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JSON Encoding of Data Modeled with YANG
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Abstract

This document defines encoding rules for representing configuration, state data, RPC input and output parameters, and notifications defined using YANG as JavaScript Object Notation (JSON) text.

Status of This Memo

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1. Introduction

The NETCONF protocol [RFC6241] uses XML [W3C.REC-xml-20081126] for encoding data in its Content Layer. Other management protocols might want to use other encodings while still benefiting from using YANG [I-D.ietf-netmod-rfc6020bis] as the data modeling language.

For example, the RESTCONF protocol [I-D.ietf-netconf-restconf] supports two encodings: XML (media type "application/yang.data+xml") and JSON (media type "application/yang.data+json).

The specification of YANG 1.1 data modelling language [I-D.ietf-netmod-rfc6020bis] defines only XML encoding for data instances, i.e., contents of configuration datastores, state data, RFC input and output parameters, and event notifications. The aim of this document is to define rules for encoding the same data as JavaScript Object Notation (JSON) text [RFC7159].

In order to achieve maximum interoperability while allowing implementations to use a variety of available JSON parsers, the JSON encoding rules follow, as much as possible, the constraints of the I-JSON restricted profile [RFC7493]. Section 7 discusses I-JSON conformance in more detail.

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 [I-D.ietf-netmod-rfc6020bis]:

- anydata,
- anyxml,
- augment,
- container,
- data node,
- identity,
- instance identifier,
- leaf,
- leaf-list,
- list,
- module,
- submodule.

3. Validation of JSON-encoded Instance Data

Instance data validation as defined in [I-D.ietf-netmod-rfc6020bis], sec. 8.3.3, is only applicable to XML-encoded data. For one, semantic constraints in "must" statements are expressed using XPath 1.0 [W3C.REC-xpath-19991116], which can be properly interpreted only in the XML context.

This document and the corresponding "XML Mapping Rules" sections from [I-D.ietf-netmod-rfc6020bis] also define an implicit schema-driven mapping of JSON-encoded instances to XML-encoded instances (and vice versa). This mapping is mostly straightforward. In cases where doubts could arise, this document gives explicit instructions for mapping JSON-encoded instances to XML.

In order to validate a JSON instance document, it needs first to be mapped, at least conceptually, to the corresponding XML instance document. By definition, the JSON document is then valid if and only if the XML document is valid according to the rules stated in [I-D.ietf-netmod-rfc6020bis].

4. Names and Namespaces

Instances of YANG data nodes (leafs, containers, leaf-lists, lists, anydata and anyxml nodes) are always encoded as members of a JSON object, i.e., as name/value pairs. This section defines how the name part is formed, and the following sections deal with the value part.

Except in the cases specified below, the member name is identical to the identifier of the corresponding YANG data node. Every such name belongs to a namespace which is associated with the YANG module where the corresponding data node is defined. If the data node is defined in a submodule, then the namespace is determined by the main module to which the submodule belongs.

If the namespace of a member name has to be explicitly specified, the module name SHALL be used as a prefix to the member's local name. Both parts of the member name SHALL be separated with a colon character (":"). Using ABNF [RFC5234], the namespace-qualified name can be expressed as shown in Figure 1, where the production for "identifier" is defined in sec. 13 of [I-D.ietf-netmod-rfc6020bis].

```
qualified-member-name = identifier ":" identifier
```

Figure 1: ABNF production for a qualified member name.

Names with namespace identifiers in the form shown in Figure 1 are used if and only if the parent data node belongs to a different

namespace, which also includes all top-level YANG data nodes that have no parent node.

For example, consider the following YANG module:

```
module foomod {

  namespace "http://example.com/foomod";

  prefix "foo";

  container top {
    leaf foo {
      type uint8;
    }
  }
}
```

If the data model consists only of this module, then the following is a valid JSON-encoded configuration:

```
{
  "foomod:top": {
    "foo": 54
  }
}
```

Note that the top-level container instance contains the namespace identifier (module name) but the "foo" leaf doesn't because it is defined in the same module as its parent container.

