Abstract

This specification defines media types for representing simple sensor measurements and device parameters in the Sensor Markup Language (SenML). Representations are defined in JavaScript Object Notation (JSON), Concise Binary Object Representation (CBOR), eXtensible Markup Language (XML), and Efficient XML Interchange (EXI), which share the common SenML data model. A simple sensor, such as a temperature sensor, could use this media type in protocols such as HTTP or CoAP to transport the measurements of the sensor or to be configured.

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1. Overview

Connecting sensors to the Internet is not new, and there have been many protocols designed to facilitate it. This specification defines new media types for carrying simple sensor information in a protocol such as HTTP or CoAP. This format was designed so that processors with very limited capabilities could easily encode a sensor measurement into the media type, while at the same time a server parsing the data could relatively efficiently collect a large number of sensor measurements. The markup language can be used for a variety of data flow models, most notably data feeds pushed from a sensor to a collector, and the web resource model where the sensor is requested as a resource representation (e.g., "GET /sensor/temperature").

There are many types of more complex measurements and measurements that this media type would not be suitable for. SenML strikes a balance between having some information about the sensor carried with the sensor data so that the data is self-describing but it also tries to make that a fairly minimal set of auxiliary information for efficiency reason. Other information about the sensor can be discovered by other methods such as using the CoRE Link Format [RFC6690].

SenML is defined by a data model for measurements and simple meta-data about measurements and devices. The data is structured as a single array that contains a series of SenML Records which can each contain attributes such as an unique identifier for the sensor, the time the measurement was made, the unit the measurement is in, and the current value of the sensor. Serializations for this data model are defined for JSON [RFC7159], CBOR [RFC7049], XML, and Efficient XML Interchange (EXI) [W3C.REC-exi-20110310].

For example, the following shows a measurement from a temperature gauge encoded in the JSON syntax.

```
[{ "n": "urn:dev:ow:10e2073a01080063", "v":23.1, "u":"Cel" }]
```

In the example above, the array has a single SenML Record with a measurement for a sensor named "urn:dev:ow:10e2073a01080063" with a current value of 23.1 degrees Celsius.
2. Requirements and Design Goals

The design goal is to be able to send simple sensor measurements in small packets on mesh networks from large numbers of constrained devices. Keeping the total size of payload under 80 bytes makes this easy to use on a wireless mesh network. It is always difficult to define what small code is, but there is a desire to be able to implement this in roughly 1 KB of flash on a 8 bit microprocessor. Experience with Google power meter and large scale deployments has indicated that the solution needs to support allowing multiple measurements to be batched into a single HTTP or CoAP request. This "batch" upload capability allows the server side to efficiently support a large number of devices. It also conveniently supports batch transfers from proxies and storage devices, even in situations where the sensor itself sends just a single data item at a time. The multiple measurements could be from multiple related sensors or from the same sensor but at different times.

The basic design is an array with a series of measurements. The following example shows two measurements made at different times. The value of a measurement is in the "v" tag, the time of a measurement is in the "t" tag, the "n" tag has a unique sensor name, and the unit of the measurement is carried in the "u" tag.

```javascript
[ { "n": "urn:dev:ow:10e2073a01080063", "t": 1276020076, "v":23.5, "u":"Cel" },
  { "n": "urn:dev:ow:10e2073a01080063", "t": 1276020091, "v":23.6, "u":"Cel" }
]
```

To keep the messages small, it does not make sense to repeat the "n" tag in each SenML Record so there is a concept of a Base Name which is simply a string that is prepended to the Name field of all elements in that record and any records that follow it. So a more compact form of the example above is the following.

```javascript
[ { "bn": "urn:dev:ow:10e2073a01080063", "t": 1276020076, "v":23.5, "u":"Cel" },
  { "t": 1276020091, "v":23.6, "u":"Cel" }
]
```

In the above example the Base Name is in the "bn" tag and the "n" tags in each Record are the empty string so they are omitted.

Some devices have accurate time while others do not so SenML supports absolute and relative times. Time is represented in floating point
as seconds and values greater than zero represent an absolute time
relative to the Unix epoch while values of 0 or less represent a
relative time in the past from the current time. A simple sensor
with no absolute wall clock time might take a measurement every
second and batch up 60 of them then send it to a server. It would
include the relative time the measurement was made to the time the
batch was send in the SenML Pack. The server might have accurate NTP
time and use the time it received the data, and the relative offset,
to replace the times in the SenML with absolute times before saving
the SenML Pack in a document database.

3. Terminology

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
[RFC2119].

This document also uses the following terms:

SenML Record: One measurement or configuration instance in time
presented using the SenML data model.

SenML Pack: One or more SenML Records in an array structure.

4. SenML Structure and Semantics

Each SenML Pack carries a single array that represents a set of
measurements and/or parameters. This array contains a series of
SenML Records with several attributes described below. There are two
kind of attributes: base and regular. The base attributes can only
be included in the first SenML Record and they apply to the entries
in all Records. All base attributes are optional. Regular
attributes can be included in any SenML Record and apply only to that
Record.

4.1. Base attributes

Base Name: This is a string that is prepended to the names found in
the entries.

Base Time: A base time that is added to the time found in an entry.

