OPC Unified Architecture

Specification

Part 3: Address Space Model

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UNIFIED ARCHITECTURE –

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Revision 1.03 Highlights

The following table includes the Mantis issues resolved with this revision.

Mantis ID	Summary	Resolution
2247	Figure 27 uses wrong name for EventType.	Changed figure to use the correct name.
2374	Invalid use of complex data type.	The specification was using the wrong terminology in some places. This has been fixed always using the right terminology.
2451	Missing information in example.	In 6.4.4.5.3 the example had an incomplete sentence and a missing possible combination (A14) that was added.
2514	Need for alternative notation for type definition shortcut.	Added an alternative notation to D.2.3.
2427	Use Enumerations for Flags	OptionSet DataType added in 8.41 supporting bitmasks for enumerations and Property OptionSetValues to DataType NodeClass in 5.8.3.
2600	How to detect that status and timestamp is writeable	Added status bits to AccessLevel and UserAccessLevel in Table 8.
2601	Clarification on how to define MaxArrayLength for array of bytes	Added clarification that in that case not ByteString but array of Bytes shall be used in Table 8.
2727	Add support for Union DataType	Added abstract DataType Union in 8.42.
2834	Improve description of EnumValueType	Improved the description in 8.40.
2842	Clarification on case sensitivity of BrowseNames	Added clarification in 5.2.4.
2215 2075 2065 2064 2063	Add data types NormalizedString, DecimalString, DurrationString, TimeString and DateString	Added sections 8.43, 8.44, 8.45, 8.46, and 8.47
3016	Clarification on DataTypeDictionaries	Removed misleading example in 5.8.4
3015	Make inverse relationship from DataTypeDictionary to DataTypeEncoding mandatory.	Changed 5.8.4 and made inverse relationship mandatory in order to simplify data type handling for clients.
2998	Clarifiaction on Structure DataType	Removed sentence in 8.33 as more concrete sentence about inheritance is already in 5.8.2

OPC Unified Architecture Specification

Part 3: Address Space Model

1 Scope

This specification describes the OPC Unified Architecture (OPC UA) *AddressSpace* and its *Objects*. This Part is the OPC UA meta model on which OPC UA information models are based.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application.

Part 1: OPC UA Specification: Part 1 – Overview and Concepts

http://www.opcfoundation.org/UA/Part1/

Part 2: OPC UA Specification: Part 2 – Security Model

http://www.opcfoundation.org/UA/Part2/

Part 4: OPC UA Specification: Part 4 – Services

http://www.opcfoundation.org/UA/Part4/

Part 5: OPC UA Specification: Part 5 – Information Model

http://www.opcfoundation.org/UA/Part5/

Part 6: OPC UA Specification: Part 6 – Mappings

http://www.opcfoundation.org/UA/Part6/

Part 8: OPC UA Specification: Part 8 – Data Access

http://www.opcfoundation.org/UA/Part8/

Part 9: OPC UA Specification: Part 9 – Alarms and conditions

http://www.opcfoundation.org/UA/Part9/

Part 11: OPC UA Specification: Part 11 – Historical Access

http://www.opcfoundation.org/UA/Part11/

ISO/IEC 10918-1, *Information technology – Digital compression and coding of continuous-tone still images: Requirements and guidelines*

ISO/IEC 15948, *Information technology – Computer graphics and image processing – Portable Network Graphics (PNG): Functional specification*

ISO 639 (all parts), *Codes for the representation of names of languages*

ISO 3166 (all parts), *Codes for the representation of names of countries and their subdivisions*

IEEE 754-1985, *IEEE Standard for Binary Floating-Point Arithmetic*,http://ieeexplore.ieee.org/servlet/opac?punumber=2355

IETF RFC 3066, *Tags for the Identification of Languages*, http://tools.ietf.org/html/rfc3066

XML Schema Part 1: http://www.w3.org/TR/xmlschema-1/

XML Schema Part 2: http://www.w3.org/TR/xmlschema-2/

XPATH: http://www.w3.org/TR/xpath/

ISO 8601-2000: Data elements and interchange formats

Unicode: Annex15: Unicode Standard Annex #15: Unicode Normalization Forms http://www.unicode.org/reports/tr15/.

W3C XML Schema Definition Language (XSD)

3 Terms, definitions, abbreviations and conventions

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in Part 1 as well as the following apply.

3.1.1
DataType
instance of a *DataType Node* that is used together with the *ValueRank Attribute* to define the data type of a *Variable*

3.1.2
DataTypeId
NodeId of a *DataType Node*

3.1.3
DataVariable
Variables that represent *values* of *Objects*, either directly or indirectly for complex *Variables*, where the *Variables* are always the *TargetNode* of a *HasComponent Reference*

3.1.4
EventType
ObjectType Node that represents the type definition of an *Event*

3.1.5
hierarchical Reference
Reference that is used to construct hierarchies in the *AddressSpace*

Note 1 to entry: All hierarchical ReferenceTypes are derived from HierarchicalReferences.

3.1.6
InstanceDeclaration
Node that is used by a complex *TypeDefinitionNode* to expose its complex structure

Note 1 to entry: It is an instance used by a type definition.

3.1.7
ModellingRule
metadata of an *InstanceDeclaration* that defines how the *InstanceDeclaration* will be used for instantiation and also defines subtyping rules for an *InstanceDeclaration*

3.1.8
Property
Variables that are the *TargetNode* for a *HasProperty Reference*

Note 1 to entry: *Properties* describe the characteristics of a *Node.*

3.1.9
SourceNode
Node having a *Reference* to another *Node*

EXAMPLE: In the *Reference* “A contains B”, “A” is the *SourceNode.*

3.1.10
TargetNode
Node that is referenced by another *Node*

EXAMPLE: In the *Reference* “A Contains B”, “B” is the *TargetNode.*

3.1.11
TypeDefinitionNode
Node that is used to define the type of another *Node*

Note 1 to entry: *ObjectType* and *VariableType Nodes* are *TypeDefinitionNodes*.

3.1.12
VariableType
Node that represents the type definition for a *Variable*

3.2 Abbreviations

UA Unified Architecture

UML Unified Modeling Language

URI Uniform Resource Identifier

W3C World Wide Web Consortium

XML Extensible Markup Language

3.3 Conventions

3.3.1 Conventions for AddressSpace figures

Nodes and their *References* to each other are illustrated using figures. Figure 1 illustrates the conventions used in these figures.

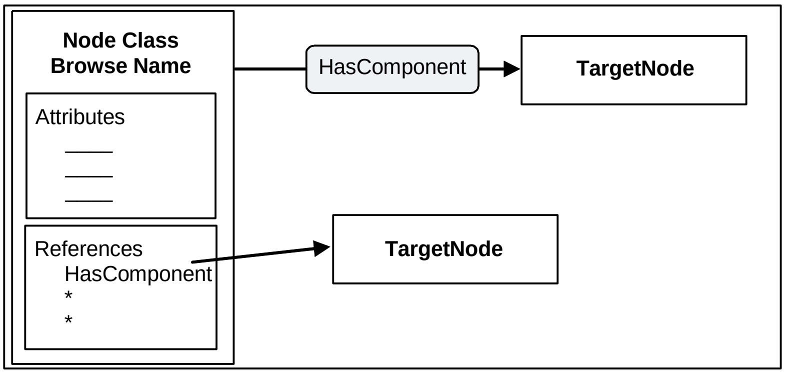


Figure 1 – AddressSpace Node diagrams

In these figures, rectangles represent *Nodes*. *Node* rectangles may be titled with one or two lines of text. When two lines are used, the first text line in the rectangle identifies the *NodeClass* and the second line contains the *BrowseName*. When one line is used, it contains the *BrowseName*.

Node rectangles may contain boxes used to define their *Attributes* and *References*. Specific names in these boxes identify specific *Attributes* and *References*.

Shaded rectangles with rounded corners and with arrows passing through them represent *References*. The arrow that passes through them begins at the *SourceNode* and points to the *TargetNode*. *References* may also be shown by drawing an arrow that starts at the *Reference* name in the “References” box and ends at the *TargetNode*.

3.3.2 Conventions for defining NodeClasses

Clause 5 defines *AddressSpace NodeClasses*. Table 1 describes the format of the tables used to define *NodeClasses*.

Table 1 – NodeClass Table Conventions

Name	Use	Data Type	Description
Attributes			
“Attribute name”	“M” or “O”	Data type of the *Attribute*	Defines the *Attribute*
References			
“Reference name”	“1”, “0..1” or “0..*”	Not used	Describes the use of the *Reference* by the *NodeClass*
Standard Properties			
“Property name”	“M” or “O”	Data type of the *Property*	Defines the *Property*

The Name column contains the name of the *Attribute*, the name of the *ReferenceType* used to create a *Reference* or the name of a *Property* referenced using the *HasProperty Reference*.

The Use column defines whether the *Attribute* or *Property* is mandatory (M) or optional (O). When mandatory the *Attribute* or *Property* shall exist for every *Node* of the *NodeClass*. For *References* it specifies the cardinality. The following values may apply:

- “0..*” identifies that there are no restrictions, that is, the *Reference* does not have to be provided but there is no limitation how often it can be provided;
- “0..1” identifies that the *Reference* is provided at most once;
- “1” identifies that the *Reference* shall be provided exactly once.

The Data Type column contains the name of the *DataType* of the *Attribute* or *Property*. It is not used for *References*.

The Description column contains the description of the *Attribute*, the *Reference* or the *Property*.

Only this standard may define *Attributes*. Thus, all *Attributes* of the *NodeClass* are specified in the table and can only be extended by other parts of this series of standards.

This standard also defines *ReferenceTypes*, but *ReferenceTypes* can also be specified by a *Server* or by a client using the *NodeManagement Services* specified in Part 4. Thus, the *NodeClass* tables contained in this standard can contain the base *ReferenceType* called *References* identifying that any *ReferenceType* may be used for the *NodeClass,* including system specific *ReferenceTypes*. The *NodeClass* tables only specify how the *NodeClasses* can be used as *SourceNodes* of *References*, not as *TargetNodes*. If a *NodeClass* table allows a *ReferenceType* for its *NodeClass* to be used as *SourceNode*, this is also true for subtypes of the *ReferenceType*. However, subtypes of the *ReferenceType* may restrict its *SourceNodes*.

This standard defines *Properties*, but *Properties* can be defined by other standard organizations or vendors and *Nodes* can have *Properties* that are not standardised. *Properties* defined in this standard are defined by their name, which is mapped to the *BrowseName* having the *NamespaceIndex* 0, which represents the *Namespace* for OPC UA.