Now, assume the container "top" is augmented from another module, "barmod":

```
module barmod {

  namespace "http://example.com/barmod";

  prefix "bar";

  import foomod {
    prefix "foo";
  }

  augment "/foo:top" {
    leaf bar {
      type boolean;
    }
  }
}
```

A valid JSON-encoded configuration containing both leafs may then look like this:

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

The name of the "bar" leaf is prefixed with the namespace identifier because its parent is defined in a different module, hence it belongs to another namespace.

Explicit namespace identifiers are sometimes needed when encoding values of the "identityref" and "instances-identifier" types. The same form as shown in Figure 1 is then used as well. See Sections 6.8 and 6.11 for details.

5. Encoding of YANG Data Node Instances

Every complete JSON instance document, such as a configuration datastore content, is an object. Its members are instances of all top-level data nodes defined by the YANG data model.

Character encoding MUST be UTF-8.

Any data node instance is encoded as a name/value pair where the name is formed from the data node identifier using the rules of Section 4. The value depends on the category of the data node as explained in the following subsections.

5.1. The "leaf" Data Node

A leaf instance is encoded as a name/value pair where the value can be a string, number, literal "true" or "false", or the special array "[null]", depending on the type of the leaf (see Section 6 for the type encoding rules).

Example: For the leaf node definition

```
leaf foo {
  type uint8;
}
```

the following is a valid JSON-encoded instance:

```
"foo": 123
```

5.2. The "container" Data Node

A container instance is encoded as a name/object pair. The container's child data nodes are encoded as members of the object.

Example: For the container definition

```
container bar {
  leaf foo {
    type uint8;
  }
}
```

the following is a valid JSON-encoded instance:

```
"bar": {
  "foo": 123
}
```

5.3. The "leaf-list" Data Node

A leaf-list is encoded as a name/array pair, and the array elements are values of some scalar type, which can be a string, number, literal "true" or "false", or the special array "[null]", depending on the type of the leaf-list (see Section 6 for the type encoding rules).

The ordering of array elements follows the same rules as the ordering of XML elements representing leaf-list entries in the XML encoding. Specifically, the "ordered-by" properties (sec. 7.7.7 in [I-D.ietf-netmod-rfc6020bis]) MUST be observed.

Example: For the leaf-list definition

```
leaf-list foo {
  type uint8;
}
```

the following is a valid JSON-encoded instance:

```
"foo": [123, 0]
```

5.4. The "list" Data Node

A list instance is encoded as a name/array pair, and the array elements are JSON objects.

The ordering of array elements follows the same rules as the ordering of XML elements representing list entries in the XML encoding. Specifically, the "ordered-by" properties (sec. 7.7.7 in [I-D.ietf-netmod-rfc6020bis]) MUST be observed.

Unlike the XML encoding, where list keys are required to precede any other siblings within a list entry, and appear in the order specified by the data model, the order of members in a JSON-encoded list entry is arbitrary because JSON objects are fundamentally unordered collections of members.

Example: For the list definition

```
list bar {
  key foo;
  leaf foo {
    type uint8;
  }
  leaf baz {
    type string;
  }
}
```

the following is a valid JSON-encoded instance:

```
"bar": [
  {
    "foo": 123,
    "baz": "zig"
  },
  {
    "baz": "zag",
    "foo": 0
  }
]
```

5.5. The "anydata" Data Node

Anydata data node is a new feature in YANG 1.1. It serves as a container for data that appear as normal YANG-modeled data, except their data model is not a priori known.

An anydata instance is thus encoded in the same way as a container, and its content is subject to the following rules:

- It is a valid I-JSON message [RFC7493].
- Any member name is either a YANG identifier as defined by the "identifier" production in sec. 13 of [I-D.ietf-netmod-rfc6020bis], or two such identifiers separated by the colon character (":"). See also Section 4.
- Any JSON array contains either only unique scalar values (as a leaf-list, see Section 5.3), or only objects (as a list, see Section 5.4).
- The "null" value is only allowed in the single-element array "[null]" corresponding to the encoding of the "empty" type, see Section 6.9.

