**Problem**

There is currently no standard way to represent BACnet content in Semantic Web applications. ANNEX Y and ANNEX Z that define XML and JSON document formats for exchanging BACnet content are not suitable for the Resource Description Framework (RDF) used by the Semantic Web.

**Background**

The Semantic Interoperability Working Group (SI-WG) is developing an RDF data model that can be used to build a graph of building equipment with interconnected components. This graph is similar to a schematic view presented to a technician to show relationships between building automation components and with interactive applications to show near real-time values of Key Performance Indicators (KPI) such as temperatures, pressures, and flows. While these schematic views are created with iconography for human interpretation, they are not necessarily machine interpretable.

One part of these building models is the association of a KPI with a measurement location within the graph and a reference for getting the value of the KPI. For example, the “discharge air temperature” of a specific fan could be measured by a sensor at the outlet of the fan, and where the value of this KPI is available as a BACnet object, the “property” of the air is given a BACnetDeviceObjectProperty reference.

For constructing an SI-WG model of a facility it is convenient to have all of the BACnet devices, objects, properties and values available in a graph. When combined with asset descriptions, alarm history, and maintenance data this is often called an Enterprise Knowledge Graph (EKG). One application of an SI-WG model is to create a “digital twin” of a facility for the purpose of Fault Detection and Diagnostics (FDD) and analytics which require the proper alignment of KPIs with the algorithm inputs. While object names and descriptions are not standardized in format, they typically follow local naming conventions so it is possible to see what KPIs are available as near-real-time data and by using pattern matching infer point classification (colloquially known as “tagging”), which then drive what kinds of FDD algorithms are appropriate for a system.

BACnet devices, objects, and properties naturally fit in directed acyclic graph as a hierarchy when serialized as a CSML document and similar rules for serialization of the abstract data model described in ANNEX Y can be used for RDF.

There are certain aspects of RDF that simplify the serialization process:

* RDF use IRI references which by their nature contain namespaces removing the necessity for embedding the vendor identifier prefix into metadata names as a substitute for XML Namespaces like   
  “0-BACnetDeviceObjectReference” and can simply be specified with the IRI bacnet:DeviceObjectReference.
* RDF supports multilingual values removing the necessity for ‘$$locale’ encoding
* RDF literal values include the datatype removing the necessity for ‘$base’ and wrapping values in extra object structures

The rest of this document describes the serialization of primitive data elements and constructed data of “classic” BACnet as described in Clause 12 and ASN.1 in Clause 20.

**YY RDF DATA FORMAT (NORMATIVE)**

(This annex is part of this standard and is required for its use.)

This annex defines the structuring of BACnet content as Resource Description Framework (RDF) data for exchange with Semantic Web applications. The encoding examples in this annex use the Terse RDF Triple Language (Turtle). Other serialization formats such as RDF/XML, N-Triples, JSON-LD are syntactically different but convey identical content.

The Turtle serialization format specifies that IRIs may be written as relative or absolute IRIs or prefixed names. The prefix label is defined by using the "@prefix" directive followed by a colon followed by a partial IRI. The encoding

examples used in this document assume the following prefix statement:

@prefix bacnet: <https://data.ashrae.org/bacnet/> .

A prefixed name is turned into an IRI by concatenating the IRI associated with the prefix and the local part. The '@prefix' directive associates a prefix label with an IRI. Subsequent '@prefix' directives may re-map the same prefix

label.

**YY.1 Encoding Primitive Data**

Primitive data is encoded as specific IRIs or RDF literals.

**YY.1.1 Encoding of a Null Value**

The NULL value is encoded as the IRI bacnet:Null.

**YY.1.2 Encoding of a Boolean Value**

Boolean values are encoded using the xsd:boolean datatype, for example "true"^^xsd:boolean or "false"^^xsd:boolean. See XSD Clause 3.3.2.

**YY.1.3 Encoding of an Unsigned Integer Value**

Unsigned integer values are encoded using the xsd:unsignedInt datatype, for example "12"^^xsd:unsignedInt. See XSD Clause 3.4.22.