The Use column (optional or mandatory) does not imply a specific *ModellingRule* for *Properties*. Different *Server* implementations will choose to use *ModellingRules* appropriate for them.

4 AddressSpace concepts

4.1 Overview

The remainder of 4 defines the concepts of the *AddressSpace*. Clause 5 defines the *NodeClasses* of the *AddressSpace* representing the *AddressSpace* concepts. Clause 6 defines details on the type model for *ObjectTypes* and *VariableTypes*. Standard *ReferenceTypes*, *DataTypes* and *EventTypes* are defined in Clauses 7 to 9.

The informative Annex A describes general considerations on how to use the Address Space Model and the informative Annex B provides a UML Model of the Address Space Model. The normative Annex C defines the OPC Binary Types Description System as a format to specify data type structures and the normative Annex D defines a graphical notation for OPC UA data.

4.2 Object Model

The primary objective of the OPC UA *AddressSpace* is to provide a standard way for *Servers* to represent *Objects* to *Clients*. The OPC UA Object Model has been designed to meet this objective. It defines *Objects* in terms of *Variables* and *Methods*. It also allows relationships to other *Objects* to be expressed. Figure 2 illustrates the model.

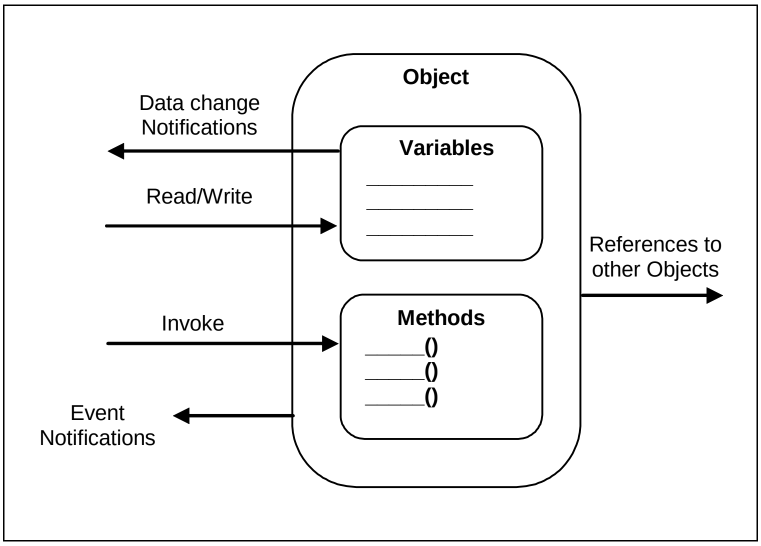


Figure 2 – OPC UA Object Model

The elements of this model are represented in the *AddressSpace* as *Nodes*. Each *Node* is assigned to a *NodeClass* and each *NodeClass* represents a different element of the Object Model. Clause 5 defines the *NodeClasses* used to represent this model.

4.3 Node Model

4.3.1 General

The set of *Objects* and related information that the OPC UA *Server* makes available to *Clients* is referred to as its *AddressSpace*. The model for *Objects* is defined by the OPC UA Object Model (see 4.2).

Objects and their components are represented in the *AddressSpace* as a set of *Nodes* described by *Attributes* and interconnected by *References*. Figure 3 illustrates the model of a *Node* and the remainder of 4.3 discusses the details of the Node Model.

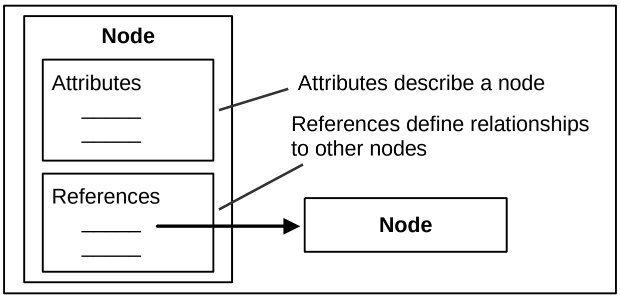


Figure 3 – AddressSpace Node Model

4.3.2 NodeClasses

NodeClasses are defined in terms of the *Attributes* and *References* that shall be instantiated (given values) when a *Node* is defined in the *AddressSpace*. *Attributes* are discussed in 4.3.3 and *References* in 4.3.4.

Clause 5 defines the *NodeClasses* for the OPC UA *AddressSpace*. These *NodeClasses* are referred to collectively as the metadata for the *AddressSpace*. Each *Node* in the *AddressSpace* is an instance of one of these *NodeClasses*. No other *NodeClasses* shall be used to define *Nodes*, and as a result, *Clients* and *Servers* are not allowed to define *NodeClasses* or extend the definitions of these *NodeClasses*.

4.3.3 Attributes

Attributes are data elements that describe *Nodes*. *Clients* can access *Attribute* values using Read, Write, Query, and Subscription/MonitoredItem *Services*. These *Services* are defined in Part 4.

Attributes are elementary components of *NodeClasses*. *Attribute* definitions are included as part of the *NodeClass* definitions in Clause 5 and, therefore, are not included in the *AddressSpace*.

Each *Attribute* definition consists of an attribute id (for attribute ids of *Attributes*, see Part 6), a name, a description, a data type and a mandatory/optional indicator. The set of *Attributes* defined for each *NodeClass* shall not be extended by *Clients* or *Servers*.

When a *Node* is instantiated in the *AddressSpace*, the values of the *NodeClass Attributes* are provided. The mandatory/optional indicator for the *Attribute* indicates whether the *Attribute* has to be instantiated.

4.3.4 References

References are used to relate *Nodes* to each other. They can be accessed using the browsing and querying *Services* defined in Part 4.

Like *Attributes*, they are defined as fundamental components of *Nodes*. Unlike *Attributes*, *References* are defined as instances of *ReferenceType Nodes*. *ReferenceType Nodes* are visible in the *AddressSpace* and are defined using the *ReferenceType NodeClass* (see 5.3).

The *Node* that contains the *Reference* is referred to as the *SourceNode* and the *Node* that is referenced is referred to as the *TargetNode*. The combination of the *SourceNode*, the *ReferenceType* and the *TargetNode* are used in OPC UA *Services* to uniquely identify *References*. Thus, each *Node* can reference another *Node* with the same *ReferenceType* only once. Any subtypes of concrete *ReferenceTypes* are considered to be equal to the base concrete *ReferenceTypes* when identifying *References* (see 5.3 for subtypes of *ReferenceTypes*). Figure 4 illustrates this model of a *Reference*.

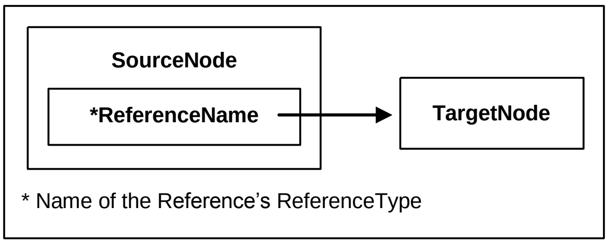


Figure 4 – Reference Model

The *TargetNode* of a *Reference* may be in the same *AddressSpace* or in the *AddressSpace* of another OPC UA *Server*. *TargetNodes* located in other *Servers* are identified in OPC UA *Services* using a combination of the remote *Server* name and the identifier assigned to the *Node* by the remote *Server*.

OPC UA does not require that *the TargetNode* exists, thus *References* may point to a *Node* that does not exist.

4.4 Variables

4.4.1 General

Variables are used to represent *values*. Two types of *Variables* are defined, *Properties* and *DataVariables*. They differ in the kind of data that they represent and whether they can contain other *Variables*.

4.4.2 Properties

Properties are *Server*-defined characteristics of *Objects*, *DataVariables* and other *Nodes*. *Properties* differ from *Attributes* in that they characterise *what* the *Node* represents, such as a device or a purchase order. *Attributes* define additional metadata that is instantiated for all *Nodes* from a *NodeClass*. *Attributes* are common to all *Nodes* of a *NodeClass* and only defined by this specification whereas *Properties* can be *Server*-defined.

For example, an *Attribute* defines the *DataType* of *Variables* whereas a *Property* can be used to specify the engineering unit of some *Variables*.

To prevent recursion, *Properties* are not allowed to have *Properties* defined for them. To easily identify *Properties*, the *BrowseName* of a *Property* shall be unique in the context of the *Node* containing the *Properties* (see 5.6.3 for details).

A *Node* and its *Properties* shall always reside in the same *Server*.

4.4.3 DataVariables

DataVariables represent the content of an *Object*. For example, a file *Object* may be defined that contains a stream of bytes. The stream of bytes may be defined as a *DataVariable* that is an array of bytes. *Properties* may be used to expose the creation time and owner of the file *Object*.

For example, if a *DataVariable* is defined by a data structure that contains two fields, “startTime” and “endTime” then it might have a *Property* specific to that data structure, such as “earliestStartTime”.

As another example, function blocks in control systems might be represented as *Objects*. The parameters of the function block, such as its setpoints, may be represented as *DataVariables*. The function block *Object* might also have *Properties* that describe its execution time and its type.

DataVariables may have additional *DataVariables*, but only if they are complex. In this case, their *DataVariables* shall always be elements of their complex definitions. Following the example introduced by the description of *Properties* in 4.4.2, the *Server* could expose “startTime” and “endTime” as separate components of the data structure.

As another example, a complex *DataVariable* may define an aggregate of temperature values generated by three separate temperature transmitters that are also visible in the *AddressSpace*. In this case, this complex *DataVariable* could define *HasComponent References* from it to the individual temperature values that it is composed of.

4.5 TypeDefinitionNodes

4.5.1 General

OPC UA *Servers* shall provide type definitions for *Objects* and *Variables*. The *HasTypeDefinition Reference* shall be used to link an instance with its type definition represented by a *TypeDefinitionNode*. Type definitions are required; however, Part 5 defines a *BaseObjectType*, a *PropertyType,* and a *BaseDataVariableType* so a *Server* can use such a base type if no more specialised type information is available. *Objects* and *Variables* inherit the *Attributes* specified by their *TypeDefinitionNode* (see 6.4 for details).

In some cases, the *NodeId* used by the *HasTypeDefinition Reference* will be well-known to *Clients* and *Servers*. Organizations may define *TypeDefinitionNodes* that are well-known in the industry. Well-known *NodeIds* of *TypeDefinitionNodes* provide for commonality across OPC UA *Servers* and allow *Clients* to interpret the *TypeDefinitionNode* without having to read it from the

Server. Therefore, *Servers* may use well-known *NodeIds* without representing the corresponding *TypeDefinitionNodes* in their *AddressSpace*. However, the *TypeDefinitionNodes* shall be provided for generic *Clients*. These *TypeDefinitionNodes* may exist in another *Server*.

