2). Bits position are either explicitly assigned using the YANG statement 'position' or automatically assigned based on the algorithm defined in [RFC7950] section 9.7.4.2.

Bits position 0 to 7 are assigned to the first byte within the byte string, bits 8 to 15 to the second byte, and subsequent bytes are assigned similarly. Within each byte, bits are assigned from least to most significant.

The following example shows the encoding of a 'mybits' leaf instance with the 'disable-nagle' and '10-Mb-only' flags set.

Definition example from [RFC7950]:

```
leaf mybits {
  type bits {
    bit disable-nagle {
      position 0;
    }
    bit auto-sense-speed {
      position 1;
    }
    bit 10-Mb-only {
      position 2;
    }
  }
}
```

CBOR diagnostic notation: h'05'

CBOR encoding: 41 05

6.8. The 'binary' Type

Leafs of type binary MUST be encoded using a CBOR byte string data item (major type 2).

The following example shows the encoding of an 'aes128-key' leaf instance set to 0x1f1ce6a3f42660d888d92a4d8030476e.

Definition example:

```
leaf aes128-key {
  type binary {
    length 16;
  }
}
```

CBOR diagnostic notation: h'1f1ce6a3f42660d888d92a4d8030476e'

CBOR encoding: 50 1f1ce6a3f42660d888d92a4d8030476e

6.9. The 'leafref' Type

Leafs of type leafref MUST be encoded using the rules of the schema node referenced by the 'path' YANG statement.

The following example shows the encoding of an 'interface-state-ref' leaf instance set to "eth1".

Definition example from [RFC7223]:

```
typedef interface-state-ref {
  type leafref {
    path "/interfaces-state/interface/name";
  }
}

container interfaces-state {
  list interface {
    key "name";
    leaf name {
      type string;
    }
    leaf-list higher-layer-if {
      type interface-state-ref;
    }
  }
}
```

CBOR diagnostic notation: "eth1"

CBOR encoding: 64 65746831

6.10. The 'identityref' Type

This specification supports two approaches for encoding identityref, a YANG Schema Item iDentifier (SID) as defined in Section 2.1 or a name as defined in [RFC7951] section 6.8.

6.10.1. SIDs as identityref

When schema nodes of type identityref are implemented using SIDs, they MUST be encoded using a CBOR unsigned integer data item (major type 0). (Note that no delta mechanism is employed for SIDs as identityref.)

The following example shows the encoding of a 'type' leaf instance set to the value 'iana-if-type:ethernetCsmacd' (SID 1180).

Definition example from [RFC7317]:

```
identity interface-type {
}

identity iana-interface-type {
  base interface-type;
}

identity ethernetCsmacd {
  base iana-interface-type;
}

leaf type {
  type identityref {
    base interface-type;
  }
}
```

CBOR diagnostic notation: 1180

CBOR encoding: 19 049c

6.10.2. Name as identityref

Alternatively, an identityref may be encoded using a name as defined in [RFC7951] section 6.8. When names are used, identityref MUST be encoded using a CBOR text string data item (major type 3). If the identity is defined in another module than the leaf node containing the identityref value, the namespace-qualified form MUST be used. Otherwise, both the simple and namespace-qualified forms are permitted. Names and namespaces are defined in [RFC7951] section 4.

The following example shows the encoding of the identity 'iana-if-type:ethernetCsmacd' using its name. This example is described in Section 6.10.1.

CBOR diagnostic notation: "iana-if-type:ethernetCsmacd"

CBOR encoding: 78 1b
69616e612d69662d747970653a65746865726e657443736d616364

6.11. The 'empty' Type

Leafs of type empty MUST be encoded using the CBOR null value (major type 7, additional information 22).

The following example shows the encoding of a 'is-router' leaf instance when present.