If a data model for anydata content is not available, it may be impossible to map a JSON-encoded anydata instance to XML, and vice versa. Note, however, that such a mapping is not needed for validation purposes (Section 3) because anydata contents are generally not subject to YANG-based validation (see sec. 7.10 in [I-D.ietf-netmod-rfc6020bis]).

Example: for the anydata definition

```
anydata data;
```

the following is a valid JSON-encoded instance:

```
"data": {
  "ietf-notification:notification": {
    "eventTime": "2014-07-29T13:43:01Z",
    "example-event:event": {
      "event-class: "fault",
      "reporting-entity": {
        "card": "Ethernet0"
      },
      "severity": "major"
    }
  }
}
```

5.6. The "anyxml" Data Node

An anyxml instance is encoded as a JSON name/value pair which MUST satisfy I-JSON constraints. Otherwise it is unrestricted, i.e., the value can be an object, array, number, string or one of the literals "true", "false" and "null".

As in the case of anydata (Section 5.5), there is no universal procedure for mapping JSON-encoded anyxml instances to XML, and vice versa.

Example: For the anyxml definition

```
anyxml bar;
```

the following is a valid JSON-encoded instance:

```
"bar": [true, null, true]
```

6. The Mapping of YANG Data Types to JSON Values

The type of the JSON value in an instance of the leaf or leaf-list data node depends on the type of that data node as specified in the following subsections.

6.1. Numeric Types

A value of the "int8", "int16", "int32", "uint8", "uint16" and "uint32" is represented as a JSON number.

A value of the "int64", "uint64" or "decimal64" type is encoded as a JSON string whose contents is the lexical representation of that numeric value as specified in sections 9.2.1 and 9.3.1 of [I-D.ietf-netmod-rfc6020bis].

For example, if the type of the leaf "foo" in Section 5.1 was "uint64" instead of "uint8", the instance would have to be encoded as

"foo": "123"

The special handling of 64-bit numbers follows from I-JSON recommendation to encode numbers exceeding the IEEE 754-2008 double precision range as strings, see sec. 2.2 in [RFC7493].

6.2. The "string" Type

A "string" value encoded as a JSON string, subject to JSON string encoding rules.

6.3. The "boolean" Type

A "boolean" value is mapped to the corresponding JSON literal name "true" or "false".

6.4. The "enumeration" Type

An "enumeration" value is mapped in the same way as a string except that the permitted values are defined by "enum" statements in YANG. See sec. 9.6 in [I-D.ietf-netmod-rfc6020bis].

6.5. The "bits" Type

A "bits" value is mapped to a JSON string identical to the lexical representation of this value in XML, i.e., space-separated names representing the individual bit values that are set. See sec. 9.7 in [I-D.ietf-netmod-rfc6020bis].

6.6. The "binary" Type

A "binary" value is mapped to a JSON string identical to the lexical representation of this value in XML, i.e., base64-encoded binary data. See sec. 9.8 in [I-D.ietf-netmod-rfc6020bis].

6.7. The "leafref" Type

A "leafref" value is mapped according to the same rules as the type of the leaf being referred to.

6.8. The "identityref" Type

An "identityref" value is mapped to a string representing the name of an identity. Its namespace MUST be expressed as shown in Figure 1 if

it is different from the namespace of the leaf node containing the identityref value, and MAY be expressed otherwise.

For example, consider the following schematic module:

```
module exmod {
  ...
  import ietf-interfaces {
    prefix if;
  }
  import iana-if-type {
    prefix ianaift;
  }
  ...
  leaf type {
    type identityref {
      base "if:interface-type";
    }
  }
}
```

A valid instance of the "type" leaf is then encoded as follows:

```
"type": "iana-if-type:ethernetCsmacd"
```

The namespace identifier "iana-if-type" must be present in this case because the "ethernetCsmacd" identity is not defined in the same module as the "type" leaf.