The following example, illustrated in Figure 5, describes the use of the *HasTypeDefinition Reference*. In this example, a setpoint parameter "SP" is represented as a *DataVariable* in the *AddressSpace*. This *DataVariable* is part of an *Object* not shown in the figure.

To provide for a common setpoint definition that can be used by other *Objects*, a specialised *VariableType* is used. Each setpoint *DataVariable* that uses this common definition will have a *HasTypeDefinition Reference* that identifies the common "SetPoint" *VariableType*.

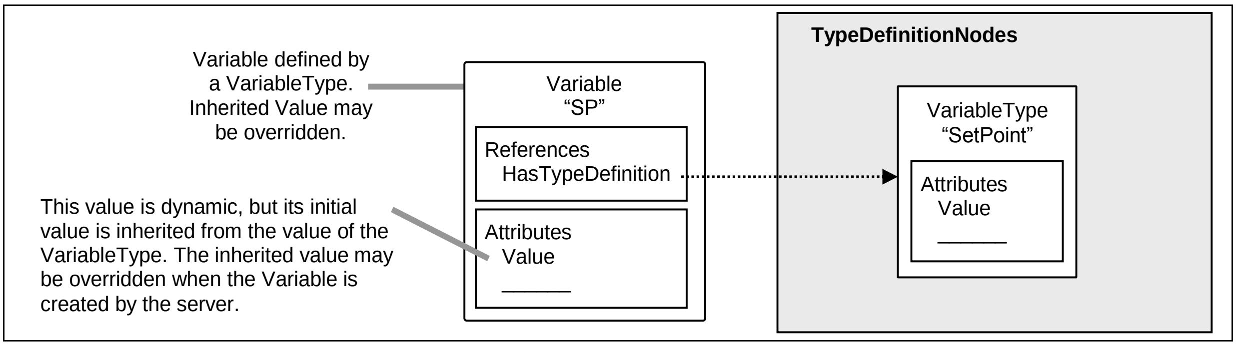


Figure 5 – Example of a Variable defined by a VariableType

4.5.2 Complex TypeDefinitionNodes and their InstanceDeclarations

TypeDefinitionNodes can be complex. A complex *TypeDefinitionNode* also defines *References* to other *Nodes* as part of the type definition. The *ModellingRules* defined in 6.4.4 specify how those *Nodes* are handled when creating an instance of the type definition.

A *TypeDefinitionNode* references instances instead of other *TypeDefinitionNodes* to allow unique names for several instances of the same type, to define default values and to add *References* for those instances that are specific to this complex *TypeDefinitionNode* and not to the *TypeDefinitionNode* of the instance. For example, in Figure 6 the *ObjectType* "AI_BLK_TYPE", representing a function block, has a *HasComponent Reference* to a *Variable* "SP" of the *VariableType* "SetPoint". "AI_BLK_TYPE" could have an additional setpoint *Variable* of the same type using a different name. It could add a *Property* to the *Variable* that was not defined by its *TypeDefinitionNode* "SetPoint". And it could define a default value for "SP", that is, each instance of "AI_BLK_TYPE" would have a *Variable* "SP" initially set to this value.

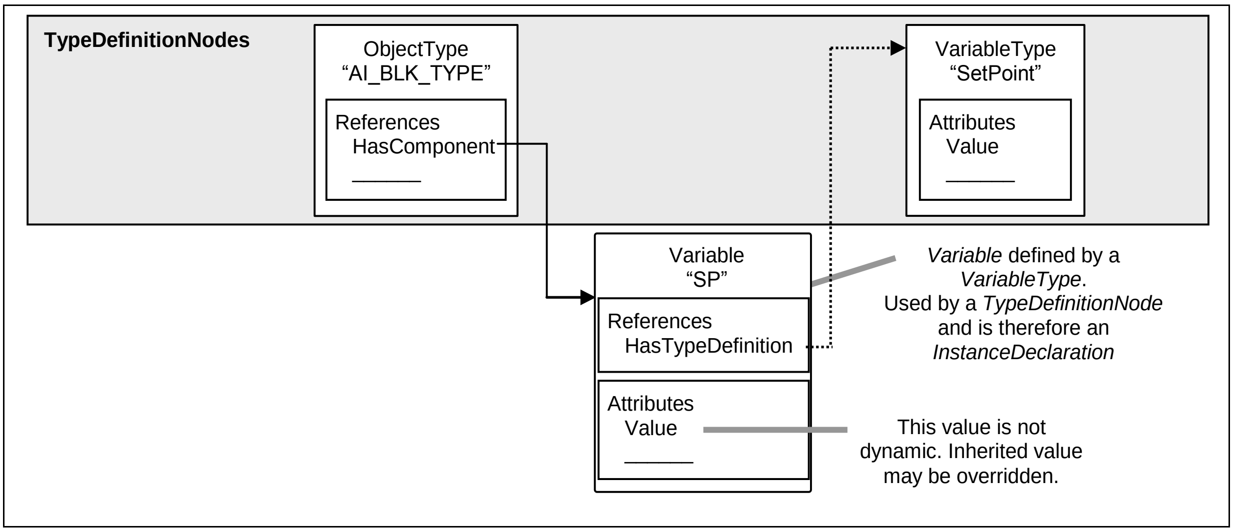


Figure 6 – Example of a Complex TypeDefinition

This approach is commonly used in object-oriented programming languages in which the variables of a class are defined as instances of other classes. When the class is instantiated, each variable is also instantiated, but with the default values (constructor values) defined for the containing class. That is, typically, the constructor for the component class runs first, followed by the constructor for the containing class. The constructor for the containing class may override component values set by the component class.

To distinguish instances used for the type definitions from instances that represent real data, those instances are called *InstanceDeclarations*. However, this term is used to simplify this specification, if an instance is an *InstanceDeclaration* or not is only visible in the *AddressSpace* by following its *References*. Some instances may be shared and therefore referenced by *TypeDefinitionNodes*, *InstanceDeclarations* and instances. This is similar to class variables in object-oriented programming languages.

4.5.3 Subtyping

This standard allows subtyping of type definitions. The subtyping rules are defined in Clause 6. Subtyping of *ObjectTypes* and *VariableTypes* allows:

- *Clients* that only know the supertype to handle an instance of the subtype as if it were an instance of the supertype;
- instances of the supertype to be replaced by instances of the subtype;
- specialised types that inherit common characteristics of the base type.

In other words, subtypes reflect the structure defined by their supertype but may add additional characteristics. For example, a vendor may wish to extend a general “TemperatureSensor” *VariableType* by adding a *Property* providing the next maintenance interval. The vendor would do this by creating a new *VariableType* which is a *TargetNode* for a *HasSubtype* reference from the original *VariableType* and adding the new *Property* to it.

4.5.4 Instantiation of complex TypeDefinitionNodes

The instantiation of complex *TypeDefinitionNodes* depends on the *ModellingRules* defined in 6.4.4. However, the intention is that instances of a type definition will reflect the structure defined by the *TypeDefinitionNode*. Figure 7 shows an instance of the *TypeDefinitionNode* “AI_BLK_TYPE”, where the *ModellingRule Mandatory*, defined in 6.4.4.5.2, was applied for its containing *Variable*. Thus, an instance of “AI_BLK_TYPE”, called AI_BLK_1”, has a *HasTypeDefinition Reference* to “AI_BLK_TYPE”. It also contains a *Variable* “SP” having the same *BrowseName* as the *Variable* “SP” used by the *TypeDefinitionNode* and thereby reflects the structure defined by the *TypeDefinitionNode*.

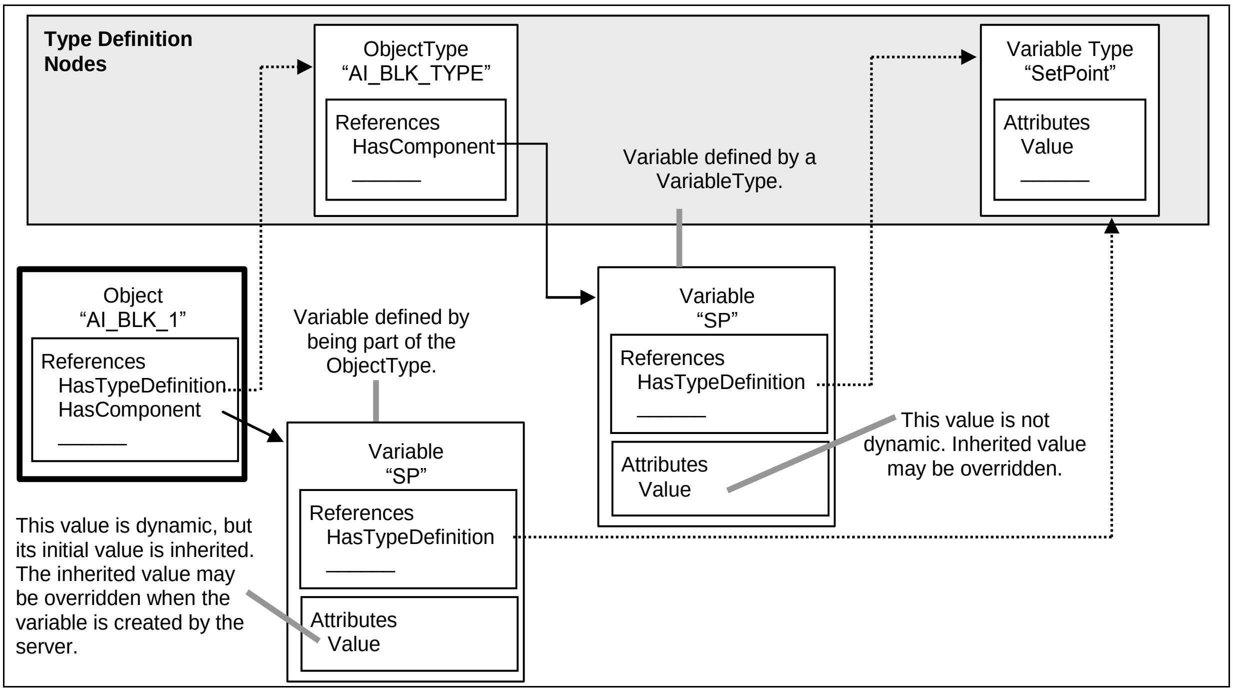


Figure 7 – Object and its Components defined by an ObjectType

A client knowing the *ObjectType* “AI_BLK_TYPE” can use this knowledge to directly browse to the containing *Nodes* for each instance of this type. This allows programming against the *TypeDefinitionNode*. For example, a graphical element may be programmed in the client that handles all instances of “AI_BLK_TYPE” in the same way by showing the value of “SP”.

