Internet Engineering Task Force
Internet-Draft
Intended status: Standards Track
Expires: 28 July 2021

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24 January 2021

CBOR Encoding of Data Modeled with YANG
draft-ietf-core-yang-cbor-15

Abstract

This document defines encoding rules for serializing configuration data, state data, RPC input and RPC output, action input, action output, notifications and yang-data extension defined within YANG modules using the Concise Binary Object Representation (CBOR, RFC 8949).

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1. Introduction

The specification of the YANG 1.1 data modeling 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.

An additional set of encoding rules has been defined in [RFC7951] based on the JavaScript Object Notation (JSON) Data Interchange Format [RFC8259].

The aim of this document is to define a set of encoding rules for the Concise Binary Object Representation (CBOR) [RFC8949]. 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", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

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 [RFC8040]:

* yang-data extension

This specification also makes use of the following terminology:

* child: A schema node defined as a child node of 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 YANG SID and a reference YANG SID. A reference YANG 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 container, list, case, notification, RPC input, RPC output, action input or action output node in which a schema node is defined.

* YANG Schema Item iDentifier (YANG SID or simply SID): Unsigned integer used to identify different YANG items.

3. Properties of the CBOR Encoding

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

A node from the data tree 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 types of CBOR keys; YANG Schema Item iDentifier (YANG SID) as defined in Section 3.2 and names as defined in Section 3.3. Each of these key types is encoded using a specific CBOR type which allows their interpretation during the deserialization process. Protocols or mechanisms implementing this specification 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 SID not encoded as delta, anyxml schema nodes and the union datatype to distinguish explicitly the use of different YANG datatypes encoded using the same CBOR major type.

Unless specified otherwise by the protocol or mechanism implementing this specification, the indefinite lengths encoding as defined in Section 3.2 of [RFC8949] SHALL be supported by CBOR decoders.

Data nodes implemented using a CBOR array, map, byte string, and text string can be instantiated but empty. In this case, they are encoded with a length of zero.

When schema node are serialized using the rules defined by this specification as part of an application payload, the payload SHOULD include information that would allow a stateless way to identify each node, such as the SID number associated with the node, SID delta from another SID in the application payload, the namespace qualified name or the instance-identifier.

Examples in Section 4 include a root CBOR map with a single entry having a key set to either a namespace qualified name or a SID. This root CBOR map is provided only as a typical usage example and is not part of the present encoding rules. Only the value within this CBOR map is compulsory.

3.1. CBOR diagnostic notation

Within this document, CBOR binary contents are represented using an equivalent textual form called CBOR diagnostic notation as defined in Section 8 of [RFC8949]. 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

Note: CBOR binary contents shown in this specification are annotated with comments. These comments are delimited by slashes ("/") as defined in [RFC8610] Appendix G.6.

3.2. YANG Schema Item iDentifier

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 strings. 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, is an unsigned integer. The following items are identified using YANG SIDs (often shortened to 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 their size, SIDs used as keys in inner CBOR maps are typically encoded using deltas. Conversion from SIDs to deltas and back to SIDs are stateless processes solely based on the data serialized or deserialized. These SIDs may also be encoded as absolute number when enclosed by CBOR tag 47.

Mechanisms and processes used to assign SIDs to YANG items and to guarantee their uniqueness are 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 [I-D.ietf-core-sid].

3.3. Name

This specification also supports the encoding of YANG item identifiers as string, similar as those used by the JSON Encoding of Data Modeled with YANG [RFC7951]. This approach can be used to avoid the management overhead associated to SIDs allocation. The main drawback is the significant increase in size of the encoded data.

YANG item identifiers implemented using names MUST be in one of the following forms:

* simple - the identifier of the YANG item (i.e. schema node or identity).

* namespace qualified - the identifier of the YANG item is prefixed with the name of the module in which this item is defined, separated by the colon character (":").

The name of a module determines the namespace of all YANG items defined in that module. If an item is defined in a submodule, then the namespace qualified name uses the name of the main module to which the submodule belongs.

ABNF syntax [RFC5234] of a name is shown in Figure 1, where the production for "identifier" is defined in Section 14 of [RFC7950].

```
name = [identifier ":"] identifier
```

Figure 1: ABNF Production for a simple or namespace qualified name

A namespace qualified name MUST be used for all members of a top-level CBOR map and then also whenever the namespaces of the data node and its parent node are different. In all other cases, the simple form of the name SHOULD be used.