Base Unit: A base unit that is assumed for all entries, unless
otherwise indicated. If a record does not contain a Unit value,
then the Base Unit is used. Otherwise the value found in the Unit
(if any) is used.
Base Value: A base value is added to the value found in an entry, similar to Base Time.

Version: Version number of media type format. This attribute is an optional positive integer and defaults to 5 if not present. [RFC Editor: change the default value to 10 when this specification is published as an RFC and remove this note]

4.2. Regular attributes

Name: Name of the sensor or parameter. When appended to the Base Name attribute, this must result in a globally unique identifier for the resource. The name is optional, if the Base Name is present. If the name is missing, Base Name must uniquely identify the resource. This can be used to represent a large array of measurements from the same sensor without having to repeat its identifier on every measurement.

Unit: Units for a measurement value. Optional. If the Record has no Unit, the Base Unit is used as the Unit. Having no Unit and no Base Unit is allowed.

Value: Value of the entry. Optional if a Sum value is present, otherwise required. Values are represented using three basic data types, Floating point numbers ("v" field for "Value"), Booleans ("vb" for "Boolean Value"), Strings ("vs" for "String Value") and Binary Data ("vd" for "Data Value") . Exactly one of these four fields MUST appear unless there is Sum field in which case it is allowed to have no Value field or to have "v" field.

Sum: Integrated sum of the values over time. Optional. This attribute is in the units specified in the Unit value multiplied by seconds.

Time: Time when value was recorded. Optional.

Update Time: An optional time in seconds that represents the maximum time before this sensor will provide an updated reading for a measurement. This can be used to detect the failure of sensors or communications path from the sensor.

4.3. Considerations

The SenML format can be extended with further custom attributes. Both new base and regular attributes are allowed. See Section 11.2 for details. Implementations MUST ignore attributes they don’t recognize.
Systems reading one of the objects MUST check for the Version attribute. If this value is a version number larger than the version which the system understands, the system SHOULD NOT use this object. This allows the version number to indicate that the object contains mandatory to understand attributes. New version numbers can only be defined in an RFC that updates this specification or its successors.

The Name value is concatenated to the Base Name value to get the name of the sensor. The resulting name needs to uniquely identify and differentiate the sensor from all others. If the object is a representation resulting from the request of a URI [RFC3986], then in the absence of the Base Name attribute, this URI is used as the default value of Base Name. Thus in this case the Name field needs to be unique for that URI, for example an index or subresource name of sensors handled by the URI.

Alternatively, for objects not related to a URI, a unique name is required. In any case, it is RECOMMENDED that the full names are represented as URIs or URNs [RFC2141]. One way to create a unique name is to include some bit string that has guaranteed uniqueness (such as a 1-wire address) that is assigned to the device. Some of the examples in this draft use the device URN type as specified in [I-D.arkko-core-dev-urn]. UUIDs [RFC4122] are another way to generate a unique name. Note that long-term stable unique identifiers are problematic for privacy reasons [RFC7721] and should be used with care or avoided.

The resulting concatenated name MUST consist only of characters out of the set "A" to "Z", "a" to "z", "0" to "9", ":", ".", or "_" and it MUST start with a character out of the set "A" to "Z", "a" to "z", or "0" to "9". This restricted character set was chosen so that these names can be directly used as in other types of URI including segments of an HTTP path with no special encoding and can be directly used in many databases and analytic systems. [RFC5952] contains advice on encoding an IPv6 address in a name.

If either the Base Time or Time value is missing, the missing attribute is considered to have a value of zero. The Base Time and Time values are added together to get the time of measurement. A time of zero indicates that the sensor does not know the absolute time and the measurement was made roughly "now". A negative value is used to indicate seconds in the past from roughly "now". A positive value is used to indicate the number of seconds, excluding leap seconds, since the start of the year 1970 in UTC.

Representing the statistical characteristics of measurements, such as accuracy, can be very complex. Future specification may add new
attributes to provide better information about the statistical properties of the measurement.

A SenML object is referred to as "expanded" if it does not contain any base values and has no relative times.

4.4. Associating Meta-data

SenML is designed to carry the minimum dynamic information about measurements, and for efficiency reasons does not carry significant static meta-data about the device, object or sensors. Instead, it is assumed that this meta-data is carried out of band. For web resources using SenML Packs, this meta-data can be made available using the CoRE Link Format [RFC6690]. The most obvious use of this link format is to describe that a resource is available in a SenML format in the first place. The relevant media type indicator is included in the Content-Type (ct=) attribute.

5. JSON Representation (application/senml+json)

The SenML labels (JSON object member names) shown in Table 1 are used in JSON SenML Record attributes.