There are several constraints related to programming against the *TypeDefinitionNode*. A *TypeDefinitionNode* or an *InstanceDeclaration* shall never reference two *Nodes* having the same *BrowseName* using *hierarchical References* in the forward direction. Instances based on *InstanceDeclarations* shall always keep the same *BrowseName* as the *InstanceDeclaration* they are derived from. A special *Service* defined in Part 4 called TranslateBrowsePathsToNodeIds may be used to identify the instances based on the *InstanceDeclarations*. Using the simple Browse *Service* might not be sufficient since the uniqueness of the *BrowseName* is only required for *TypeDefinitionNodes* and *InstanceDeclarations*, not for other instances. Thus, “AI_BLK_1” may have another *Variable* with the *BrowseName* “SP”, although this one would not be derived from an *InstanceDeclaration* of the *TypeDefinitionNode*.

Instances derived from an *InstanceDeclaration* shall be of the same *TypeDefinitionNode* or a subtype of this *TypeDefinitionNode*.

A *TypeDefinitionNode* and its *InstanceDeclarations* shall always reside in the same *Server*. However, instances may point with their *HasTypeDefinition Reference* to a *TypeDefinitionNode* in a different *Server*.

4.6 Event Model

4.6.1 General

The Event Model defines a general purpose eventing system that can be used in many diverse vertical markets.

Events represent specific transient occurrences. System configuration changes and system errors are examples of *Events*. *Event Notifications* report the occurrence of an *Event*. *Events* defined in this document are not directly visible in the OPC UA *AddressSpace*. *Objects* and *Views* can be used to subscribe to *Events*. The *EventNotifier Attribute* of those *Nodes* identifies if the *Node* allows subscribing to *Events*. *Clients* subscribe to such *Nodes* to receive *Notifications* of *Event* occurrences.

Event Subscriptions use the Monitoring and Subscription *Services* defined in Part 4 to subscribe to the *Event Notifications* of a *Node*.

Any OPC UA *Server* that supports eventing shall expose at least one *Node* as *EventNotifier*. The *Server Object* defined in Part 5 is used for this purpose. *Events* generated by the *Server* are available via this *Server Object*. A *Server* is not expected to produce *Events* if the connection to the event source is down for some reason (i.e. the system is offline).

Events may also be exposed through other *Nodes* anywhere in the *AddressSpace*. These *Nodes* (identified via the *EventNotifier Attribute*) provide some subset of the *Events* generated by the *Server*. The position in the *AddressSpace* dictates what this subset will be. For example, a process area *Object* representing a functional area of the process would provide *Events* originating from that area of the process only. It should be noted that this is only an example and it is fully up to the *Server* to determine what *Events* should be provided by which *Node*.

4.6.2 EventTypes

Each *Event* is of a specific *EventType*. A *Server* may support many types. This part defines the *BaseEventType* that all other *EventTypes* derive from. It is expected that other companion specifications will define additional *EventTypes* deriving from the base types defined in this part.

The *EventTypes* supported by a *Server* are exposed in the *AddressSpace* of a *Server*. *EventTypes* are represented as *ObjectTypes* in the *AddressSpace* and do not have a special *NodeClass* associated to them. Part 5 defines how a *Server* exposes the *EventTypes* in detail.

EventTypes defined in this document are specified as abstract and therefore never instantiated in the *AddressSpace*. Event occurrences of those *EventTypes* are only exposed via a *Subscription*. *EventTypes* exist in the *AddressSpace* to allow *Clients* to discover the *EventType*. This information is used by a client when establishing and working with *Event Subscriptions*. *EventTypes* defined by other parts of this series of standards or companion specifications as well as *Server* specific *EventTypes* may be defined as not abstract and therefore instances of those *EventTypes* may be visible in the *AddressSpace* although *Events* of those *EventTypes* are also accessible via the *Event Notification* mechanisms.

Standard *EventTypes* are described in Clause 9. Their representation in the *AddressSpace* is specified in Part 5.

4.6.3 Event Categorization

Events can be categorised by creating new *EventTypes* which are subtypes of existing *EventTypes* but do not extend an existing type. They are used only to identify an event as being of the new *EventType*. For example, the *EventType* DeviceFailureEventType could be subtyped into TransmitterFailureEventType and ComputerFailureEventType. These new subtypes would not add new *Properties* or change the semantic inherited from the DeviceFailureEventType other than purely for categorization of the *Events*.

Event sources can also be organised into groups by using the *Event ReferenceTypes* described in 7.17 and 7.19. For example, a *Server* may define *Objects* in the *AddressSpace* representing *Events* related to physical devices, or *Event* areas of a plant or functionality contained in the *Server*. *Event References* would be used to indicate which *Event* sources represent physical devices and which ones represent some *Server*-based functionality. In addition, *References* can be used to group the physical devices or *Server*-based functionality into hierarchical *Event* areas. In some cases, an *Event* source may be categorised as being both a device and a *Server* function. In this case, two relationships would be established. Refer to the description of the *Event ReferenceTypes* for additional examples.

Clients can select a category or categories of *Events* by defining content filters that include terms specifying the *EventType* of the *Event* or a grouping of *Event* sources. The two mechanisms allow for a single *Event* to be categorised in multiple manners. A client could obtain all *Events* related to a physical device or all failures of a particular device.

4.7 Methods

Methods are “lightweight” functions, whose scope is bounded by an owning (see Note) *Object*, similar to the methods of a class in object-oriented programming or an owning *ObjectType*, similar to static methods of a class. *Methods* are invoked by a client, proceed to completion on the *Server* and return the result to the client. The lifetime of the *Method’s* invocation instance begins when the client calls the *Method* and ends when the result is returned.

NOTE The owning *Object* or *ObjectType* is specified in the service call when invoking the *Method*.

While *Methods* may affect the state of the owning *Object*, they have no explicit state of their own. In this sense, they are stateless. *Methods* can have a varying number of input arguments and return resultant arguments. Each *Method* is described by a *Node* of the *Method NodeClass*. This *Node* contains the metadata that identifies the *Method’s* arguments and describes its behaviour.

Methods are invoked by using the Call *Service* defined in Part 4. Each *Method* is invoked within the context of an existing session. If the session is terminated during *Method* execution, the results of the *Method’s* execution cannot be returned to the client and are discarded. In that case, the Method execution is undefined, that is, the *Method* may be executed until it is finished or it may be aborted.

Clients discover the *Methods* supported by a *Server* by browsing for the owning *Objects* *References* that identify their supported *Methods*.

5 Standard NodeClasses

5.1 Overview

Clause 5 defines the *NodeClasses* used to define *Nodes* in the OPC UA *AddressSpace*. *NodeClasses* are derived from a common *Base NodeClass*. This *NodeClass* is defined first, followed by those used to organise the *AddressSpace* and then by the *NodeClasses* used to represent *Objects*.

The *NodeClasses* defined to represent *Objects* fall into three categories: those used to define instances, those used to define types for those instances and those used to define data types. Subclause 6.3 describes the rules for subtyping and 6.4 the rules for instantiation of the type definitions.

5.2 Base NodeClass

5.2.1 General

The OPC UA Address Space Model defines a *Base NodeClass* from which all other *NodeClasses* are derived. The derived *NodeClasses* represent the various components of the OPC UA Object Model (see 4.2). The *Attributes* of the *Base NodeClass* are specified in Table 2. There are no *References* specified for the *Base NodeClass*.

Table 2 – Base NodeClass

Name	Use	Data Type	Description
Attributes			
NodeId	M	NodeId	See 5.2.2
NodeClass	M	NodeClass	See 5.2.3
BrowseName	M	QualifiedName	See 5.2.4
DisplayName	M	LocalizedText	See 5.2.5
Description	O	LocalizedText	See 5.2.6
WriteMask	O	UInt32	See 5.2.7
UserWriteMask	O	UInt32	See 5.2.8
References			No *References* specified for this *NodeClass*

5.2.2 NodeId

Nodes are unambiguously identified using a constructed identifier called the *NodeId*. Some *Servers* may accept alternative *NodeIds* in addition to the canonical *NodeId* represented in this

Attribute. A *Server* shall persist the *NodeId* of a *Node*, that is, it shall not generate new *NodeIds* when rebooting. The structure of the *NodeId* is defined in 8.2.

5.2.3 NodeClass

The *NodeClass Attribute* identifies the *NodeClass* of a *Node*. Its data type is defined in 8.30.

5.2.4 BrowseName

Nodes have a *BrowseName Attribute* that is used as a non-localised human-readable name when browsing the *AddressSpace* to create paths out of *BrowseNames*. The TranslateBrowsePathsToNodeIds *Service* defined in Part 4 can be used to follow a path constructed of *BrowseNames*.

A *BrowseName* should never be used to display the name of a *Node*. The *DisplayName* should be used instead for this purpose.

Unlike *NodeIds*, the *BrowseName* cannot be used to unambiguously identify a *Node*. Different *Nodes* may have the same *BrowseName*.

Subclause 8.3 defines the structure of the *BrowseName*. It contains a namespace and a string. The namespace is provided to make the *BrowseName* unique in some cases in the context of a *Node* (e.g. *Properties* of a *Node*) although not unique in the context of the *Server*. If different organizations define *BrowseNames* for *Properties*, the namespace of the *BrowseName* provided by the organization makes the *BrowseName* unique, although different organizations may use the same string having a slightly different meaning.

Servers may often choose to use the same namespace for the *NodeId* and the *BrowseName*. However, if they want to provide a standard *Property*, its *BrowseName* shall have the namespace of the standards body although the namespace of the *NodeId* reflects something else, for example the local *Server*.

It is recommended that standard bodies defining standard type definitions use their namespace for the *NodeId* of the *TypeDefinitionNode* as well as for the *BrowseName* of the *TypeDefinitionNode.*

The string-part of the *BrowseName* is case sensitive. That is, *Clients* shall consider them case sensitive. *Servers* are allowed to handle *BrowseNames* passed in *Service* requests as case insensitive. Examples are the *TranslateBrowsePathsToNodeIds Service* or *Event* filter.

5.2.5 DisplayName

The *DisplayName Attribute* contains the localised name of the *Node*. *Clients* should use this *Attribute* if they want to display the name of the *Node* to the user. They should not use the *BrowseName* for this purpose. The *Server* may maintain one or more localised representations for each *DisplayName*. *Clients* negotiate the locale to be returned when they open a session with the *Server*. Refer to Part 4 for a description of session establishment and locales. Subclause 8.5 defines the structure of the *DisplayName*. The string part of the *DisplayName* is restricted to 512 characters.

5.2.6 Description

The optional *Description Attribute* shall explain the meaning of the *Node* in a localised text using the same mechanisms for localisation as described for the *DisplayName* in 5.2.5.