Definition example:

```
module example-foomod {
  container top {
    leaf foo {
      type uint8;
    }
  }
}

module example-barmod {
  import example-foomod {
    prefix "foomod";
  }
  augment "/foomod:top" {
    leaf bar {
      type boolean;
    }
  }
}
```

A valid CBOR encoding of the 'top' container is as follows.

CBOR diagnostic notation:

```
{
  "example-foomod:top": {
    "foo": 54,
    "example-barmod:bar": true
  }
}
```

Both the 'top' container and the 'bar' leaf defined in a different YANG module as its parent container are encoded as namespace qualified names. The 'foo' leaf defined in the same YANG module as its parent container is encoded as simple name.

4. Encoding of YANG Schema Node Instances

Schema node instances defined using the YANG modeling language are encoded using CBOR [RFC8949] based on the rules defined in this section. We assume that the reader is already familiar with both YANG [RFC7950] and CBOR [RFC8949].

4.1. The 'leaf'

A 'leaf' MUST be encoded accordingly to its datatype using one of the encoding rules specified in Section 6.

The following examples shows the encoding of a 'hostname' leaf using a SID or a name.

Definition example from [RFC7317]:

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

4.1.1. Using SIDs in keys

CBOR diagnostic notation:

```
{
  1752 : "myhost.example.com"     / hostname (SID 1752) /
}
```

CBOR encoding:

```
A1                                          # map(1)
   19 06D8                                  # unsigned(1752)
   72                                       # text(18)
      6D79686F73742E6578616D706C652E636F6D # "myhost.example.com"
```

4.1.2. Using names in keys

CBOR diagnostic notation:

```
{
  "ietf-system:hostname" : "myhost.example.com"
}
```

CBOR encoding:

```
A1                                          # map(1)
   74                                       # text(20)
      696574662D73797374656D3A686F73746E616D65
   72                                       # text(18)
      6D79686F73742E6578616D706C652E636F6D
```

4.2. The 'container' and other nodes from the data tree

Containers, list instances, notification contents, 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 schema node identifier, each value is set to the value of this schema node instance according to the instance datatype.

This specification supports two types of CBOR keys; SID as defined in Section 3.2 and names as defined in Section 3.3.

The following examples shows the encoding of a 'system-state' container instance using SIDs or names.

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;
    }
  }
}
```

4.2.1. Using SIDs in keys

In the context of containers and other nodes from the data tree, CBOR map keys within inner CBOR maps can be encoded using deltas or SIDs. In the case of deltas, they MUST be encoded using a CBOR unsigned integer (major type 0) or CBOR negative integer (major type 1), depending on the actual delta value. In the case of SID, they are encoded using the SID value enclosed by CBOR tag 47 as defined in Section 9.3.

Delta values are computed as follows:

* In the case of a 'container', deltas are equal to the SID of the current schema node minus the SID of the parent 'container'.

* In the case of a 'list', deltas are equal to the SID of the current schema node minus the SID of the parent 'list'.

* In the case of an 'rpc input' or 'rpc output', deltas are equal to the SID of the current schema node minus the SID of the 'rpc'.

* In the case of an 'action input' or 'action output', deltas are equal to the SID of the current schema node minus the SID of the 'action'.

* In the case of an 'notification content', deltas are equal to the SID of the current schema node minus the SID of the 'notification'.

CBOR diagnostic notation:

```
{
  1720 : {                              / system-state (SID 1720) /
    1 : {                               / clock  (SID 1721) /
      2 : "2015-10-02T14:47:24Z-05:00", / current-datetime(SID 1723)/
      1 : "2015-09-15T09:12:58Z-05:00"  / boot-datetime (SID 1722) /
    }
  }
}
```

CBOR encoding:

```
A1                                      # map(1)
   19 06B8                              # unsigned(1720)
   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
```

Figure 2: System state clock encoding

4.2.2. Using names in keys

CBOR map keys implemented using names MUST be encoded using a CBOR text string data item (major type 3). A namespace-qualified name MUST be used each time the namespace of a schema node and its parent differ. In all other cases, the simple form of the 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.

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;
    }
  }
}
```

CBOR diagnostic notation:

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

CBOR encoding:

```
A1                                      # map(1)
   78 18                                # text(24)
      696574662D73797374656D3A73797374656D2D7374617465
   A1                                   # map(1)
      65                                # text(5)
         636C6F636B                     # "clock"
      A2                                # map(2)
         70                             # text(16)
            63757272656E742D6461746574696D65
         78 1A                          # text(26)
            323031352D31302D30325431343A34373A32345A2D30353A3030
         6D                             # text(13)
            626F6F742D6461746574696D65
         78 1A                          # text(26)
            323031352D30392D31355430393A31323A35385A2D30353A3030
```

4.3. The 'leaf-list'

A leaf-list MUST be encoded using a CBOR array data item (major type 4). Each entry of this array MUST be encoded accordingly to its datatype using one of the encoding rules specified in Section 6.

The following example shows the encoding of the 'search' leaf-list instance containing 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;
}
```

4.3.1. Using SIDs in keys

CBOR diagnostic notation:

```
{
  1746 : [ "ietf.org", "ieee.org" ]     / search (SID 1746) /
}
```

CBOR encoding:

```
A1                        # map(1)
   19 06D2                # unsigned(1746)
   82                     # array(2)
      68                  # text(8)
         696574662E6F7267 # "ietf.org"
      68                  # text(8)
         696565652E6F7267 # "ieee.org"
```

4.3.2. Using names in keys

CBOR diagnostic notation:

```
{
  "ietf-system:search" : [ "ietf.org", "ieee.org" ]
}
```

CBOR encoding:

```
A1                                          # map(1)
   72                                       # text(18)
      696574662D73797374656D3A736561726368 # "ietf-system:search"
   82                                       # array(2)
      68                                    # text(8)
         696574662E6F7267                   # "ietf.org"
      68                                    # text(8)
         696565652E6F7267                   # "ieee.org"
```

4.4. The 'list' and 'list' instance(s)

A list or a subset of 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 encoding rules of a collection as defined in Section 4.2.

It is important to note that this encoding rule also apply to a single 'list' instance.

The following examples show the encoding of a 'server' list using SIDs or names.

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;
  }
}
```

4.4.1. Using SIDs in keys

The encoding rules of each 'list' instance are defined in Section 4.2.1. Deltas of list members are equal to the SID of the current schema node minus the SID of the 'list'.

CBOR diagnostic notation:

```
{
  1756 : [                      / server (SID 1756) /
    {
      3 : "NRC TIC server",     / name (SID 1759) /
      5 : {                     / udp (SID 1761) /
        1 : "tic.nrc.ca",       / address (SID 1762) /
        2 : 123                 / port (SID 1763) /
      },
      1 : 0,                    / association-type (SID 1757) /
      2 : false,                / iburst (SID 1758) /
      4 : true                  / prefer (SID 1760) /
    },
    {
      3 : "NRC TAC server",     / name (SID 1759) /
      5 : {                     / udp (SID 1761) /
        1 : "tac.nrc.ca"        / address (SID 1762) /
      }
    }
  ]
}
```

CBOR encoding:

```
A1                                      # map(1)
   19 06DC                              # unsigned(1756)
   82                                   # array(2)
      A5                                # map(5)
         03                             # unsigned(3)
         6E                             # text(14)
            4E52432054494320736572766572 # "NRC TIC server"
         05                             # unsigned(5)
         A2                             # map(2)
            01                          # unsigned(1)
            6A                          # text(10)
               7469632E6E72632E6361     # "tic.nrc.ca"
            02                          # unsigned(2)
            18 7B                       # unsigned(123)
         01                             # unsigned(1)
         00                             # unsigned(0)
         02                             # unsigned(2)
         F4                             # primitive(20)
         04                             # unsigned(4)
         F5                             # primitive(21)
      A2                                # map(2)
         03                             # unsigned(3)
         6E                             # text(14)
            4E52432054414320736572766572 # "NRC TAC server"
         05                             # unsigned(5)
         A1                             # map(1)
            01                          # unsigned(1)
            6A                          # text(10)
               7461632E6E72632E6361     # "tac.nrc.ca"
```

4.4.2. Using names in keys

The encoding rules of each 'list' instance are defined in Section 4.2.2.