6.9. The "empty" Type

An "empty" value is mapped to "[null]", i.e., an array with the "null" literal being its only element. For the purposes of this document, "[null]" is treated as an atomic scalar value.

This encoding of the "empty" type was chosen instead of using simply "null" in order to facilitate the use of empty leafs in common programming languages. When used in a boolean context, the "[null]" value, unlike "null", evaluates to true.

Example: For the leaf definition

```
leaf foo {
  type empty;
}
```

a valid instance is

```
"foo": [null]
```

6.10. The "union" Type

A value of the "union" type is encoded as the value of any of the member types.

Unlike XML, JSON conveys part of the type information already in the encoding. When validating a value of the "union" type, this information MUST also be taken into account.

For example, consider the following YANG definition:

```
leaf bar {
  type union {
    type uint16;
    type string;
  }
}
```

In RESTCONF [I-D.ietf-netconf-restconf], it is fully acceptable to set the value of "bar" in the following way when using the "application/yang.data+xml" media type:

```
<bar>13.5</bar>
```

because the value may be interpreted as a string, i.e., the second member type of the union. When using the "application/yang.data+json" media type, however, this is an error:

```
"bar": 13.5
```

In this case, the JSON encoding indicates the value is supposed to be a number rather than a string.

6.11. The "instance-identifier" Type

An "instance-identifier" value is encoded as a string that is analogical to the lexical representation in XML encoding, see sec. 9.13.3 in [I-D.ietf-netmod-rfc6020bis]. However, the encoding of namespaces in instance-identifier values follows the rules stated in Section 4, namely:

- The namespace identifier is the module name where each data node is defined.

- The encoding of a node name with an explicit namespace is as shown in Figure 1.

- The leftmost (top-level) node name is always prefixed with the namespace identifier.

- Any subsequent node name has the namespace identifier if and only if its parent node has a different namespace. This also holds for node names appearing in predicates.

For example,

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

is a valid instance-identifer 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".

When translating an instance-identifier value from JSON to XML, the namespace identifier (YANG module name) in each component of the instance-identifier MUST be replaced by an XML namespace prefix that is associated with the namespace URI reference of the module in the scope of the element containing the instance-identifier value.

7. I-JSON Compliance

I-JSON [RFC7493] is a restricted profile of JSON that guarantees maximum interoperability for protocols that use JSON in their messages, no matter what JSON encoders/decoders are used in protocol implementations. The encoding defined in this document therefore observes the I-JSON requirements and recommendations as closely as possible.

In particular, the following properties are guaranteed:

- Character encoding is UTF-8.

- Member names within the same JSON object are always unique.

- The order of JSON object members is never relied upon.

- Numbers of any type supported by YANG can be exchanged reliably. See Section 6.1 for details.

This document deviates from I-JSON only in the encoding of values with the "binary" type. It uses the base64 encoding scheme (Section 6.6), whereas I-JSON recommends base64url instead. Theoretically, values of the "binary" type might appear in URI references, such as Request-URI in RESTCONF, although in practice the cases where it is really needed should be extremely rare.

8. Security Considerations

This document defines an alternative encoding for data modeled in the YANG data modeling language. As such, it doesn't contribute any new security issues beyond those discussed in sec. 16 of [I-D.ietf-netmod-rfc6020bis].

JSON processing is rather different from XML, and JSON parsers may thus suffer from other types of vulnerabilities than their XML counterparts. To minimize these new 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. Acknowledgments

The author wishes to thank Andy Bierman, Martin Bjorklund, Dean Bogdanovic, Balazs Lengyel, Juergen Schoenwaelder and Phil Shafer for their helpful comments and suggestions.