5.2.7 WriteMask

The optional *WriteMask Attribute* exposes the possibilities of a client to write the *Attributes* of the *Node*. The *WriteMask Attribute* does not take any user access rights into account, that is, although an *Attribute* is writable this may be restricted to a certain user/user group.

If the OPC UA *Server* does not have the ability to get the *WriteMask* information for a specific *Attribute* from the underlying system, it should state that it is writable. If a write operation is called on the *Attribute*, the *Server* should transfer this request and return the corresponding *StatusCode* if such a request is rejected. *StatusCodes* are defined in Part 4.

The *WriteMask Attribute* is a 32-bit unsigned integer with the structure defined in Table 3. If the bit is set to 0, it means the *Attribute* is not writable, if it is set to 1, it means it is writable. If a *Node* does not support a specific *Attribute*, the corresponding bit has to be set to 0.

Table 3 – Bit mask for WriteMask and UserWriteMask

Field	Bit	Description
AccessLevel	0	Indicates if the AccessLevel Attribute is writable.
ArrayDimensions	1	Indicates if the ArrayDimensions Attribute is writable.
BrowseName	2	Indicates if the BrowseName Attribute is writable.
ContainsNoLoops	3	Indicates if the ContainsNoLoops Attribute is writable.
DataType	4	Indicates if the DataType Attribute is writable.
Description	5	Indicates if the Description Attribute is writable.
DisplayName	6	Indicates if the DisplayName Attribute is writable.
EventNotifier	7	Indicates if the EventNotifier Attribute is writable.
Executable	8	Indicates if the Executable Attribute is writable.
Historizing	9	Indicates if the Historizing Attribute is writable.
InverseName	10	Indicates if the InverseName Attribute is writable.
IsAbstract	11	Indicates if the IsAbstract Attribute is writable.
MinimumSamplingInterval	12	Indicates if the MinimumSamplingInterval Attribute is writable.
NodeClass	13	Indicates if the NodeClass Attribute is writable.
NodeId	14	Indicates if the NodeId Attribute is writable.
Symmetric	15	Indicates if the Symmetric Attribute is writable.
UserAccessLevel	16	Indicates if the UserAccessLevel Attribute is writable.
UserExecutable	17	Indicates if the UserExecutable Attribute is writable.
UserWriteMask	18	Indicates if the UserWriteMask Attribute is writable.
ValueRank	19	Indicates if the ValueRank Attribute is writable.
WriteMask	20	Indicates if the WriteMask Attribute is writable.
ValueForVariableType	21	Indicates if the *Value Attribute* is writable for a *VariableType*. It does not apply for *Variables* since this is handled by the *AccessLevel* and *UserAccessLevel Attributes* for the *Variable*. For *Variables* this bit shall be set to 0.
Reserved	22:31	Reserved for future use. Shall always be zero.

5.2.8 UserWriteMask

The optional *UserWriteMask Attribute* exposes the possibilities of a client to write the *Attributes* of the *Node* taking user access rights into account. It uses the same bit mask as used in the *WriteMask Attribute*, defined in Table 3.

The *UserWriteMask Attribute* can only further restrict the *WriteMask Attribute,* when it is set to not writable in the general case that applies for every user.

5.3 ReferenceType NodeClass

5.3.1 General

References are defined as instances of *ReferenceType Nodes*. *ReferenceType Nodes* are visible in the *AddressSpace* and are defined using the *ReferenceType NodeClass* as specified in Table 4. In contrast, a *Reference* is an inherent part of a *Node* and no *NodeClass* is used to represent *References*.

This standard defines a set of *ReferenceTypes* provided as an inherent part of the OPC UA Address Space Model. These *ReferenceTypes* are defined in Clause 7 and their representation in the *AddressSpace* is defined in Part 5. *Servers* may also define *ReferenceTypes*. In addition, Part 4 defines *NodeManagement Services* that allow *Clients* to add *ReferenceTypes* to the *AddressSpace*.

Table 4 – ReferenceType NodeClass

Name	Use	Data Type	Description
Attributes			
Base NodeClass Attributes	M	--	Inherited from the *Base NodeClass*. See 5.2.
IsAbstract	M	Boolean	A boolean *Attribute* with the following values: TRUE it is an abstract *ReferenceType*, i.e. no *Reference* of this type shall exist, only of its subtypes. FALSE it is not an abstract *ReferenceType*, i.e. *References* of this type can exist.
Symmetric	M	Boolean	A boolean *Attribute* with the following values: TRUE the meaning of the *ReferenceType* is the same as seen from both the *SourceNode* and the *TargetNode.* FALSE the meaning of the *ReferenceType* as seen from the *TargetNode* is the inverse of that as seen from the *SourceNode*.
InverseName	O	LocalizedText	The inverse name of the *Reference*, that is the meaning of the *ReferenceType* as seen from the *TargetNode*.
References			
HasProperty	0..*		Used to identify the Properties (see 5.3.3.2).
HasSubtype	0..*		Used to identify subtypes (see 5.3.3.3).
Standard Properties			
NodeVersion	O	String	The *NodeVersion Property* is used to indicate the version of a *Node*. The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value changes do not cause the *NodeVersion* to change. *Clients* may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed.

5.3.2 Attributes

The *ReferenceType NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2. The inherited *BrowseName Attribute* is used to specify the meaning of the *ReferenceType* as seen from the *SourceNode*. For example, the *ReferenceType* with the *BrowseName* “Contains” is used in *References* that specify that the *SourceNode* contains the *TargetNode*. The inherited *DisplayName Attribute* contains a translation of the *BrowseName.*

The *BrowseName* of a *ReferenceType* shall be unique in a *Server*. It is not allowed that two different *ReferenceTypes* have the same *BrowseName*.

The *IsAbstract Attribute* indicates if the *ReferenceType* is abstract. Abstract *ReferenceTypes* cannot be instantiated and are used only for organizational reasons, for example to specify some general semantics or constraints that its subtypes inherit.

The *Symmetric Attribute* is used to indicate whether or not the meaning of the *ReferenceType* is the same for both the *SourceNode* and *TargetNode*.

If a *ReferenceType* is symmetric, the *InverseName Attribute* shall be omitted. Examples of symmetric *ReferenceTypes* are “Connects To” and “Communicates With”. Both imply the same semantic coming from the *SourceNode* or the *TargetNode*. Therefore both directions are considered to be forward References.

If the *ReferenceType* is non-symmetric and not abstract, the *InverseName Attribute* shall be set. The *InverseName Attribute* specifies the meaning of the *ReferenceType* as seen from the *TargetNode*. Examples of non-symmetric *ReferenceTypes* include “Contains” and “Contained In”, and “Receives From” and “Sends To”.

References that use the *InverseName*, such as “Contained In” *References*, are referred to as inverse *References*.

Figure 8 provides examples of symmetric and non-symmetric *References* and the use of the *BrowseName* and the *InverseName*.

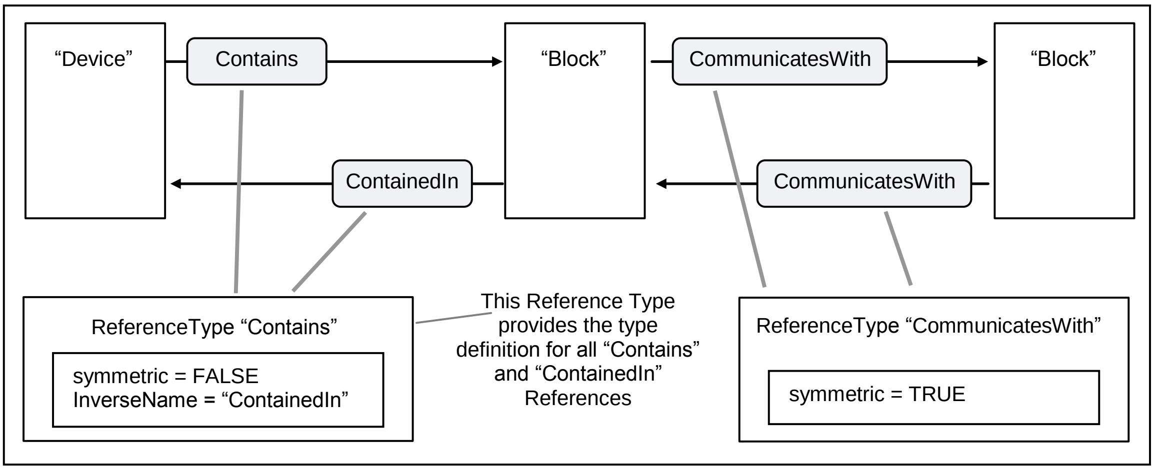


Figure 8 – Symmetric and Non-Symmetric References

It might not always be possible for *Servers* to instantiate both forward and inverse *References* for non-symmetric *ReferenceTypes* as shown in Figure 8. When they do, the *References* are referred to as *bidirectional*. Although not required, it is recommended that all *hierarchical References* be instantiated as bidirectional to ensure browse connectivity. A bidirectional *Reference* is modelled as two separate *References*.

As an example of a *unidirectional Reference*, it is often the case that a subscriber knows its publisher, but its publisher does not know its subscribers. The subscriber would have a "Subscribes To" *Reference* to the publisher, without the publisher having the corresponding "Publishes To" inverse *References* to its subscribers.

The *DisplayName* and the *InverseName* are the only standardised places to indicate the semantic of a *ReferenceType*. There may be more complex semantics associated with a *ReferenceType* than can be expressed in those *Attributes* (e.g. the semantic of *HasSubtype*). This standard does not specify how this semantic should be exposed. However, the *Description Attribute* can be used for this purpose. This standard provides a semantic for the *ReferenceTypes* specified in Clause 7.

A *ReferenceType* can have constraints restricting its use. For example, it can specify that starting from *Node* A and only following *References* of this *ReferenceType* or one of its subtypes, it shall never be able to return to A, that is, a "No Loop" constraint.

This standard does not specify how those constraints could or should be made available in the *AddressSpace*. Nevertheless, for the standard *ReferenceTypes*, some constraints are specified in Clause 7. This standard does not restrict the kind of constraints valid for a *ReferenceType*. It can, for example, also affect an *ObjectType*. The restriction that a *ReferenceType* can only be used by relating *Nodes* of some *NodeClasses* with a defined cardinality is a special constraint of a *ReferenceType*.

5.3.3 References

5.3.3.1 General

HasSubtype References and *HasProperty References* are the only *ReferenceTypes* that may be used with *ReferenceType Nodes* as *SourceNode*. *ReferenceType Nodes* shall not be the *SourceNode* of other types of *References*.