**YY.1.4 Encoding of a Signed Integer Value**

Signed integer values are encoded using the xsd:int datatype, for example "-12"^^xsd:int. See XSD Clause 3.4.17.

**YY.1.5 Encoding of a Real Number Value**

Real number values are encoded using the xsd:float datatype, for example "75.3"^^xsd:float. See XSD Clause 3.2.4.

**YY.1.6 Encoding of a Double Precision Real Value**

Double precision number values are encoded using the xsd:double datatype, for example "478.08"^^xsd:double. See XSD Clause 3.2.5.

**YY.1.7 Encoding of an Octet String Value**

Octet string values are encoded using the xsd:hexBinary datatype, for example "DEADBEEF"^^xsd:hexBinary. See XSD Clause 3.3.15.

**YY.1.8 Encoding of a Character String Value**

Character strings are encoded as quoted literals optionally followed by a language tag, for example "Fan Speed" is a plain literal and "vitesse du ventilateur"@fn is French. Lauguage tags are defined by [RFC-3066] and are always in lowercase. See RDF Clause 3.3.

**YY.1.9 Encoding of a Bit String Value**

Bit strings are encoded as an rdf:Seq container with members encoded as named bits. Standard bit names are IRIs constructed as the bit string name followed by a period followed by the bit name as provided in the ASN.1, for example bacnet:LogStatus.buffer-purged. Vendors may follow other conventions for named bits.

**YY.1.10 Encoding of an Enumerated Value**

Enumerated values are IRIs. Standard enumeration value names are constructed using the enumeration name followed by a period followed by the enumeration name as described in the ASN.1, for example, bacnet:EventState.high-limit. Vendors may follow other conventions for enumerations.

**YY.1.11 Encoding of a Date Value**

Date values are encoded using the xsd:date type, for example "2022-11-03"^^xsd:date. See XSD Clause 3.3.9.

**YY.1.12 Encoding of a Date Pattern Value**

Date data that contains one or more “unspecified” fields is encoded as a bacnet:date type, for example "2022-11-\* 1"^^bacnet:datePattern. See Clause Y.12.14.

**YY.1.12 Encoding of a Time Value**

Time values with a zero hundredths value are encoded using the xsd:time type, for example "15:30:05"^^xsd:time. See XSD Clause 3.3.8.

**YY.1.12 Encoding of a Time Pattern Value**

Time data that contains one or more “unspecified” fields or with a non-zero hundredths value is encoded as a bacnet:time type, for example "15:30:\*.\*"^^bacnet:timePattern. See Clause Y.12.18.

**YY.1.13 Encoding of a DateTime Value**

DateTime values are encoded using the xsd:dateTime type, for example "2022-11-03T13:45:00.0"^^xsd:dateTime. See XSD Clause X.X.X.

**YY.1.14 Encoding of a DateTime Pattern Value**

Date data that contains one or more “unspecified” fields is encoded as a bacnet:dateTimePattern type, for example "2022-11-\* 1 13:45:00"^^bacnet:datePattern. See Clause Y.X.X.

**YY.1.15 Encoding of an Object Identifier Value**

Object identifiers are encoded as a plain literal strings of the form “T,N” where T represents the type and N represents the object instance number. The object type formatted as a decimal number with no leading zeroes, or a standard type name exactly equal to the names specified in the definition for BACnetObjectTypes in Clause 21. See Y.20.1.

**YY.2 Encoding Constructed Data**

RDF encodings of the ASN.1 productions in Clause 21 follow the “name-centric” approach to mapping SEQUENCE and CHOICE structured types outlined in Clause Z.1.1 which describes JSON encoding. The context specific tags in the ASN.1 notation are not used in the RDF encoding.

**YY.2.1 Encoding of a Sequence Value**

An instance of a SEQUENCE is a set of RDF statements with a common subject resource identifier, each sequence element is a bacnet: prefixed predicate and the object is a literal encoded per YY.1 or another RDF node. Sequences may be explicitly typed by the sequence name replacing the BACnet prefix with the bacnet: namespace prefix.

For example, a BACnetDeviceObjectReference is a sequence with an optional device-identifier element and a required object-identifier element. This is an example of an explicitly-typed RDF blank node with just the object-identifier:

[] a bacnet:DeviceObjectReference ;

bacnet:object-identifier "analog-value,1" .