10. References

10.1. Normative References

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10.2. Informative References

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Appendix A. A Complete Example

The JSON document shown below represents the same data as the reply to the NETCONF <get> request appearing in Appendix D of [RFC7223]. The data model is a combination of two YANG modules: "ietf-interfaces" and "ex-vlan" (the latter is an example module from Appendix C of [RFC7223]). The "if-mib" feature defined in the "ietf-interfaces" module is considered to be active.

```
{
  "ietf-interfaces:interfaces": {
    "interface": [
      {
        "name": "eth0",
        "type": "iana-if-type:ethernetCsmacd",
        "enabled": false
      },
      {
        "name": "eth1",
        "type": "iana-if-type:ethernetCsmacd",
        "enabled": true,
        "ex-vlan:vlan-tagging": true
      },
      {
        "name": "eth1.10",
```

```
          "type": "iana-if-type:l2vlan",
          "enabled": true,
          "ex-vlan:base-interface": "eth1",
          "ex-vlan:vlan-id": 10
        },
        {
          "name": "lo1",
          "type": "iana-if-type:softwareLoopback",
          "enabled": true
        }
      ]
    },
    "ietf-interfaces:interfaces-state": {
      "interface": [
        {
          "name": "eth0",
          "type": "iana-if-type:ethernetCsmacd",
          "admin-status": "down",
          "oper-status": "down",
          "if-index": 2,
          "phys-address": "00:01:02:03:04:05",
          "statistics": {
            "discontinuity-time": "2013-04-01T03:00:00+00:00"
          }
        },
        {
          "name": "eth1",
          "type": "iana-if-type:ethernetCsmacd",
          "admin-status": "up",
          "oper-status": "up",
          "if-index": 7,
          "phys-address": "00:01:02:03:04:06",
          "higher-layer-if": [
            "eth1.10"
          ],
          "statistics": {
            "discontinuity-time": "2013-04-01T03:00:00+00:00"
          }
        },
        {
          "name": "eth1.10",
          "type": "iana-if-type:l2vlan",
          "admin-status": "up",
          "oper-status": "up",
          "if-index": 9,
          "lower-layer-if": [
            "eth1"
          ],
```

```
          "statistics": {
            "discontinuity-time": "2013-04-01T03:00:00+00:00"
          }
        },
        {
          "name": "eth2",
          "type": "iana-if-type:ethernetCsmacd",
          "admin-status": "down",
          "oper-status": "down",
          "if-index": 8,
          "phys-address": "00:01:02:03:04:07",
          "statistics": {
            "discontinuity-time": "2013-04-01T03:00:00+00:00"
          }
        },
        {
          "name": "lo1",
          "type": "iana-if-type:softwareLoopback",
          "admin-status": "up",
          "oper-status": "up",
          "if-index": 1,
          "statistics": {
            "discontinuity-time": "2013-04-01T03:00:00+00:00"
          }
        }
      ]
    }
  }
```

Appendix B. Change Log

RFC Editor: Remove this section upon publication as an RFC.

B.1. Changes Between Revisions -03 and -04

- I-D.ietf-netmod-rfc6020bis is used as a normative reference instead of RFC 6020.
- Removed noncharacters as an I-JSON issue because it doesn't exist in YANG 1.1.
- Section about anydata encoding was added.
- Require I-JSON for anyxml encoding.
- Use ABNF for defining qualified name.

B.2. Changes Between Revisions -02 and -03

- Namespace encoding is defined without using RFC 2119 keywords.
- Specification for anyxml nodes was extended and clarified.
- Text about ordering of list entries was corrected.

B.3. Changes Between Revisions -01 and -02

- Encoding of namespaces in instance-identifiers was changed.
- Text specifying the order of array elements in leaf-list and list instances was added.

B.4. Changes Between Revisions -00 and -01

- Metadata encoding was moved to a separate I-D, draft-lhotka-netmod-yang-metadata.
- JSON encoding is now defined directly rather than via XML-JSON mapping.
- The rules for namespace encoding has changed. This affect both node instance names and instance-identifiers.
- I-JSON-related changes. The most significant is the string encoding of 64-bit numbers.
- When validating union type, the partial type info present in JSON encoding is taken into account.
- Added section about I-JSON compliance.
- Updated the example in appendix.
- Wrote Security Considerations.
- Removed IANA Considerations as there are none.

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