<table>
<thead>
<tr>
<th>Name</th>
<th>label</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Name</td>
<td>bn</td>
<td>String</td>
</tr>
<tr>
<td>Base Time</td>
<td>bt</td>
<td>Number</td>
</tr>
<tr>
<td>Base Unit</td>
<td>bu</td>
<td>String</td>
</tr>
<tr>
<td>Base Value</td>
<td>bv</td>
<td>Number</td>
</tr>
<tr>
<td>Version</td>
<td>bver</td>
<td>Number</td>
</tr>
<tr>
<td>Name</td>
<td>n</td>
<td>String</td>
</tr>
<tr>
<td>Unit</td>
<td>u</td>
<td>String</td>
</tr>
<tr>
<td>Value</td>
<td>v</td>
<td>Number</td>
</tr>
<tr>
<td>String Value</td>
<td>vs</td>
<td>String</td>
</tr>
<tr>
<td>Boolean Value</td>
<td>vb</td>
<td>Boolean</td>
</tr>
<tr>
<td>Data Value</td>
<td>vd</td>
<td>String</td>
</tr>
<tr>
<td>Value Sum</td>
<td>s</td>
<td>Number</td>
</tr>
<tr>
<td>Time</td>
<td>t</td>
<td>Number</td>
</tr>
<tr>
<td>Update Time</td>
<td>ut</td>
<td>Number</td>
</tr>
</tbody>
</table>

Table 1: JSON SenML Labels

The root content consists of an array with one JSON object for each SenML Record. All the fields in the above table MAY occur in the records with the type specified in the table.
Only the UTF-8 form of JSON is allowed. Characters in the String Value are encoded using the escape sequences defined in [RFC7159]. Characters in the Data Value are base64 encoded with URL safe alphabet as defined in Section 5 of [RFC4648].

Systems receiving measurements MUST be able to process the range of floating point numbers that are representable as an IEEE double-precision floating-point numbers [IEEE.754.1985]. The number of significant digits in any measurement is not relevant, so a reading of 1.1 has exactly the same semantic meaning as 1.10. If the value has an exponent, the "e" MUST be in lower case. The mantissa SHOULD be less than 19 characters long and the exponent SHOULD be less than 5 characters long. This allows time values to have better than micro second precision over the next 100 years.

5.1. Examples

TODO - Add example with string, data, boolean, and base value

5.1.1. Single Datapoint

The following shows a temperature reading taken approximately "now" by a 1-wire sensor device that was assigned the unique 1-wire address of 10e2073a01080063:

```json
[ { "n": "urn:dev:ow:10e2073a01080063", "v":23.1, "u":"Cel" }]
```

5.1.2. Multiple Datapoints

The following example shows voltage and current now, i.e., at an unspecified time.

```json
[ { "bn": "urn:dev:ow:10e2073a01080063",
  "n": "voltage", "t": 0, "u": "V", "v": 120.1 },
 { "n": "current", "t": 0, "u": "A", "v": 1.2 } ]
```

The next example is similar to the above one, but shows current at Tue Jun 8 18:01:16.001 UTC 2010 and at each second for the previous 5 seconds.
Note that in some usage scenarios of SenML the implementations MAY store or transmit SenML in a stream-like fashion, where data is collected over time and continuously added to the object. This mode of operation is optional, but systems or protocols using SenML in this fashion MUST specify that they are doing this. SenML defines a separate media type to indicate Sensor Streaming Markup Language (SensML) for this usage (see Section 11.3.1). In this situation the SensML stream can be sent and received in a partial fashion, i.e., a measurement entry can be read as soon as the SenML Record is received and not have to wait for the full SensML Stream to be complete.

For instance, the following stream of measurements may be sent via a long lived HTTP POST from the producer of a SensML to the consumer of that, and each measurement object may be reported at the time it was measured:

```json
[ {
    "bn": "urn:dev:ow:10e2073a01080063",
    "bt": 1320067464,
    "bu": "%RH",
    "v": 21.2, "t": 0 },
    { "v": 21.3, "t": 10 },
    { "v": 21.4, "t": 20 },
    { "v": 21.5, "t": 30 },
    { "v": 21.5, "t": 40 },
    { "v": 21.5, "t": 50 },
    { "v": 21.5, "t": 60 },
    { "v": 21.6, "t": 70 },
    { "v": 21.7, "t": 80 },
    { "v": 21.5, "t": 90 },
    ...
]```
5.1.3. Multiple Measurements

The following example shows humidity measurements from a mobile device with a 1-wire address 10e2073a01080063, starting at Mon Oct 31 13:24:24 UTC 2011. The device also provides position data, which is provided in the same measurement or parameter array as separate entries. Note time is used to for correlating data that belongs together, e.g., a measurement and a parameter associated with it. Finally, the device also reports extra data about its battery status at a separate time.

```json
[{
"bn": "urn:dev:ow:10e2073a01080063",
"bt": 1320067464,
"bu": "%RH",
"v": 20.0, "t": 0 },
{ "v": 24.30621, "u": "lon", "t": 0 },
{ "v": 60.07965, "u": "lat", "t": 0 },
{ "v": 20.3, "t": 60 },
{ "v": 24.30622, "u": "lon", "t": 60 },
{ "v": 60.07965, "u": "lat", "t": 60 },
{ "v": 20.7, "t": 120 },
{ "v": 24.30623, "u": "lon", "t": 120 },
{ "v": 60.07966, "u": "lat", "t": 120 },
{ "v": 98.0, "u": "%EL", "t": 150 },
{ "v": 21.2, "t": 180 },
{ "v": 24.30628, "u": "lon", "t": 180 },
{ "v": 60.07967, "u": "lat", "t": 180 }
]
```

The size of this example represented in various forms, as well as that form compressed with gzip is given in the following table.

<table>
<thead>
<tr>
<th>Encoding</th>
<th>Size</th>
<th>Compressed Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSON</td>
<td>573</td>
<td>206</td>
</tr>
<tr>
<td>XML</td>
<td>649</td>
<td>235</td>
</tr>
<tr>
<td>CBOR</td>
<td>254</td>
<td>196</td>
</tr>
<tr>
<td>EXI</td>
<td>173</td>
<td>196</td>
</tr>
</tbody>
</table>

Table 2: Size Comparisons

Note the EXI sizes are not using the schema guidance so the EXI representation could be a bit smaller.
5.1.4. Collection of Resources

The following example shows how to query one device that can provide multiple measurements. The example assumes that a client has fetched information from a device at 2001:db8::2 by performing a GET operation on http://[2001:db8::2] at Mon Oct 31 16:27:09 UTC 2011, and has gotten two separate values as a result, a temperature and humidity measurement.