Definition example from [RFC7277]:

```
leaf is-router {
  type empty;
}
```

CBOR diagnostic notation: null

CBOR encoding: f6

6.12. The 'union' Type

Leafs of type union MUST be encoded using the rules associated with one of the types listed. When used in a union, the following YANG datatypes are prefixed by CBOR tag to avoid confusion between different YANG datatypes encoded using the same CBOR major type.

- bits
- enumeration
- identityref
- instance-identifier

See Section 8.1 for more information about these CBOR tags.

The following example shows the encoding of an 'ip-address' leaf instance when set to "2001:db8:a0b:12f0::1".

Definition example from [RFC7317]:

```
typedef ipv4-address {
  type string {
  pattern '(([0-9]|[1-9][0-9]|1[0-9][0-9]|2[0-4][0-9]|25[0-5])\.){3}
           ([0-9][1-9][0-9]|1[0-9][0-9]|2[0-4][0-9]|25[0-5])(%[\p{N}
           \p{L}]+)?';
  }
}

typedef ipv6-address {
  type string {
    pattern '((:|[0-9a-fA-F]{0,4}):)([0-9a-fA-F]{0,4}:){0,5}((([0-9a
             -fA-F]{0,4}:)?(:|[0-9a-fA-F]{0,4}))|(((25[0-5]|2[0-4][0
             -9]|[01]?[0-9]?[0-9])\.){3}(25[0-5]|2[0-4][0-9]|[01]?[0
             -9]?[0-9])))(%[\p{N}\p{L}]+)?';
    pattern '(([^:]+:){6}(([^:]+:[^:]+)|(.*\..*)))|((([^:]+:)*[^:]+)
             ?::(([^:]+:)*[^:]+)?)(%.+)?';
  }
}

typedef ip-address {
  type union {
    type ipv4-address;
    type ipv6-address;
  }
}

leaf address {
  type inet:ip-address;
}
```

CBOR diagnostic notation: "2001:db8:a0b:12f0::1"

CBOR encoding: 74 323030313a6462383a6130623a313266303a3a31

6.13. The 'instance-identifier' Type

This specification supports two approaches for encoding an instance-identifier, one based on YANG Schema Item iDentifier (SID) as defined in Section 2.1 and one based on names as defined in [RFC7951] section 6.11.

6.13.1. SIDs as instance-identifier

SIDs uniquely identify a data node. In the case of a single instance data node, a data node defined at the root of a YANG module or submodule or data nodes defined within a container, the SID is sufficient to identify this instance.

In the case of a data node member of a YANG list, a SID is combined with the list key(s) to identify each instance within the YANG list(s).

Single instance data nodes MUST be encoded using a CBOR unsigned integer data item (major type 0) and set to the targeted data node SID.

Data nodes member of a YANG list MUST be encoded using a CBOR array data item (major type 4) containing the following entries:

- The first entry MUST be encoded as a CBOR unsigned integer data item (major type 0) and set to the targeted data node SID.

- The following entries MUST contain the value of each key required to identify the instance of the targeted data node. These keys MUST be ordered as defined in the 'key' YANG statement, starting from top level list, and follow by each of the subordinate list(s).

First example:

The following example shows the encoding of a leaf instance of type instance-identifier which identifies the data node "/system/contact" (SID 1737).

Definition example from [RFC7317]:

```
container system {

  leaf contact {
    type string;
  }

  leaf hostname {
    type inet:domain-name;
  }
}
```

CBOR diagnostic notation: 1737

CBOR encoding: 19 06c9

Second example:

The following example shows the encoding of a leaf instance of type instance-identifier which identify the data node instance

"/system/authentication/user/authorized-key/key-data" (SID 1730) for user name "bob" and authorized-key "admin".