CBOR diagnostic notation:

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

CBOR encoding:

```
A1                                      # map(1)
   72                                   # text(18)
      696574662D73797374656D3A736572766572
   82                                   # array(2)
      A5                                # map(5)
         64                             # text(4)
            6E616D65                    # "name"
         6E                             # text(14)
            4E52432054494320736572766572
         63                             # text(3)
            756470                      # "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)
         70                             # text(16)
            6173736F63696174696F6E2D74797065
         00                             # unsigned(0)
         66                             # text(6)
            696275727374                # "iburst"
         F4                             # primitive(20)
         66                             # text(6)
            707265666572                # "prefer"
         F5                             # primitive(21)
      A2                                # map(2)
         64                             # text(4)
            6E616D65                    # "name"
         6E                             # text(14)
            4E52432054414320736572766572
         63                             # text(3)
            756470                      # "udp"
         A1                             # map(1)
            67                          # text(7)
               61646472657373           # "address"
            6A                          # text(10)
               7461632E6E72632E6361     # "tac.nrc.ca"
```

4.5. The 'anydata'

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:

* CBOR map keys of any inner schema nodes MUST be set to valid deltas or 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).

* CBOR map values MUST follow the encoding rules of one of the datatypes listed in Section 4.

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

Definition example:

```
module event-log {
  ...
  anydata last-event;                # SID 60123
```

This example also assumes the assistance of the following notification.

```
module example-port {
  ...

  notification example-port-fault {  # SID 60200
    leaf port-name {                 # SID 60201
      type string;
    }
    leaf port-fault {                # SID 60202
      type string;
    }
  }
}
```

4.5.1. Using SIDs in keys

CBOR diagnostic notation:

```
{
  60123 : {                    / last-event (SID 60123) /
    77 : {                     / example-port-fault (SID 60200) /
      1 : "0/4/21",            / port-name (SID 60201) /
      2 : "Open pin 2"         / port-fault (SID 60202) /
    }
  }
}
```

CBOR encoding:

```
A1                                # map(1)
   19 EADB                        # unsigned(60123)
   A1                             # map(1)
      18 4D                       # unsigned(77)
      A2                          # map(2)
         18 4E                    # unsigned(78)
         66                       # text(6)
            302F342F3231          # "0/4/21"
         18 4F                    # unsigned(79)
         6A                       # text(10)
            4F70656E2070696E2032 # "Open pin 2"
```

In some implementations, it might be simpler to use the absolute SID tag encoding for the anydata root element. The resulting encoding is as follows:

```
{
  60123 : {                    / last-event (SID 60123) /
    47(60200) : {              / event-port-fault (SID 60200) /
      1 : "0/4/21",            / port-name (SID 60201) /
      2 : "Open pin 2"         / port-fault (SID 60202) /
    }
  }
}
```

4.5.2. Using names in keys

CBOR diagnostic notation:

```
{
  "event-log:last-event" : {
    "example-port:example-port-fault" : {
      "port-name" : "0/4/21",
      "port-fault" : "Open pin 2"
    }
  }
}
```

CBOR encoding:

```
A1                                      # map(1)
   74                                   # text(20)
      6576656E742D6C6F673A6C6173742D6576656E74
   A1                                   # map(1)
      78 20                             # text(32)
         6578616D706C652D706F72743A206578616D7
         06C652D706F72742D6661756C74
      A2                                # map(2)
         69                             # text(9)
            706F72742D6E616D65          # "port-name"
         66                             # text(6)
            302F342F3231                # "0/4/21"
         6A                             # text(10)
            706F72742D6661756C74        # "port-fault"
         6A                             # text(10)
            4F70656E2070696E2032        # "Open pin 2"
```

4.6. The 'anyxml'

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 tags listed in Section 9.3, these tags shall be supported.

The following example shows a valid CBOR encoded instance consisting of a CBOR array containing the CBOR simple values 'true', 'null' and 'true'.

Definition example from [RFC7951]:

```
module bar-module {
  ...
  anyxml bar;      # SID 60000
```

4.6.1. Using SIDs in keys

CBOR diagnostic notation:

```
{
  60000 : [true, null, true]   / bar (SID 60000) /
}
```

CBOR encoding:

```
A1         # map(1)
   19 EA60 # unsigned(60000)
   83      # array(3)
      F5   # primitive(21)
      F6   # primitive(22)
      F5   # primitive(21)
```

4.6.2. Using names in keys

CBOR diagnostic notation:

```
{
  "bar-module:bar" : [true, null, true]   / bar (SID 60000) /
}
```

CBOR encoding:

```
A1                                # map(1)
   6E                             # text(14)
      6261722D6D6F64756C653A626172 # "bar-module:bar"
   83                             # array(3)
      F5                          # primitive(21)
      F6                          # primitive(22)
      F5                          # primitive(21)
```

5. Encoding of 'yang-data' extension

The yang-data extension [RFC8040] is used to define data structures in YANG that are not intended to be implemented as part of a datastore.