This is a similar example with an implicit node type and both device and object identifiers are provided:

[] bacnet:device-identifier "device,123" ;

bacnet:object-identifier "analog-value,1" .

**YY.2.2 Encoding of a Sequence-Of Value**

Encoding a SEQUENCE OF type is an rdf:Seq where each element is the same type.

For example, the Structured View Object Type (see Clause 12.29) contains a Subordinate\_Tags property which is an array BACnetNameValueCollection, which in turn contains a members element which is a SEQUENCE OF BACnetNameValue items:

<ex:svo-1> bacnet:object-type bacnet:ObjectType.structured-view ;

bacnet:object-identifier "structured-view,1" ;

bacnet:subordinate-tags (

[ bacnet:members (

[ bacnet:name "temp" ]

[ bacnet:name "room" ; bacnet:value "B03" ]

)

]

) .

**YY.2.3 Encoding of a Choice Value**

An instance of a CHOICE is an RDF statement where the chosen sequence element is a bacnet: prefixed predicate and the object is a literal encoded per YY.1 or another RDF node. Choices may be explicitly-typed by the choice name replacing the BACnet prefix with the bacnet: namespace prefix. See Clause YY.5.

For example, a BACnetHostAddress is a choice of none, an IP address, or an Internet host name. This is an example of an explicitly-typed RDF blank node with the “none” choice:

[] a bacnet:HostAddress ;

bacnet:none bacnet:Null .

This is a similar example where the node type is implicit and an IPv4 address is provided:

[] bacnet:ip-address "C0A8010A"^^xsd:hexBinary .

**YY.2.4 Encoding of a Value of the ANY Type**

The value of an ANY type is typically a primitive data element encoded as an RDF literal according to Clause YY.1. Other data structures are encoded as nodes with primitive data elements (like a SEQUENCE) or lists of nodes composed of primitive data elements (like a SEQUENCE OF) according to Clause YY.2.

**YY.2.5 Encoding of an Array and List Value**

Array and List values are encoded as an rdf:Seq of values.

**YY.3 Encoding Objects**

Objects are encoded as a set of RDF statements with a common subject resource identifier, a predicate IRI with the bacnet: namespace prefix and property identifier as specified in the BACnetPropertyIdentifier ASN.1 production in Clause 21, and primitive property value encoded according to Clause YY.1 or constructed value according to Clause YY.2. See ZZ.1 for an example of an encoded object.

**YY.4 Encoding Devices**

Devices are encoded as an RDF node with the relation bacnet:contains referencing each of the objects in the device. See YY.3 for object encoding.

**YY.5 BACnet RDFS Schema References**

RDF Schema (RDFS) provides a data modeling vocabulary for RDF data. This vocabulary provides a “class” concept and predicates to explicitly specify that an RDF resource is an instance of the set of members of the class and rules for the relationships between the sets members of classes.

The BACnet RDFS Schema provides a collection of class names that correspond to the constructed type names in Clause 21 in addition to object type names in Clause 12. These class names can be used to provide explicit type information when the type cannot be implicitly determined.

RDF statements use the rdf:type predicate to associate a resource identifier to a BACnet RDFS Schema class.

**YY.5.1 ASN.1 Constructed Type Names**

Clause 21.6 defines constructed types that all use the “BACnet” name prefix which follow the ASN.1 naming conventions, for example an access rule of an Access Rights Object is called “BACnetAccessRule”. For each constructed type there is a corresponding IRI reference of an RDF Schema Class using the bacnet: prefix, for example:

bacnet:AccessRule rdf:type rdfs:Class .

This class IRI can be used to explicitly state that a specific resource is a member of the class extension of the class. This is an example of a partially specified access rule, not all of the required elements are provided:

<ex:ar-1> rdf:type bacnet:AccessRule ;

bacnet:enable true .