Definition example from [RFC7317]:

```
list user {
  key name;

  leaf name {
    type string;
  }
  leaf password {
    type ianach:crypt-hash;
  }

  list authorized-key {
    key name;

    leaf name {
      type string;
    }
    leaf algorithm {
      type string;
    }
    leaf key-data {
      type binary;
  }
}
```

CBOR diagnostic notation: [1730, "bob", "admin"]

CBOR encoding:

```
83                      # array(3)
   19 06c2              # unsigned(1730)
   63                   # text(3)
      626f62            # "bob"
   65                   # text(5)
      61646d696e        # "admin"
```

Third example:

The following example shows the encoding of a leaf instance of type instance-identifier which identify the list instance "/system/authentication/user" (SID 1726) corresponding to the user name "jack".

CBOR diagnostic notation: [1726, "jack"]

CBOR encoding:

```
82                      # array(2)
   19 06be              # unsigned(1726)
   64                   # text(4)
      6a61636b          # "jack"
```

6.13.2. Names as instance-identifier

The use of names as instance-identifier is defined in [RFC7951] section 6.11. The resulting xpath MUST be encoded using a CBOR text string data item (major type 3).

First example:

This example is described in Section 6.13.1.

CBOR diagnostic notation: "/ietf-system:system/contact"

CBOR encoding:

```
78 1c 2f20696574662d73797374656d3a73797374656d2f636f6e74616374
```

Second example:

This example is described in Section 6.13.1.

CBOR diagnostic notation:

"/ietf-system:system/authentication/user[name='bob']/authorized-key
[name='admin']/key-data"

CBOR encoding:

```
78 59
   2f696574662d73797374656d3a73797374656d2f61757468656e74696361
   74696f6e2f757365725b6e616d653d27626f62275d2f617574686f72697a
   65642d6b65795b6e616d653d2761646d696e275d2f6b65792d64617461
```

Third example:

This example is described in Section 6.13.1.

CBOR diagnostic notation:

"/ietf-system:system/authentication/user[name='bob']"

CBOR encoding:

```
78 33
   2f696574662d73797374656d3a73797374656d2f61757468656e74696361
   74696f6e2f757365725b6e616d653d27626f62275d
```

7. Security Considerations

The security considerations of [RFC7049] and [RFC7950] apply.

This document defines an alternative encoding for data modeled in the YANG data modeling language. As such, this encoding does not contribute any new security issues in addition of those identified for the specific protocol or context for which it is used.

To minimize security risks, software on the receiving side SHOULD reject all messages that do not comply to the rules of this document and reply with an appropriate error message to the sender.

8. IANA Considerations

8.1. Tags Registry

This specification requires the assignment of CBOR tags for the following YANG datatypes. These tags are added to the Tags Registry as defined in section 7.2 of [RFC7049].

Tag	Data Item	Semantics	Reference
40	bits	YANG bits datatype	RFC XXXX
41	enumeration	YANG enumeration datatype	RFC XXXX
42	identityref	YANG identityref datatype	RFC XXXX
43	instance-identifier	YANG instance-identifier datatype	RFC XXXX

// RFC Ed.: update Tag values using allocated tags if needed and remove this note // RFC Ed.: replace XXXX with RFC number and remove this note

9. Acknowledgments

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Authors' Addresses

Michel Veillette (editor)
Trilliant Networks Inc.
610 Rue du Luxembourg
Granby, Quebec J2J 2V2
Canada

Phone: +14503750556
Email: michel.veillette@trilliantinc.com

Alexander Pelov (editor)
Acklio
2bis rue de la Chataigneraie
Cesson-Sevigne, Bretagne 35510
France

Email: a@ackl.io

Abhinav Somaraju
Tridonic GmbH & Co KG
Farbergasse 15
Dornbirn, Vorarlberg 6850
Austria

Phone: +43664808926169
Email: abhinav.somaraju@tridonic.com

Randy Turner
Landis+Gyr
30000 Mill Creek Ave
Suite 100
Alpharetta, GA 30022
US

Phone: ++16782581292
Email: randy.turner@landisgyr.com
URI: http://www.landisgyr.com/

Ana Minaburo
Acklio
2bis rue de la chataigneraie
Cesson-Sevigne, Bretagne 35510
France

Email: ana@ackl.io