The yang-data extension MUST be encoded using the encoding rules of nodes of data trees as defined in Section 4.2.

Just like YANG containers, yang-data extension can be encoded using either SIDs or names.

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

```
module ietf-coreconf {
  ...

  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;
      }
    }
  }
}
```

5.1. Using SIDs in keys

The yang-data extensions encoded using SIDs are carried in a CBOR map containing a single item pair. The key of this item is set to the SID assigned to the yang-data extension container, the value is set the CBOR encoding of this container as defined in Section 4.2.

This example shows a serialization example of the yang-errors yang-data extension as defined in [I-D.ietf-core-comi] using SIDs as defined in Section 3.2.

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 : "Maximum 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)
      70                                # text(16)
         4D6178696D756D206578636565646564
```

5.2. Using names in keys

The yang-data extensions encoded using names are carried in a CBOR map containing a single item pair. The key of this item is set to the namespace qualified name of the yang-data extension container, the value is set the CBOR encoding of this container as defined in Section 3.3.

This example shows a serialization example of the yang-errors yang-data extension as defined in [I-D.ietf-core-comi] using names as defined Section 3.3.

CBOR diagnostic notation:

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

CBOR encoding:

```
A1                                          # map(1)
   73                                       # text(19)
      696574662D636F7265636F6E663A6572726F72 # "ietf-coreconf:error"
   A4                                       # map(4)
      69                                    # text(9)
         6572726F722D746167                 # "error-tag"
      6D                                    # text(13)
         696E76616C69642D76616C7565         # "invalid-value"
      6D                                    # text(13)
         6572726F722D6170702D746167         # "error-app-tag"
      6C                                    # text(12)
         6E6F742D696E2D72616E6765           # "not-in-range"
      6F                                    # text(15)
         6572726F722D646174612D6E6F6465     # "error-data-node"
      73                                    # text(19)
         74696D657A6F6E652D7574632D6F6666736574
                                            # "timezone-utc-offset"
      6D                                    # text(13)
         6572726F722D6D657373616765         # "error-message"
      70                                    # text(16)
         4D6178696D756D206578636565646564
```

6. Representing YANG Data Types in CBOR

The CBOR encoding of an instance of a leaf or leaf-list schema node depends on the built-in type of that schema node. The following sub-section defines 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 schema 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 [RFC8344]:

```
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 Section 3.4.4 of [RFC8949].

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 [RFC8343]:

```
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 simple value 'true' (major type 7, additional information 21) or 'false' (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

Values of 'enumeration' types defined in a 'union' type MUST be encoded using a CBOR text string data item (major type 3) and MUST contain one of the names assigned by 'enum' statements in YANG. The encoding MUST be enclosed by the enumeration CBOR tag as specified in Section 9.3.

Definition example from [RFC7950]:

```
type union {
  type int32;
  type enumeration {
    enum unbounded;
  }
}
```

CBOR diagnostic notation: 44("unbounded")

CBOR encoding: D8 2C 69 756E626F756E646564

6.7. The 'bits' Type

Keeping in mind that bit positions are either explicitly assigned using the YANG statement 'position' or automatically assigned based on the algorithm defined in [RFC7950] section 9.7.4.2, each element of type bits could be seen as a set of bit positions (or offsets from position 0), that have a value of ether 1, which represents the bit being set or 0, which represents that the bit is not set.

Leafs of type bits MUST be encoded either using a CBOR array or byte string (major type 2). In case CBOR array representation is used, each element is either a positive integer (major type 0 with value 0 being disallowed) that can be used to calculate the offset of the next byte string, or a byte string (major type 2) that carries the information whether certain bits are set or not. The initial offset value is 0 and each unsigned integer modifies the offset value of the next byte string by the integer value multiplied by 8. For example, if the bit offset is 0 and there is an integer with value 5, the first byte of the byte string that follows will represent bit positions 40 to 47 both ends included. If the byte string has a second byte, it will carry information about bits 48 to 55 and so on. Within each byte, bits are assigned from least to most significant. After the byte string, the offset is modified by the number of bytes in the byte string multiplied by 8. Bytes with no bits set at the end of the byte string are removed. An example follows.

The following example shows the encoding of an 'alarm-state' leaf instance with the 'critical', 'warning' and 'indeterminate' flags set.