```
[["bn": "http://[2001:db8::2]/", "bt": 1320078429, "bver": 5, "n": "temperature", "v": 27.2, "u": "Cel" ],
{ "n": "humidity", "v": 80, "u": "%RH" }
```

6. CBOR Representation (application/senml+cbor)

The CBOR [RFC7049] representation is equivalent to the JSON representation, with the following changes:

- For compactness, the CBOR representation uses integers for the map keys defined in Table 3. This table is conclusive, i.e., there is no intention to define any additional integer map keys; any extensions will use string map keys.

- For JSON Numbers, the CBOR representation can use integers, floating point numbers, or decimal fractions (CBOR Tag 4); the common limitations of JSON implementations are not relevant for these. For the version number, however, only an unsigned integer is allowed.
The following example shows a dump of the CBOR example for the same sensor measurement as in Section 5.1.2.

![CBOR Example]

<table>
<thead>
<tr>
<th>Name</th>
<th>JSON label</th>
<th>CBOR label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>bver</td>
<td>-1</td>
</tr>
<tr>
<td>Base Name</td>
<td>bn</td>
<td>-2</td>
</tr>
<tr>
<td>Base Time</td>
<td>bt</td>
<td>-3</td>
</tr>
<tr>
<td>Base Units</td>
<td>bu</td>
<td>-4</td>
</tr>
<tr>
<td>Base Value</td>
<td>bv</td>
<td>-5</td>
</tr>
<tr>
<td>Name</td>
<td>n</td>
<td>0</td>
</tr>
<tr>
<td>Units</td>
<td>u</td>
<td>1</td>
</tr>
<tr>
<td>Value</td>
<td>v</td>
<td>2</td>
</tr>
<tr>
<td>String Value</td>
<td>vs</td>
<td>3</td>
</tr>
<tr>
<td>Boolean Value</td>
<td>vb</td>
<td>4</td>
</tr>
<tr>
<td>Value Sum</td>
<td>s</td>
<td>5</td>
</tr>
<tr>
<td>Time</td>
<td>t</td>
<td>6</td>
</tr>
<tr>
<td>Update Time</td>
<td>ut</td>
<td>7</td>
</tr>
<tr>
<td>Data Value</td>
<td>vd</td>
<td>8</td>
</tr>
</tbody>
</table>

### Table 3: CBOR representation: integers for map keys

7. XML Representation (application/senml+xml)

A SenML Pack or Stream can also be represented in XML format as defined in this section. The following example shows an XML example for the same sensor measurement as in Section 5.1.2.
The SenML Stream is represented as a sensml tag that contains a series of senml tags for each SenML Record. The SenML Fields are represented as XML attributes. The following table shows the mapping of the SenML labels to the attribute names and types used in the XML senml tags.

+---------------+------+---------+
|          Name | XML  | Type    |
|---------------+------+---------|
|     Base Name | bn   | string  |
|     Base Time | bt   | double  |
|     Base Unit | bu   | string  |
|     Base Value| bv   | double  |
|  Base Version | bver | int     |
|            Name | n    | string  |
|            Unit | u    | string  |
|            Value | v    | double  |
|  String Value | vs   | string  |
|   Data Value  | vd   | string  |
|  Boolean Value| vb   | boolean |
|     Value Sum | s    | double  |
|          Time | t    | double  |
|   Update Time | ut   | double  |

Table 4: XML SenML Labels

The RelaxNG schema for the XML is:
default namespace = "urn:ietf:params:xml:ns:senml"
namespace rng = "http://relaxng.org/ns/structure/1.0"

senml = element senml {
    attribute bn { xsd:string }?,
    attribute bt { xsd:double }?,
    attribute bv { xsd:double }?,
    attribute bu { xsd:string }?,
    attribute bver { xsd:int }?,
    attribute n { xsd:string }?,
    attribute s { xsd:double }?,
    attribute t { xsd:double }?,
    attribute u { xsd:string }?,
    attribute ut { xsd:double }?,
    attribute v { xsd:double }?,
    attribute vb { xsd:boolean }?,
    attribute vs { xsd:string }?,
    attribute vd { xsd:string }?
}
sensml =
    element sensml {
        senml+
    }

start = sensml

8. EXI Representation (application/senml-exi)

For efficient transmission of SenML over e.g. a constrained network, Efficient XML Interchange (EXI) can be used. This encodes the XML Schema structure of SenML into binary tags and values rather than ASCII text. An EXI representation of SenML SHOULD be made using the strict schema-mode of EXI. This mode however does not allow tag extensions to the schema, and therefore any extensions will be lost in the encoding. For uses where extensions need to be preserved in EXI, the non-strict schema mode of EXI MAY be used.

The EXI header option MUST be included. An EXI schemaID options MUST be set to the value of "a" indicating the scheme provided in this specification. Future revisions to the schema can change this schemaID to allow for backwards compatibility. When the data will be transported over CoAP or HTTP, an EXI Cookie SHOULD NOT be used as it simply makes things larger and is redundant to information provided in the Content-Type header.
TODO - examples probably have the wrong setting for the schemaID

The following is the XSD Schema to be used for strict schema guided EXI processing. It is generated from the RelaxNG.