**YY.5.2 ASN.1 Constructed Anonymous Type Names**

In some cases the ASN.1 definition of a constructed type includes anonymous elements that are defined inline with the element. For example, the BACnetAccessRule defines the “time-range-specifier” element to be an instance of an anonymous enumerated type. For these elements the BACnet RDFS Schema has a class name that is the ASN.1 sequence name followed by a period followed by the element name translated to title-case:

bacnet:AccessRule.TimeRangeSpecifier rdfs:subClassOf bacnet:EnumerationKind .

Following the naming convention for enumerated values in Clause YY.1.10, the IRI for the “always” enumeration value is the rdfs:Class name followed by a period followed by the enumeration name:

<ex:ar-1> rdf:type bacnet:AccessRule ;

bacnet:time-range-specifier

bacnet:AccessRule.TimeRangeSpecifier.always ;

bacnet:enable true .

**YY.5.2 Object Type Names**

The BACnet RDFS Schema specifies RDFS class names that correspond to the object type name in title-case with the embedded hypen removed in the case of multi-state objects. For example, Clause 12.1.4 defines an Analog Value Object Type and the corresponding class name is

bacnet:AnalogValueObject rdfs:subClassOf bacnet:Object .

**YY.5.3 BACnet RDFS Schema Classes**

BACnet/RDF provides a set of classes that are common concepts in the standard defined in Clause 3.2 and elsewhere but not formally labeled.

**YY.5.3.1 bacnet:Device Class**

This is the class of all devices, physical or virtual, that supports digital communication using the BACnet protocol.

**YY.5.3.2 bacnet:Object Class**

This is the abstract superclass of all BACnet object classes. Each member of this class must also be a member of one and only one of its subclasses.

**YY.5.3.3 bacnet:EnumerationKind Class**

This is the abstract superclass of all BACnet enumeration kinds.

**YY.5.3.4 bacnet:EnumerationValue Class**

This is the abstract superclass of all BACnet enumeration values.

**YY.5.4 BACnet RDFS Schema Predicates**

BACnet/RDF provides predicates that are common relationships in the standard defined in Clause 3.2 and elsewhere but not formally labeled.

**YY.5.4.1 bacnet:contains Predicate**

This predicate relates a bacnet:Device object to an object within the device. For example, this specifies that ex:dev-23 is a bacnet:Device instance that has a bacnet:AnalogValueObject instance with an instance number 45:

<ex:dev-23> bacnet:contains [

bacnet:object-identifier "analog-value,45" ;

] .

The same content with explicit type information:

<ex:dev-23> rdf:type bacnet:Device ;

bacnet:contains [

rdf:type bacnet:Object, bacnet:AnalogValueObject ;

bacnet:object-identifier "analog-value,45" ;

] .

More formally defined using RDFS:

bacnet:contains rdf:type rdf:Property ;

rdfs:domain bacnet:Device ;

rdfs:range bacnet:Object .

**YY.5.4.2 bacnet:device-instance Predicate**

This predicate relates a bacnet:Device object to its device instance number. For example, this specifies that ex:dev-23 is a bacnet:Device instance that has a bacnet:device-instance instance with an instance number 23:

<ex:dev-23> bacnet:device-instance 23 .

**YY.5.4.3 bacnet:device-address Predicate**

This predicate relates a bacnet:Device object to its BACnet address. For example, this specifies that ex:dev-23 is a bacnet:Device instance that has an IPv4 address 192.168.1.10, port 47808 on BACnet/IPv4 network 5:

<ex:dev-23> bacnet:device-address [

bacnet:network-number 5 ;

bacnet:mac-address "C0A8010ABAC0"^^xsd:hexBinary ;

] .

The bacnet:network-number and bacnet:mac-address have the same meaning and encoding as a bacnet:Address instance, with the additional restriction that the bacnet:mac-address cannot be a string of length zero which would indicate a broadcast address.

**YY.5.4.4 bacnet:name Predicate**

This predicate relates a bacnet:PropertyIdentifierEnumerationValue object to its ASN.1 identifier. See Clause YY.5.4.6.

**YY.5.4.5 bacnet:predicate Predicate**

This predicate relates a bacnet:PropertyIdentifierEnumerationValue object to the predicate used to relate a bacnet:Object to the property value. See Clause YY.5.4.6.