```
typedef alarm-state {
  type bits {
    bit unknown;
    bit under-repair;
    bit critical;
    bit major;
    bit minor;
    bit warning {
      position 8;
    }
    bit indeterminate {
      position 128;
    }
  }
}

leaf alarm-state {
  type alarm-state;
}
```

CBOR diagnostic notation: [h'0401', 14, h'01']

CBOR encoding: 83 42 0401 0E 41 01

In a number of cases the array would only need to have one element - a byte string with a small number of bytes inside. For this case, it is expected to omit the array element and have only the byte array that would have been inside. To illustrate this, let us consider the same example yang definition, but this time encoding only 'under-repair' and 'critical' flags. The result would be

CBOR diagnostic notation: h'06'

CBOR encoding: 41 06

Elements in the array MUST be either byte strings or positive unsigned integers, where byte strings and integers MUST alternate, i.e., adjacent byte strings or adjacent integers are an error. An array with a single byte string MUST instead by encoded as just that byte string. An array with a single positive integer is an error.

Values of 'bit' types defined in a 'union' type MUST be encoded using a CBOR text string data item (major type 3) and MUST contain a space-separated sequence of names of 'bit' that are set. The encoding MUST be enclosed by the bits CBOR tag as specified in Section 9.3.

The following example shows the encoding of an 'alarm-state' leaf instance defined using a union type with the 'under-repair' and 'critical' flags set.

Definition example:

```
leaf alarm-state-2 {
  type union {
    type alarm-state;
    type bits {
      bit extra-flag;
    }
  }
}
```

CBOR diagnostic notation: 43("under-repair critical")

CBOR encoding: D8 2B 75 756E6465722D72657061697220637269746963616C

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 [RFC8343]:

```
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 as defined in Section 3.2 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 1880).

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: 1880

CBOR encoding: 19 0758

6.10.2. Name as identityref

Alternatively, an identityref MAY be encoded using a name as defined in Section 3.3. When names are used, identityref MUST be encoded using a CBOR text string data item (major type 3). If the identity is defined in different module than the leaf node containing the identityref data node, the namespace qualified form MUST be used. Otherwise, both the simple and namespace qualified forms are permitted. Names and namespaces are defined in Section 3.3.

The following example shows the encoding of the identity 'iana-if-type:ethernetCsmacd' using its namespace qualified 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 [RFC8344]:

```
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 enclosed by a CBOR tag to avoid confusion between different YANG datatypes encoded using the same CBOR major type.

* bits

* enumeration

* identityref

* instance-identifier

See Section 9.3 for the assigned value of these CBOR tags.

As mentioned in Section 6.6 and in Section 6.7, 'enumeration' and 'bits' are encoded as CBOR text string data item (major type 3) when defined within a 'union' type.

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 as defined in Section 3.2 and one based on names as defined in Section 3.3.

6.13.1. SIDs as instance-identifier

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

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

Schema 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 schema node SID.

* The following entries MUST contain the value of each key required to identify the instance of the targeted schema 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).

Examples within this section assume the definition of a schema node of type 'instance-identifier':

Definition example from [RFC7950]:

```
container system {
  ...
  leaf reporting-entity {
    type instance-identifier;
  }

leaf contact { type string; }

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

First example:

The following example shows the encoding of the 'reporting-entity' value referencing data node instance "/system/contact" (SID 1741).

Definition example from [RFC7317]:

```
container system {

  leaf contact {
    type string;
  }

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

CBOR diagnostic notation: 1741

CBOR encoding: 19 06CD

Second example:

The following example shows the encoding of the 'reporting-entity' value referencing list instance "/system/authentication/user/authorized-key/key-data" (SID 1734) 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: [1734, "bob", "admin"]

CBOR encoding:

```
83                # array(3)
   19 06C6        # unsigned(1734)
   63             # text(3)
      626F62      # "bob"
   65             # text(5)
      61646D696E # "admin"
```

Third example:

The following example shows the encoding of the 'reporting-entity' value referencing the list instance "/system/authentication/user" (SID 1730) corresponding to user name "jack".

CBOR diagnostic notation: [1730, "jack"]

CBOR encoding:

```
82              # array(2)
   19 06C2      # unsigned(1730)
   64           # text(4)
      6A61636B # "jack"
```

6.13.2. Names as instance-identifier

An "instance-identifier" value is encoded as a string that is analogical to the lexical representation in XML encoding; see Section 9.13.2 in [RFC7950]. However, the encoding of namespaces in instance-identifier values follows the rules stated in Section 3.3, namely:

* The leftmost (top-level) data node name is always in the namespace qualified form.

* Any subsequent data node name is in the namespace qualified form if the node is defined in a module other than its parent node, and the simple form is used otherwise. This rule also holds for node names appearing in predicates.

For example,

/ietf-interfaces:interfaces/interface[name='eth0']/ietf-ip:ipv4/ip

is a valid instance-identifier value because the data nodes "interfaces", "interface", and "name" are defined in the module "ietf-interfaces", whereas "ipv4" and "ip" are defined in "ietf-ip".

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 2F696574662D73797374656D3A73797374656D2F636F6E74616374
```

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
   65642D6B65790D0A5B6E616D653D2761646D696E275D2F6B65792D64617461
```

Third example:

This example is described in Section 6.13.1.

CBOR diagnostic notation:

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

CBOR encoding:

```
78 33
   2F696574662D73797374656D3A73797374656D2F61757468656E74696361
   74696F6E2F757365725B6E616D653D27626F62275D
```

7. Content-Types

The following Content-Type is defined:

application/yang-data+cbor; id=name: This Content-Type represents a CBOR YANG document containing one or multiple data node values. Each data node is identified by its associated namespace qualified name as defined in Section 3.3.

FORMAT: CBOR map of name, instance-value

The message payload of Content-Type 'application/yang-data+cbor' is encoded using a CBOR map. Each entry within the CBOR map contains the data node identifier (i.e. its namespace qualified name) and the associated instance-value. Instance-values are encoded using the rules defined in Section 4

8. Security Considerations

The security considerations of [RFC8949] 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.

9. IANA Considerations

9.1. Media-Types Registry

This document adds the following Media-Type to the "Media Types" registry.

Name	Template	Reference
yang-data+cbor	application/yang-data+cbor	RFC XXXX

Table 2

// RFC Ed.: please replace RFC XXXX with this RFC number and remove this note.

Type name: application
Subtype name: yang-data+cbor
Required parameters: none
Optional parameters: none
Encoding considerations: binary (CBOR)
Security considerations: see Section 8 of RFC XXXX
Published specification: RFC XXXX
Person & email address to contact for further information: CORE WG mailing list (core@ietf.org), or IETF Applications and Real-Time Area (art@ietf.org)
Intended usage: COMMON
Restrictions on usage: none
Author/Change controller: IETF

9.2. CoAP Content-Formats Registry

This document adds the following Content-Format to the "CoAP Content-Formats", within the "Constrained RESTful Environments (CoRE) Parameters" registry.

Media Type	Content Coding	ID	Reference
application/yang-data+cbor; id=name		TBD1	RFC XXXX

Table 3

// RFC Ed.: please replace TBD1 with assigned IDs and remove this note. // RFC Ed.: please replace RFC XXXX with this RFC number and remove this note.

9.3. CBOR Tags Registry

This specification requires the assignment of CBOR tags for the following YANG datatypes. These tags are added to the CBOR Tags Registry as defined in Section 9.2 of [RFC8949].

Tag	Data Item	Semantics	Reference
43	text string	YANG bits datatype ; see Section 6.7.	[this]
44	text string	YANG enumeration datatype ; see Section 6.6.	[this]
45	unsigned integer or text string	YANG identityref datatype ; see Section 6.10.	[this]
46	unsigned integer or text string or array	YANG instance-identifier datatype; see Section 6.13.	[this]
47	unsigned integer	YANG Schema Item iDentifier ; see Section 3.2.	[this]

Table 4

// RFC Ed.: please replace [this] with RFC number and remove this note

10. Acknowledgments

This document has been largely inspired by the extensive works done by Andy Bierman and Peter van der Stok on [I-D.ietf-core-comi]. [RFC7951] has also been a critical input to this work. The authors would like to thank the authors and contributors to these two drafts.

The authors would also like to acknowledge the review, feedback, and comments from Ladislav Lhotka and Juergen Schoenwaelder.

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