```xml
<?xml version="1.0" encoding="utf-8"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  elementFormDefault="qualified"
  targetNamespace="urn:ietf:params:xml:ns:senml"
  xmlns:ns1="urn:ietf:params:xml:ns:senml">
  <xs:element name="senml">
    <xs:complexType>
      <xs:attribute name="bn" type="xs:string" />  
      <xs:attribute name="bt" type="xs:double" />  
      <xs:attribute name="bv" type="xs:double" />  
      <xs:attribute name="bu" type="xs:string" />  
      <xs:attribute name="bver" type="xs:int" />   
      <xs:attribute name="n" type="xs:string" />   
      <xs:attribute name="s" type="xs:double" />   
      <xs:attribute name="t" type="xs:double" />   
      <xs:attribute name="u" type="xs:string" />   
      <xs:attribute name="ut" type="xs:double" />  
      <xs:attribute name="v" type="xs:double" />   
      <xs:attribute name="vb" type="xs:boolean" /> 
      <xs:attribute name="vs" type="xs:string" />  
      <xs:attribute name="vd" type="xs:string" />  
    </xs:complexType>
  </xs:element>
  <xs:element name="sensml">
    <xs:complexType>
      <xs:sequence>
        <xs:element maxOccurs="unbounded" ref="ns1:senml"/>
      </xs:sequence>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

The following shows a hexdump of the EXI produced from encoding the following XML example. Note this example is the same information as the first example in Section 5.1.2 in JSON format.

```
<sensml xmlns="urn:ietf:params:xml:ns:senml">
  <senml bn="urn:dev:ow:10e2073a01080063" n="voltage" u="V" v="120.1"></senml>
  <senml n="current" u="A" v="1.2"></senml>
</sensml>
```

Which compresses with EXI to the following displayed in hexdump:
The above example used the bit packed form of EXI but it is also possible to use a byte packed form of EXI which can make it easier for a simple sensor to produce valid EXI without really implementing EXI. Consider the example of a temperature sensor that produces a value in tenths of degrees Celsius over a range of 0.0 to 55.0. It would produce an XML SenML file such as:

```xml
<sensml xmlns="urn:ietf:params:xml:ns:senml">
  <senml n="urn:dev:ow:10e2073a01080063" u="Cel" v="23.1"></senml>
</sensml>
```

The compressed form, using the byte alignment option of EXI, for the above XML is the following:

```
0000 a0 00 48 81 ee 6c ad cd ad 85 cc ec ad c5 cf 0e ..H..l............
0010 6c 80 01 06 1d 75 72 6e 3a 64 65 76 3a 6f 77 3a urn:dev:ow:|
0020 31 30 65 32 30 37 33 61 30 31 30 38 30 30 36 33 10e2073a01080063|
0030 02 05 43 65 6c 01 00 e7 01 01 00 03 01 ..Cel............
003d
```

A small temperature sensor device that only generates this one EXI file does not really need an full EXI implementation. It can simply hard code the output replacing the 1-wire device ID starting at byte 0x20 and going to byte 0x2F with it's device ID, and replacing the value "0xe7 0x01" at location 0x37 and 0x38 with the current temperature. The EXI Specification [W3C.REC-exi-20110310] contains the full information on how floating point numbers are represented, but for the purpose of this sensor, the temperature can be converted to an integer in tenths of degrees (231 in this example). EXI stores 7 bits of the integer in each byte with the top bit set to one if there are further bytes. So the first bytes at is set to low 7 bits of the integer temperature in tenths of degrees plus 0x80. In this example 231 & 0x7F + 0x80 = 0xE7. The second byte is set to the integer temperature in tenths of degrees right shifted 7 bits. In this example 231 >> 7 = 0x01.

9. Usage Considerations

The measurements support sending both the current value of a sensor as well as the an integrated sum. For many types of measurements, the sum is more useful than the current value. For example, an
An electrical meter that measures the energy a given computer uses will typically want to measure the cumulative amount of energy used. This is less prone to error than reporting the power each second and trying to have something on the server side sum together all the power measurements. If the network between the sensor and the meter goes down over some period of time, when it comes back up, the cumulative sum helps reflect what happened while the network was down. A meter like this would typically report a measurement with the units set to watts, but it would put the sum of energy used in the "s" attribute of the measurement. It might optionally include the current power in the "v" attribute.

While the benefit of using the integrated sum is fairly clear for measurements like power and energy, it is less obvious for something like temperature. Reporting the sum of the temperature makes it easy to compute averages even when the individual temperature values are not reported frequently enough to compute accurate averages. Implementors are encouraged to report the cumulative sum as well as the raw value of a given sensor.