More formally defined using RDFS:

bacnet:predicate rdf:type rdf:Property ;

rdfs:domain bacnet:PropertyIdentifierEnumerationValue ;

rdfs:range rdf:Property .

**YY.5.4.6 bacnet:value Predicate**

This predicate relates a bacnet:PropertyIdentifierEnumerationValue object to the enumeration value. For example, this specifies that the Present Value property has the ASN.1 name present-value, uses the IRI bacnet:present-value to relate an object to a value, and has the encoded value 77:

bacnet:PropertyIdentifier.object-name a

bacnet:PropertyIdentifierEnumerationValue ;

bacnet:name "object-name" ;

bacnet:predicate bacnet:object-name ;

bacnet:value "77"^^xsd:nonNegativeInteger .

.

**ZZ – EXAMPLES OF RDF ENCODING (INFORMATIVE)**

(This annex is not part of this standard but is included for informative purposes only.)

This annex provides examples of RDF encoding of objects and properties in ANNEX YY. These examples are provided in the Terse RDF Triple Language (Turtle) and assume the following common prefix declarations:

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .

@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .

@prefix bacnet: <http://data.ashrae.org/bacnet/2020#> .

For the purpose of providing named IRI nodes, the examples assume the following prefix declaration:

@prefix ex: <http://example.org/ex> .

**ZZ.1 Example Object**

The following example illustrates an Analog Input Object using the bacnet:object-type property to reference the ObjectType enumeration.

<ex:aio-1> bacnet:object-type bacnet:ObjectType.analog-input ;

bacnet:object-identifier "analog-input,1" ;

bacnet:object-name "OAT" ;

bacnet:description "Outside air temperature" .

**ZZ.2 Example Binary Value Object**

The following example illustrates a Binary Value Object using rdf:type to describe the type of RDF node. The bacnet:object-type property value can be inferred.

<ex:bv-2> rdf:type bacnet:BinaryValueObject ;

bacnet:object-identifier "binary-value,2" ;

bacnet:object-name "OCCENAB" ;

bacnet:description "Occupancy control enabled" ;

bacnet:present-value bacnet:BinaryPV.active ;

bacnet:out-of-service false ;

bacnet:event-state bacnet:EventState.normal .

In this case the example provides “telemetry data” such as the present value in addition to “configuration data.” What kinds of data must be provided to satisfy the requirements of a particular application is a local matter.

**ZZ.3 Example Device Object**

The following example illustrates a Device Object with a device-address-binding list containing a reference to another device.

<ex:dev-15> rdf:type bacnet:DeviceObject ;

bacnet:object-identifier "device,15" ;

bacnet:vendor-identifier 555 ;

bacnet:device-address-binding (

[ bacnet:device-identifier "device,16" ;

bacnet:device-address [

bacnet:network-number 6 ;

bacnet:mac-address "4A"^^xsd:hexBinary

]

]

) .

**ZZ.4 Example Choice**

The following example illustrates a reference to an ASN.1 Choice, the Client\_COV\_Increment property of a Trend Log Object, see Clause 12.25.11.

<ex:log-75> bacnet:client-cov-increment [

bacnet:real-increment "0.05"^^xsd:float ;

] .

The alternative choice would be to specify the default increment.

<ex:log-76> bacnet:client-cov-increment [

bacnet:default-increment bacnet:Null ;

] .

**ZZ.5 Example with anonymous type**

Some ASN.1 productions include nested sequences or choices. For example, the BACnetLandingCallStatus sequence contains a “command” element which is an unnamed choice of a “direction” or a “destination”. The following example illustrates an instance with the “direction” choice.

[] bacnet:floor-number 4 ;

bacnet:command [

bacnet:direction bacnet:LiftCarDirection.stopped

] ;

bacnet:floor-text "Tenant Offices" .

This same instance may provide explicit rdf:type statements referencing the BACnet Schema (See Clause YY.5):

[] rdf:type bacnet:LandingCallStatus ;

bacnet:floor-number 4 ;

bacnet:command [

rdf:type bacnet:LandingCallStatus.Command ;

bacnet:direction bacnet:LiftCarDirection.stopped

] ;

bacnet:floor-text "Tenant Offices" .