5.3.3.2 HasProperty References

HasProperty References are used to identify the *Properties* of a *ReferenceType* and shall only refer to *Nodes* of the *Variable NodeClass*.

The *Property NodeVersion* is used to indicate the version of the *ReferenceType*.

There are no additional *Properties* defined for *ReferenceTypes* in this standard. Additional parts this series of standards may define additional *Properties* for *ReferenceTypes*.

5.3.3.3 HasSubtype References

HasSubtype References are used to define subtypes of *ReferenceTypes*. It is not required to provide the *HasSubtype Reference* for the supertype, but it is required that the subtype provides the inverse *Reference* to its supertype. The following rules for subtyping apply.

a) The semantic of a *ReferenceType* (e.g. “spans a hierarchy”) is inherited to its subtypes and can be refined there (e.g. “spans a special hierarchy”). The *DisplayName*, and also the *InverseName* for non-symmetric *ReferenceTypes*, reflect the specialization.

b) If a *ReferenceType* specifies some constraints (e.g. “allow no loops”) this is inherited and can only be refined (e.g. inheriting “no loops” could be refined as “shall be a tree – only one parent”) but not lowered (e.g. “allow loops”).

c) The constraints concerning which *NodeClasses* can be referenced are also inherited and can only be further restricted. That is, if a *ReferenceType* “A” is not allowed to relate an *Object* with an *ObjectType*, this is also true for its subtypes.

d) A *ReferenceType* shall have exactly one supertype, except for the *References ReferenceType* defined in 7.2 as the root type of the *ReferenceType* hierarchy. The *ReferenceType* hierarchy does not support multiple inheritances.

5.4 View NodeClass

Underlying systems are often large and *Clients* often have an interest in only a specific subset of the data. They do not need, or want, to be burdened with viewing *Nodes* in the *AddressSpace* for which they have no interest.

To address this problem, this standard defines the concept of a *View*. Each *View* defines a subset of the *Nodes* in the *AddressSpace*. The entire *AddressSpace* is the default *View*. Each *Node* in a *View* may contain only a subset of its *References*, as defined by the creator of the *View*. The *View Node* acts as the root for the *Nodes* in the *View*. *Views* are defined using the *View NodeClass*, which is specified in Table 5.

All *Nodes* contained in a *View* shall be accessible starting from the *View Node* when browsing in the context of the *View*. It is not expected that all containing *Nodes* can be browsed directly from the *View Node* but rather browsed from other *Nodes* contained in the *View*.

A *View Node* may not only be used as additional entry point into the *AddressSpace* but as a construct to organize the *AddressSpace* and thus as the only entry point into a subset of the *AddressSpace*. Therefore *Clients* shall not ignore *View Nodes* when exposing the *AddressSpace*. Simple *Clients* that do not deal with *Views* for filtering purposes can, for example, handle a *View Node* like an *Object* of type *FolderType* (see 5.5.3).

Table 5 – View NodeClass

<table>
<tr><th>Name</th><th>Use</th><th>Data Type</th><th>Description</th></tr>
<tr><td>Attributes</td><td></td><td></td><td></td></tr>
<tr><td>Base NodeClass Attributes</td><td>M</td><td>--</td><td>Inherited from the Base NodeClass. See 5.2.</td></tr>
<tr><td>ContainsNoLoops</td><td>M</td><td>Boolean</td><td>If set to “true” this Attribute indicates that by following the References in the context of the View there are no loops, i.e. starting from a Node “A” contained in the View and following the forward References in the context of the View Node “A” will not be reached again. It does not specify that there is only one path starting from the View Node to reach a Node contained in the View.
If set to “false” this Attribute indicates that following References in the context of the View may lead to loops.</td></tr>
<tr><td>EventNotifier</td><td>M</td><td>Byte</td><td>The EventNotifier Attribute is used to indicate if the Node can be used to subscribe to Events or to read / write historic Events.
The EventNotifier is an 8-bit unsigned integer with the structure defined in the following table.
<table>
<tr><th>Field</th><th>Bit</th><th>Description</th></tr>
<tr><td>SubscribeTo Events</td><td>0</td><td>Indicates if it can be used to subscribe to Events
(0 means cannot be used to subscribe to Events, 1 means can be used to subscribe to Events)</td></tr>
<tr><td>Reserved</td><td>1</td><td>Reserved for future use. Shall always be zero.</td></tr>
<tr><td>HistoryRead</td><td>2</td><td>Indicates if the history of the Events is readable
(0 means not readable, 1 means readable)</td></tr>
<tr><td>HistoryWrite</td><td>3</td><td>Indicates if the history of the Events is writable
(0 means not writable, 1 means writable)</td></tr>
<tr><td>Reserved</td><td>4:7</td><td>Reserved for future use. Shall always be zero</td></tr>
</table>
The second two bits also indicate if the history of the Events is available via the OPC UA Server.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>References</td><td></td><td></td><td></td></tr>
<tr><td>HierarchicalReferences</td><td>0..*</td><td></td><td>Top level Nodes in a View are referenced by hierarchical References (see 7.3).</td></tr>
<tr><td>HasProperty</td><td>0..*</td><td></td><td>HasProperty References identify the Properties of the View.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>Standard Properties</td><td></td><td></td><td></td></tr>
<tr><td>NodeVersion</td><td>O</td><td>String</td><td>The NodeVersion Property is used to indicate the version of a Node.
The NodeVersion Property is updated each time a Reference is added or deleted to the Node the Property belongs to. Attribute value changes do not cause the NodeVersion to change. Clients may read the NodeVersion Property or subscribe to it to determine when the structure of a Node has changed.</td></tr>
<tr><td>ViewVersion</td><td>O</td><td>UInt32</td><td>The version number for the View. When Nodes are added to or removed from a View, the value of the ViewVersion Property is updated. Clients may detect changes to the composition of a View using this Property. The value of the ViewVersion shall always be greater than 0.</td></tr>
</table>

The *View NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2. It also defines two additional *Attributes*.

The mandatory *ContainsNoLoops Attribute* is set to false if the *Server* is not able to identify if the *View* contains loops or not.

The mandatory *EventNotifier Attribute* identifies if the *View* can be used to subscribe to *Events* that either occur in the content of the *View* or as *ModelChangeEvents* (see 9.32) of the content of the *View* or to read / write the history of the *Events*. A *View* that supports *Events* shall provide all *Events* that occur in any *Object* used as *EventNotifier* that is part of the content of the *View*. In addition, it shall provide all *ModelChangeEvents* that occur in the context of the *View*.

To avoid recursion, i.e. getting all *Events* of the *Server*, the *Server Object* defined in Part 5 shall never be part of any *View* since it provides all *Events* of the *Server*.

Views are defined by the *Server*. The browsing and querying *Services* defined in Part 4 expect the *NodeId* of a *View Node* to provide these *Services* in the context of the *View*.

HasProperty References are used to identify the *Properties* of a *View*. The *Property NodeVersion* is used to indicate the version of the *View Node*. The *ViewVersion Property* indicates the version of the content of the *View*. In contrast to the *NodeVersion*, the *ViewVersion Property* is updated even if *Nodes* not directly referenced by the *View Node* are added to or deleted from the *View*. This *Property* is optional because it might not be possible for *Servers* to detect changes in the *View* contents. *Servers* may also generate a *ModelChangeEvent,* described in 9.32, if *Nodes* are added to or deleted from the *View*. There are no additional *Properties* defined for *Views* in this document. Additional parts of this series of standards may define additional *Properties* for *Views*.

Views can be the *SourceNode* of any *hierarchical Reference*. They shall not be the *SourceNode* of any *non-hierarchical Reference*.

5.5 Objects

5.5.1 Object NodeClass

Objects are used to represent systems, system components, real-world objects and software objects. *Objects* are defined using the *Object NodeClass*, specified in Table 6.

Table 6 – Object NodeClass

<table>
<tr><th>Name</th><th>Use</th><th>Data Type</th><th>Description</th></tr>
<tr><td>**Attributes**</td><td></td><td></td><td></td></tr>
<tr><td>Base NodeClass Attributes</td><td>M</td><td>--</td><td>Inherited from the *Base NodeClass*. See 5.2.</td></tr>
<tr><td>EventNotifier</td><td>M</td><td>Byte</td><td>The *EventNotifier Attribute* is used to indicate if the *Node* can be used to subscribe to *Events* or the read / write historic *Events*.
The *EventNotifier* is an 8-bit unsigned integer with the structure defined in the following table:
<table>
<tr><th>Field</th><th>Bit</th><th>Description</th></tr>
<tr><td>SubscribeToEvents</td><td>0</td><td>Indicates if it can be used to subscribe to *Events* (0 means cannot be used to subscribe to *Events*, 1 means can be used to subscribe to *Events*).</td></tr>
<tr><td>Reserved</td><td>1</td><td>Reserved for future use. Shall always be zero.</td></tr>
<tr><td>HistoryRead</td><td>2</td><td>Indicates if the history of the *Events* is readable (0 means not readable, 1 means readable).</td></tr>
<tr><td>HistoryWrite</td><td>3</td><td>Indicates if the history of the *Events* is writable (0 means not writable, 1 means writable).</td></tr>
<tr><td>Reserved</td><td>4:7</td><td>Reserved for future use. Shall always be zero.</td></tr>
</table>
The second two bits also indicate if the history of the *Events* is available via the OPC UA *Server*.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>**References**</td><td></td><td></td><td></td></tr>
<tr><td>HasComponent</td><td>0..*</td><td></td><td>*HasComponent References* identify the *DataVariables*, the *Methods* and *Objects* contained in the *Object*.</td></tr>
<tr><td>HasProperty</td><td>0..*</td><td></td><td>*HasProperty References* identify the *Properties* of the *Object*.</td></tr>
<tr><td>HasModellingRule</td><td>0..1</td><td></td><td>*Objects* can point to at most one *ModellingRule Object* using a *HasModellingRule Reference* (see 6.4.4 for details on *ModellingRules*).</td></tr>
<tr><td>HasTypeDefinition</td><td>1</td><td></td><td>The *HasTypeDefinition Reference* points to the type definition of the *Object.* Each *Object* shall have exactly one type definition and therefore be the *SourceNode* of exactly one *HasTypeDefinition Reference* pointing to an *ObjectType*. See 4.5 for a description of type definitions.</td></tr>
<tr><td>HasEventSource</td><td>0..*</td><td></td><td>The *HasEventSource Reference* points to event sources of the *Object*. *References* of this type can only be used for *Objects* having their “SubscribeToEvents” bit set in the *EventNotifier Attribute*. See 7.17 for details.</td></tr>
<tr><td>HasNotifier</td><td>0..*</td><td></td><td>The *HasNotifier Reference* points to notifiers of the *Object*. *References* of this type can only be used for *Objects* having their “SubscribeToEvents” bit set in the *EventNotifier Attribute*. See 7.19 for details.</td></tr>
<tr><td>Organizes</td><td>0..*</td><td></td><td>This *Reference* should be used only for *Objects* of the *ObjectType FolderType* (see 5.5.3).</td></tr>
<tr><td>HasDescription</td><td>0..1</td><td></td><td>This *Reference* shall be used only for *Objects* of the *ObjectType DataTypeEncodingType* (see 5.8.4).</td></tr>
<tr><td><other References></td><td>0..*</td><td></td><td>*Objects* may contain other *References*.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>**Standard Properties**</td><td></td><td></td><td></td></tr>
<tr><td>NodeVersion</td><td>O</td><td>String</td><td>The *NodeVersion Property* is used to indicate the version of a *Node*.
The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value changes do not cause the *NodeVersion* to change. *Clients* may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed.</td></tr>
<tr><td>Icon</td><td>O</td><td>Image</td><td>The *Icon Property* provides an image that can be used by *Clients* when displaying the *Node*. It is expected that the *Icon Property* contains a relatively small image.</td></tr>
<tr><td>NamingRule</td><td>O</td><td>NamingRuleType</td><td>The *NamingRule* Property defines the *NamingRule* of a *ModellingRule* (see 6.4.4.2.1 for details). This *Property* shall only be used for *Objects* of the type *ModellingRuleType* defined in 6.4.4.</td></tr>
</table>

The *Object NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2.