Applications that use the cumulative sum values need to understand they are very loosely defined by this specification, and depending on the particular sensor implementation may behave in unexpected ways. Applications should be able to deal with the following issues:

1. Many sensors will allow the cumulative sums to "wrap" back to zero after the value gets sufficiently large.
2. Some sensors will reset the cumulative sum back to zero when the device is reset, loses power, or is replaced with a different sensor.
3. Applications cannot make assumptions about when the device started accumulating values into the sum.

Typically applications can make some assumptions about specific sensors that will allow them to deal with these problems. A common assumption is that for sensors whose measurement values are always positive, the sum should never get smaller; so if the sum does get smaller, the application will know that one of the situations listed above has happened.

10. CDDL

For reference, the JSON and CBOR representations can be described with the common CDDL [I-D.greevenbosch-appsawg-cbor-cddl] specification in Figure 1.
SenML-Pack = [initial-record, * follow-on-record]

initial-record = initial-defined .and initial-generic
follow-on-record = follow-on-defined .and follow-on-generic

; first do a specification of the labels as defined:

initial-defined = {
    ? bn => tstr, ; Base Name
    ? bt => numeric, ; Base Time
    ? bu => tstr, ; Base Units
    ? bv => numeric, ; Base value
    ? bver => uint, ; Base Version
    follow-on-defined-group,
    + base-key-value-pair
}

follow-on-defined-group = {
    ? n => tstr, ; Name
    ? u => tstr, ; Units
    ? s => numeric, ; Value Sum
    ? t => numeric, ; Time
    ? ut => numeric, ; Update Time
    * key-value-pair,
    ? ( v => numeric // ; Numeric Value
        vs => tstr // ; String Value
        vb => bool // ; Boolean Value
        vd => binary-value ) ; Data Value
}

follow-on-defined = { follow-on-defined-group }

; now define the generic versions

initial-generic = {
    follow-on-generic-group,
    * base-key-value-pair,
}

follow-on-generic-group = {
    + key-value-pair,
}

follow-on-generic = { follow-on-generic-group }

key-value-pair = { non-b-label => value }

base-key-value-pair = { b-label => value }

non-b-label = tstr .regexp "^[A-Za-z0-9][_-A-Za-z0-9]*" / uint
b-label = tstr .regexp "b[-_:A-Za-z0-9]+" / nint

value = tstr / binary-value / numeric / bool
numeric = number / decfrac

Figure 1: Common CDDL specification for CBOR and JSON SenML

For JSON, we use text labels and base64url-encoded binary data (Figure 2).

bver = "bver" n = "n" s = "s"
bn = "bn" u = "u" t = "t"
bv = "bv" vb = "vb"

binary-value = tstr ; base64url encoded

Figure 2: JSON-specific CDDL specification for SenML

For CBOR, we use integer labels and native binary data (Figure 3).

bver = -1 n = 0 s = 5
bn = -2 u = 1 t = 6
bv = -5 vb = 4

binary-value = bstr

Figure 3: CBOR-specific CDDL specification for SenML

11. IANA Considerations

Note to RFC Editor: Please replace all occurrences of "RFC-AAAA" with the RFC number of this specification.

11.1. Units Registry

IANA will create a registry of SenML unit symbols. The primary purpose of this registry is to make sure that symbols uniquely map to give type of measurement. Definitions for many of these units can be found in location such as [NIST811] and [BIPM]. Units marked with an asterisk are NOT RECOMMENDED to be produced by new implementations, but are in active use and SHOULD be implemented by consumers that can use the related base units.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>Type</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>m</td>
<td>meter</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>kg</td>
<td>kilogram</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>g</td>
<td>gram*</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>s</td>
<td>second</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>A</td>
<td>ampere</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>K</td>
<td>kelvin</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>cd</td>
<td>candela</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>mol</td>
<td>mole</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Hz</td>
<td>hertz</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>rad</td>
<td>radian</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>sr</td>
<td>steradian</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>N</td>
<td>newton</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Pa</td>
<td>pascal</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>J</td>
<td>joule</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>W</td>
<td>watt</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>C</td>
<td>coulomb</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>V</td>
<td>volt</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>F</td>
<td>farad</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Ohm</td>
<td>ohm</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>S</td>
<td>siemens</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Wb</td>
<td>weber</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>T</td>
<td>tesla</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>H</td>
<td>henry</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Cel</td>
<td>degrees Celsius</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>lm</td>
<td>lumen</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>lx</td>
<td>lux</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Bq</td>
<td>becquerel</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Gy</td>
<td>gray</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>Sv</td>
<td>sievert</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>kat</td>
<td>katal</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>m2</td>
<td>square meter (area)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>m3</td>
<td>cubic meter (volume)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>l</td>
<td>liter (volume)*</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>m/s</td>
<td>meter per second (velocity)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>m/s2</td>
<td>meter per second per square second</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>m3/s</td>
<td>cubic meter per second (flow rate)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>1/s</td>
<td>liter per second (flow rate)*</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>W/m2</td>
<td>watt per square meter (irradiance)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>cd/m2</td>
<td>candela per square meter</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>bit</td>
<td>bit (information content)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>bit/s</td>
<td>bit per second (data rate)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>lat</td>
<td>degrees latitude (note 2)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>lon</td>
<td>degrees longitude (note 2)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>pH</td>
<td>pH value (acidity; logarithmic)</td>
<td>float</td>
<td>RFC-AAAA</td>
</tr>
<tr>
<td>quantity)</td>
<td>dB</td>
<td>decibel (logarithmic quantity)</td>
<td>float</td>
</tr>
<tr>
<td>-----------</td>
<td>----</td>
<td>-------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td>Bspl</td>
<td>bel (sound pressure level); logarithmic quantity)*</td>
<td>float</td>
</tr>
<tr>
<td>count</td>
<td>/</td>
<td>1 (Ratio e.g., value of a switch, note 1)</td>
<td>float</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>1 (Ratio e.g., value of a switch, note 1)*</td>
<td>float</td>
</tr>
<tr>
<td>%RH</td>
<td>%</td>
<td>Percentage (Relative Humidity)</td>
<td>float</td>
</tr>
<tr>
<td>%EL</td>
<td>EL</td>
<td>Percentage (remaining battery energy level)</td>
<td>float</td>
</tr>
<tr>
<td></td>
<td>1/s</td>
<td>1 per second (event rate)</td>
<td>float</td>
</tr>
<tr>
<td></td>
<td>1/min</td>
<td>1 per minute (event rate, &quot;rpm&quot;)*</td>
<td>float</td>
</tr>
<tr>
<td></td>
<td>beat/min</td>
<td>1 per minute (Heart rate in beats per minute)*</td>
<td>float</td>
</tr>
<tr>
<td></td>
<td>beats</td>
<td>1 (Cumulative number of heart beats)*</td>
<td>float</td>
</tr>
</tbody>
</table>

Table 5

- Note 1: A value of 0.0 indicates the switch is off while 1.0 indicates on and 0.5 would be half on. The preferred name of this unit is "/". For historical reasons, the name "/" is also provided for the same unit - but note that while that name strongly suggests a percentage (0..100) -- it is however NOT a percentage, but the absolute ratio!

- Note 2: Assumed to be in WGS84 unless another reference frame is known for the sensor.

New entries can be added to the registration by either Expert Review or IESG Approval as defined in [RFC5226]. Experts should exercise their own good judgment but need to consider the following guidelines:

1. There needs to be a real and compelling use for any new unit to be added.

2. Units should define the semantic information and be chosen carefully. Implementors need to remember that the same word may be used in different real-life contexts. For example, degrees when measuring latitude have no semantic relation to degrees when measuring temperature; thus two different units are needed.
3. These measurements are produced by computers for consumption by computers. The principle is that conversion has to be easily be done when both reading and writing the media type. The value of a single canonical representation outweighs the convenience of easy human representations or loss of precision in a conversion.

4. Use of SI prefixes such as "k" before the unit is not recommended. Instead one can represent the value using scientific notation such as 1.2e3. The "kg" unit is exception to this rule since it is an SI base unit; the "g" unit is provided for legacy compatibility.

5. For a given type of measurement, there will only be one unit type defined. So for length, meters are defined and other lengths such as mile, foot, light year are not allowed. For most cases, the SI unit is preferred.

6. Symbol names that could be easily confused with existing common units or units combined with prefixes should be avoided. For example, selecting a unit name of "mph" to indicate something that had nothing to do with velocity would be a bad choice, as "mph" is commonly used to mean miles per hour.

7. The following should not be used because the are common SI prefixes: Y, Z, E, P, T, G, M, k, h, da, d, c, n, u, p, f, a, z, y, Ki, Mi, Gi, Ti, Pi, Ei, Zi, Yi.

8. The following units should not be used as they are commonly used to represent other measurements Ky, Gal, dyn, etg, P, St, Mx, G, Oe, Gb, sb, Lmb, mph, Ci, R, RAD, REM, gal, bbl, qt, degF, Cal, BTU, HP, pH, B/s, psi, Torr, atm, at, bar, kWh.

9. The unit names are case sensitive and the correct case needs to be used, but symbols that differ only in case should not be allocated.

10. A number after a unit typically indicates the previous unit raised to that power, and the / indicates that the units that follow are the reciprocal. A unit should have only one / in the name.

11. A good list of common units can be found in the Unified Code for Units of Measure [UCUM].
11.2. SenML label registry

IANA will create a new registry for SenML labels. The initial content of the registry are shown in Table 1 and Table 4.

New entries can be added to the registration by either Expert Review or IESG Approval as defined in [RFC5226]. Experts should exercise their own good judgment but need to consider that shorter labels should have more strict review.

All new SenML labels that have "base" semantics (see Section 4.1) must start with character ’b’. Regular labels must not start with that character.

All new entries must define the Label Name, Label, JSON Type, and XML Type.

11.3. Media Type Registration

The following registrations are done following the procedure specified in [RFC6838] and [RFC7303].

11.3.1. senml+json Media Type Registration

Type name: application

Subtype name: senml+json and sensml+json

Required parameters: none

Optional parameters: none

Encoding considerations: Must be encoded as using a subset of the encoding allowed in [RFC7159]. See RFC-AAAA for details. This simplifies implementation of very simple system and does not impose any significant limitations as all this data is meant for machine to machine communications and is not meant to be human readable.