The mandatory *EventNotifier Attribute* identifies whether the *Object* can be used to subscribe to *Events* or to read and write the history of the *Events*.

The *Object NodeClass* uses the *HasComponent Reference* to define the *DataVariables*, *Objects* and *Methods* of an *Object*.

It uses the *HasProperty Reference* to define the *Properties* of an *Object*. The *Property NodeVersion* is used to indicate the version of the *Object*. The *Property Icon* provides an icon of the *Object*. The *Property NamingRule* defines the *NamingRule* of a *ModellingRule* and shall only be applied to *Objects* of type *ModellingRuleType*. There are no additional *Properties* defined for *Objects* in this document. Additional parts of this series of standards may define additional *Properties* for *Objects*.

To specify its *ModellingRule*, an *Object* can use at most one *HasModellingRule Reference* pointing to a *ModellingRule Object*. *ModellingRules* are defined in 6.4.4.

HasNotifier and *HasEventSource References* are used to provide information about eventing and can only be applied to *Objects* used as event notifiers. Details are defined in 7.17 and 7.19.

The *HasTypeDefinition Reference* points to the *ObjectType* used as type definition of the *Object*.

Objects may use any additional *References* to define relationships to other *Nodes*. No restrictions are placed on the types of *References* used or on the *NodeClasses* of the *Nodes* that may be referenced. However, restrictions may be defined by the *ReferenceType* excluding its use for *Objects*. Standard *ReferenceTypes* are described in Clause 7.

If the *Object* is used as an *InstanceDeclaration* (see 4.5) then all *Nodes* referenced with *hierarchical References* in a forward direction shall have unique *BrowseNames* in the context of this *Object*.

If the *Object* is created based on an *InstanceDeclaration* then it shall have the same *BrowseName* as its *InstanceDeclaration*.

5.5.2 ObjectType NodeClass

ObjectTypes provide definitions for *Objects*. *ObjectTypes* are defined using the *ObjectType NodeClass*, which is specified in Table 7.

Table 7 – ObjectType NodeClass

Name	Use	Data Type	Description
Attributes			
Base NodeClass Attributes	M	--	Inherited from the *Base NodeClass*. See 5.2.
IsAbstract	M	Boolean	A boolean *Attribute* with the following values: TRUE it is an abstract *ObjectType*, i.e. no *Objects* of this type shall exist, only *Objects* of its subtypes. FALSE it is not an abstract *ObjectType*, i.e. *Objects* of this type can exist.
References			
HasComponent	0..*		*HasComponent References* identify the *DataVariables*, the *Methods*, and *Objects* contained in the *ObjectType*. If and how the referenced *Nodes* are instantiated when an *Object* of this type is instantiated, is specified in 6.4.
HasProperty	0..*		*HasProperty References* identify the *Properties* of the *ObjectType*. If and how the *Properties* are instantiated when an *Object* of this type is instantiated, is specified in 6.4.
HasSubtype	0..*		*HasSubtype References* identify *ObjectTypes* that are subtypes of this type. The inverse *SubtypeOf Reference* identifies the parent type of this type.
GeneratesEvent	0..*		*GeneratesEvent References* identify the type of *Events* instances of this type may generate.
<other References>	0..*		*ObjectTypes* may contain other *References* that can be instantiated by *Objects* defined by this *ObjectType*.
Standard Properties			
NodeVersion	O	String	The *NodeVersion Property* is used to indicate the version of a *Node*. The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value changes do not cause the *NodeVersion* to change. *Clients* may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed.
Icon	O	Image	The *Icon Property* provides an image that can be used by *Clients* when displaying the *Node*. It is expected that the *Icon Property* contains a relatively small image.

The *ObjectType NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2. The additional *IsAbstract Attribute* indicates if the *ObjectType* is abstract or not.

The *ObjectType NodeClass* uses the *HasComponent References* to define the *DataVariables*, *Objects*, and *Methods* for it.

The *HasProperty Reference* is used to identify the *Properties*. The *Property NodeVersion* is used to indicate the version of the *ObjectType*. The *Property Icon* provides an icon of the *ObjectType*. There are no additional *Properties* defined for *ObjectTypes* in this document. Additional parts of this series of standards may define additional *Properties* for *ObjectTypes*.

HasSubtype References are used to subtype *ObjectTypes*. *ObjectType* subtypes inherit the general semantics from the parent type. The general rules for subtyping apply as defined in Clause 6. It is not required to provide the *HasSubtype Reference* for the supertype, but it is required that the subtype provides the inverse *Reference* to its supertype.

GeneratesEvent References identify the type of *Events* that instances of the *ObjectType* may generate. These *Objects* may be the source of an *Event* of the specified type or one of its subtypes. *Servers* should make *GeneratesEvent References* bidirectional *References*. However, it is allowed to be unidirectional when the *Server* is not able to expose the inverse direction pointing from the *EventType* to each *ObjectType* supporting the *EventType.* Note that the *EventNotifier Attribute* of an *Object* and the *GeneratesEvent References* of its *ObjectType* are completely unrelated. *Objects* that can generate *Events* might not be used as *Objects* to which *Clients* subscribe to get the corresponding *Event* notifications.

GeneratesEvent References are optional, i.e. *Objects* may generate *Events* of an *EventType* that is not exposed by its *ObjectType*.

ObjectTypes may use any additional *References* to define relationships to other *Nodes*. No restrictions are placed on the types of *References* used or on the *NodeClasses* of the *Nodes* that may be referenced. However, restrictions may be defined by the *ReferenceType* excluding its use for *ObjectTypes*. Standard *ReferenceTypes* are described in Clause 7.

All *Nodes* referenced with *hierarchical References* shall have unique *BrowseNames* in the context of an *ObjectType* (see 4.5).

5.5.3 Standard ObjectType FolderType

The *ObjectType FolderType* is formally defined in Part 5. Its purpose is to provide *Objects* that have no other semantic than organizing of the *AddressSpace*. A special *ReferenceType* is introduced for those *Folder Objects*, the *Organizes ReferenceType*. The *SourceNode* of such a *Reference* should always be a *View* or an *Object* of the *ObjectType FolderType*; the *TargetNode* can be of any *NodeClass*. *Organizes References* can be used in any combination with *HasChild References* (*HasComponent*, *HasProperty*, etc.; see 7.5) and do not prevent loops. Thus, they can be used to span multiple hierarchies.

5.5.4 Client-side creation of Objects of an ObjectType

Objects are always based on an *ObjectType*, i.e. they have a *HasTypeDefinition Reference* pointing to its *ObjectType*.

Clients can create *Objects* using the *AddNodes Service* defined in Part 4. The *Service* requires specifying the *TypeDefinitionNode* of the *Object*. An *Object* created by the *AddNodes Service* contains all components defined by its *ObjectType* dependent on the *ModellingRules* specified for the components. However, the *Server* may add additional components and *References* to the *Object* and its components that are not defined by the *ObjectType*. This behaviour is *Server* dependent. The *ObjectType* only specifies the minimum set of components that shall exist for each *Object* of an *ObjectType*.

In addition to the *AddNodes Service ObjectTypes* may have a special *Method* with the *BrowseName* “*Create*”. This Method is used to create an *Object* of this *ObjectType*. This *Method* may be useful for the creation of *Objects* where the semantic of the creation should differ from the default behaviour expected in the context of the *AddNodes Service*. For example, the values should directly differ from the default values or additional *Objects* should be added, etc. The input and output arguments of this *Method* depend on the *ObjectType*; the only commonality is the *BrowseName* identifying that this *Method* will create an *Object* based on the *ObjectType*. *Servers* should not provide a *Method* on an *ObjectType* with the *BrowseName* “*Create*” for any other purpose than creating *Objects* of the *ObjectType*.

5.6 Variables

5.6.1 General

Two types of *Variables* are defined, *Properties* and *DataVariables*. Although they differ in the way they are used as described in 4.4 and have different constraints described in the remainder of 5.6 they use the same *NodeClass* described in 5.6.2. The constraints of *Properties* based on this *NodeClass* are defined in 5.6.3, the constraints of *DataVariables* in 5.6.4.

5.6.2 Variable NodeClass

Variables are used to represent values which may be simple or complex. *Variables* are defined by *VariableTypes*, as specified in 5.6.5.

Variables are always defined as *Properties* or *DataVariables* of other *Nodes* in the *AddressSpace*. They are never defined by themselves. A *Variable* is always part of at least one other *Node*, but may be related to any number of other *Nodes*. *Variables* are defined using the *Variable NodeClass*, specified in Table 8.

Table 8 – Variable NodeClass

Name	Use	Data Type	Description
Attributes			
Base NodeClass Attributes	M	--	Inherited from the *Base NodeClass*. See 5.2.