Security considerations: Sensor data can contain a wide range of information ranging from information that is very public, such the outside temperature in a given city, to very private information that requires integrity and confidentiality protection, such as patient health information. This format does not provide any security and instead relies on the transport protocol that carries it to provide security. Given applications need to look at the overall context of how this media type will be used to decide if the security is adequate.
Interoperability considerations: Applications should ignore any JSON key value pairs that they do not understand. This allows backwards compatibility extensions to this specification. The "bver" field can be used to ensure the receiver supports a minimal level of functionality needed by the creator of the JSON object.

Published specification: RFC-AAAA

Applications that use this media type: The type is used by systems that report e.g., electrical power usage and environmental information such as temperature and humidity. It can be used for a wide range of sensor reporting systems.

Additional information:

Magic number(s): none

File extension(s): senml and sensml

Macintosh file type code(s): none

Person & email address to contact for further information: Cullen Jennings <fluffy@iii.ca>

Intended usage: COMMON

Restrictions on usage: None

Author: Cullen Jennings <fluffy@iii.ca>

Change controller: IESG

11.3.2. senml+cbor Media Type Registration

Type name: application

Subtype name: senml+cbor and sensml+cbor

Required parameters: none

Optional parameters: none

Encoding considerations: TBD

Security considerations: See Section 11.3.1

Interoperability considerations: TBD
Published specification: RFC-AAAA

Applications that use this media type: See Section 11.3.1

Additional information:

Magic number(s): none

File extension(s): senmlc and sensmlc

Macintosh file type code(s): none

Person & email address to contact for further information: Cullen Jennings <fluffy@iii.ca>

Intended usage: COMMON

Restrictions on usage: None

Author: Cullen Jennings <fluffy@iii.ca>

Change controller: IESG

11.3.3.  senml+xml Media Type Registration

Type name: application

Subtype name: senml+xml and sensml+xml

Required parameters: none

Optional parameters: none

Encoding considerations: TBD

Security considerations: See Section 11.3.1

Interoperability considerations: TBD

Published specification: RFC-AAAA

Applications that use this media type: See Section 11.3.1

Additional information:

Magic number(s): none

File extension(s): senmlx and sensmlx
11.3.4.  senml-exi Media Type Registration

Type name: application
Subtype name: senml-exi and sensml-exi
Required parameters: none
Optional parameters: none
Encoding considerations: TBD
Security considerations: TBD
Interoperability considerations: TBD
Published specification: RFC-AAAA
Applications that use this media type: See Section 11.3.1
Additional information:
Magic number(s): none
File extension(s): senmle and sensmle
Macintosh file type code(s): none
Person & email address to contact for further information: Cullen Jennings <fluffy@iii.ca>

Intended usage: COMMON
Restrictions on usage: None
11.4. XML Namespace Registration

This document registers the following XML namespaces in the IETF XML registry defined in [RFC3688].

URI: urn:ietf:params:xml:ns:senml

Registrant Contact: The IESG.

XML: N/A, the requested URIs are XML namespaces

11.5. CoAP Content-Format Registration

IANA is requested to assign CoAP Content-Format IDs for the SenML media types in the "CoAP Content-Formats" sub-registry, within the "CoRE Parameters" registry [RFC7252]. All IDs are assigned from the "Expert Review" (0-255) range. The assigned IDs are show in Table 6.

<table>
<thead>
<tr>
<th>Media type</th>
<th>ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>application/senml+json</td>
<td>TBD</td>
</tr>
<tr>
<td>application/sensml+json</td>
<td>TBD</td>
</tr>
<tr>
<td>application/senml+cbor</td>
<td>TBD</td>
</tr>
<tr>
<td>application/senml+xml</td>
<td>TBD</td>
</tr>
<tr>
<td>application/sensml+xml</td>
<td>TBD</td>
</tr>
<tr>
<td>application/senml-exi</td>
<td>TBD</td>
</tr>
</tbody>
</table>

Table 6: CoAP Content-Format IDs

12. Security Considerations

See Section 13. Further discussion of security properties can be found in Section 11.3.

13. Privacy Considerations

Sensor data can range from information with almost no security considerations, such as the current temperature in a given city, to highly sensitive medical or location data. This specification provides no security protection for the data but is meant to be used inside another container or transport protocol such as S/MIME or HTTP.
with TLS that can provide integrity, confidentiality, and authentication information about the source of the data.

14. Acknowledgement

We would like to thank Lisa Dusseault, Joe Hildebrand, Lyndsay Campbell, Martin Thomson, John Klensin, Bjoern Hoehrmann, and Christian Amsuess for their review comments.

15. References

15.1. Normative References


15.2. Informative References


Appendix A. Links extension

An extension to SenML to support links is expected to be registered and defined by [I-D.ietf-core-links-json].

The link extension can be an array of objects that can be used for additional information. Each object in the Link array is constrained to being a map of strings to strings with unique keys.

The following shows an example of the links extension.

```
[ { "bn": "urn:dev:ow:10e2073a01080063/",
  "bt": 1320078429,
  "l": [ { "href": "humidity","foo": "bar1"},
         { "n": "temperature", "v": 27.2, "u": "Cel" },
         { "n": "humidity", "v": 80, "u": "%RH" } ]
}
```

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