<table>
<tr><th>Name</th><th>Use</th><th>Data Type</th><th>Description</th></tr>
<tr><td>Value</td><td>M</td><td>Defined by the DataType Attribute</td><td>The most recent value of the Variable that the Server has. Its data type is defined by the DataType Attribute. It is the only Attribute that does not have a data type associated with it. This allows all Variables to have a value defined by the same Value Attribute.</td></tr>
<tr><td>DataType</td><td>M</td><td>NodeId</td><td>NodeId of the DataType definition for the Value Attribute. Standard DataTypes are defined in Clause 8.</td></tr>
<tr><td>ValueRank</td><td>M</td><td>Int32</td><td>This Attribute indicates whether the Value Attribute of the Variable is an array and how many dimensions the array has.
It may have the following values:
n > 1: the Value is an array with the specified number of dimensions.
OneDimension (1): The value is an array with one dimension.
OneOrMoreDimensions (0): The value is an array with one or more dimensions.
Scalar (−1): The value is not an array.
Any (−2): The value can be a scalar or an array with any number of dimensions.
ScalarOrOneDimension (−3): The value can be a scalar or a one dimensional array.
NOTE All DataTypes are considered to be scalar, even if they have array-like semantics like ByteString and String.</td></tr>
<tr><td>ArrayDimensions</td><td>O</td><td>UInt32[]</td><td>This Attribute specifies the length of each dimension for an array value. The Attribute is intended to describe the capability of the Variable, not the current size.
The number of elements shall be equal to the value of the ValueRank Attribute. Shall be null if ValueRank ≤ 0.
A value of 0 for an individual dimension indicates that the dimension has a variable length.
For example, if a Variable is defined by the following C array:
Int32 myArray[346];
then this Variable’s DataType would point to an Int32, the Variable’s ValueRank has the value 1 and the ArrayDimensions is an array with one entry having the value 346.
Note that the maximum length of an array transferred on the wire is 2147483647 (max Int32) and a multidimentional array is encoded as a one dimensional array.</td></tr>
<tr><td>AccessLevel</td><td>M</td><td>Byte</td><td>The AccessLevel Attribute is used to indicate how the Value of a Variable can be accessed (read/write) and if it contains current and/or historic data. The AccessLevel does not take any user access rights into account, i.e. although the Variable is writable this may be restricted to a certain user / user group.
The AccessLevel is an 8-bit unsigned integer with the structure defined in the following table:
<table>
<tr><th>Field</th><th>Bit</th><th>Description</th></tr>
<tr><td>CurrentRead</td><td>0</td><td>Indicates if the current value is readable
(0 means not readable, 1 means readable).</td></tr>
<tr><td>CurrentWrite</td><td>1</td><td>Indicates if the current value is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>HistoryRead</td><td>2</td><td>Indicates if the history of the value is readable
(0 means not readable, 1 means readable).</td></tr>
<tr><td>HistoryWrite</td><td>3</td><td>Indicates if the history of the value is writable (0 means not writable, 1 means writable).</td></tr>
<tr><td>SemanticChange</td><td>4</td><td>Indicates if the Variable used as Property generates SemanticChangeEvents (see 9.33).</td></tr>
<tr><td>StatusWrite</td><td>5</td><td>Indicates if the current StatusCode of the value is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>TimestampWrite</td><td>6</td><td>Indicates if the current SourceTimestamp is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>Reserved</td><td>7</td><td>Reserved for future use. Shall always be zero.</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>Name</th><th>Use</th><th>Data Type</th><th>Description</th></tr>
<tr><td></td><td></td><td></td><td>The first two bits also indicate if a current value of this *Variable* is available and the second two bits indicates if the history of the *Variable* is available via the OPC UA *Server*.</td></tr>
<tr><td>UserAccessLevel</td><td>M</td><td>Byte</td><td>The *UserAccessLevel Attribute* is used to indicate how the *Value* of a *Variable* can be accessed (read/write) and if it contains current or historic data taking user access rights into account.
The *UserAccessLevel* is an 8-bit unsigned integer with the structure defined in the following table:
<table>
<tr><th>Field</th><th>Bit</th><th>Description</th></tr>
<tr><td>CurrentRead</td><td>0</td><td>Indicates if the current value is readable
(0 means not readable, 1 means readable).</td></tr>
<tr><td>CurrentWrite</td><td>1</td><td>Indicates if the current value is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>HistoryRead</td><td>2</td><td>Indicates if the history of the value is readable
(0 means not readable, 1 means readable).</td></tr>
<tr><td>HistoryWrite</td><td>3</td><td>Indicates if the history of the value is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>Reserved</td><td>4</td><td>Reserved for future use. Shall always be zero.</td></tr>
<tr><td>StatusWrite</td><td>5</td><td>Indicates if the current StatusCode of the value is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>Timestamp Write</td><td>6</td><td>Indicates if the current SourceTimestamp of the value is writable
(0 means not writable, 1 means writable).</td></tr>
<tr><td>Reserved</td><td>7</td><td>Reserved for future use. Shall always be zero.</td></tr>
</table>
The first two bits also indicate if a current value of this *Variable* is available and the second two bits indicate if the history of the *Variable* is available via the OPC UA *Server*.</td></tr>
<tr><td>MinimumSamplingInterval</td><td>O</td><td>Duration</td><td>The *MinimumSamplingInterval Attribute* indicates how “current” the *Value* of the *Variable* will be kept. It specifies (in milliseconds) how fast the *Server* can reasonably sample the value for changes (see Part 4 for a detailed description of sampling interval).
A *MinimumSamplingInterval* of 0 indicates that the *Server* is to monitor the item continuously. A *MinimumSamplingInterval* of -1 means indeterminate.</td></tr>
<tr><td>Historizing</td><td>M</td><td>Boolean</td><td>The *Historizing Attribute* indicates whether the *Server* is actively collecting data for the history of the *Variable*. This differs from the *AccessLevel Attribute* which identifies if the *Variable* has any historical data. A value of TRUE indicates that the *Server* is actively collecting data. A value of FALSE indicates the *Server* is not actively collecting data. Default value is FALSE.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>**References**</td><td></td><td></td><td></td></tr>
<tr><td>HasModellingRule</td><td>0..1</td><td></td><td>*Variables* can point to at most one *ModellingRule Object* using a *HasModellingRule Reference* (see 6.4.4 for details on *ModellingRules*).</td></tr>
<tr><td>HasProperty</td><td>0..*</td><td></td><td>*HasProperty References* are used to identify the *Properties* of a *DataVariable*.
Properties are not allowed to be the *SourceNode* of *HasProperty References.*</td></tr>
<tr><td>HasComponent</td><td>0..*</td><td></td><td>*HasComponent References* are used by complex *DataVariables* to identify their composed *DataVariables*.
Properties are not allowed to use this *Reference*.</td></tr>
<tr><td>HasTypeDefinition</td><td>1</td><td></td><td>The *HasTypeDefinition Reference* points to the type definition of the *Variable.* Each *Variable* shall have exactly one type definition and therefore be the *SourceNode* of exactly one *HasTypeDefinition Reference* pointing to a *VariableType*. See 4.5 for a description of type definitions.</td></tr>
<tr><td><other References></td><td>0..*</td><td></td><td>*Data Variables* may be the *SourceNode* of any other *References*.
Properties may only be the *SourceNode* of any *non-hierarchical Reference*.</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td>**Standard Properties**</td><td></td><td></td><td></td></tr>
<tr><td>NodeVersion</td><td>O</td><td>String</td><td>The *NodeVersion Property* is used to indicate the version of a *DataVariable*. It does not apply to *Properties*.
The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value</td></tr>
</table>

Name	Use	Data Type	Description
			changes except for the *DataType Attribute* do not cause the *NodeVersion* to change. *Clients* may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed. Although the relationship of a *Variable* to its *DataType* is not modelled using *References*, changes to the *DataType Attribute* of a *Variable* lead to an update of the *NodeVersion Property*.
LocalTime	O	TimeZone DataType	The *LocalTime Property* is only used for *DataVariables*. It does not apply to *Properties*. This *Property* is a structure containing the Offset and the DaylightSavingInOffset flag. The Offset specifies the time difference (in minutes) between the SourceTimestamp (UTC) associated with the value and the time at the location in which the value was obtained. The SourceTimestamp is defined in Part 4. If DaylightSavingInOffset is TRUE, then Standard/Daylight savings time (DST) at the originating location is in effect and Offset includes the DST correction. If FALSE then the Offset does not include DST correction and DST may or may not have been in effect.
DataTypeVersion	O	String	Only used for *Variables* of the *VariableType DataTypeDictionaryType* and *DataTypeDescriptionType* as described in 5.8.
DictionaryFragment	O	ByteString	Only used for *Variables* of the *VariableType DataTypeDescriptionType* as described in 5.8.
AllowNulls	O	Boolean	The *AllowNulls Property* is only used for *DataVariables*. It does not apply to *Properties*. This *Property* specifies if a null value is allowed for the *Value Attribute* of the *DataVariable*. If it is set to true, the *Server* may return null values and accept writing of null values. If it is set to false, the *Server* shall never return a null value and shall reject any request writing a null value. If this *Property* is not provided, it is *Server*-specific if null values are allowed or not.
ValueAsText	O	Localized Text	Only used for *DataVariables* having an *Enumeration DataType*. This optional *Property* provides the localized text representation of the enumeration value. It can be used by *Clients* only interested in displaying the text to subscribe to the *Property* instead of the value attribute.
MaxStringLength	O	UInt32	Only used for *DataVariables* having a *String DataType*. This optional *Property* indicates the maximum number of characters supported by the *DataVariable*.
MaxByteStringLength	O	UInt32	Only used for *DataVariables* having a *ByteString DataType*. This optional *Property* indicates the maximum number of bytes supported by the *DataVariable*.
MaxArrayLength	O	UInt32	Only used for *DataVariables* having its *ValueRank Attribute* not set to scalar. This optional *Property* indicates the maximum length of an array supported by the *DataVariable*. In a multidimensional array it indicates the overall length. For example, a three-dimensional array of 2 x 3 x 10 has the array length of 60. NOTE In order to expose the length of an array of bytes do not use the *DataType ByteString* but an array of the *DataType Byte*. In that case the *MaxArrayLength* applies.
EngineeringUnits	O	EU Information	Only used for *DataVariables* having a *Number DataType*. This optional *Property* indicates the engineering units for the value of the *DataVariable* (e.g. hertz or seconds). Details about the *Property* and what engineering units should be used are defined in Part 8. The *DataType EUInformation* is also defined in Part 8.

The *Variable NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2.

The *Variable NodeClass* also defines a set of *Attributes* that describe the *Variable's* Runtime value. The *Value Attribute* represents the *Variable* value. The *DataType*, *ValueRank* and *ArrayDimensions Attributes* provide the capability to describe simple and complex values.

The *AccessLevel Attribute* indicates the accessibility of the *Value* of a *Variable* not taking user access rights into account. If the OPC UA *Server* does not have the ability to get the *AccessLevel* information from the underlying system then it should state that it is readable and writable. If a read or write operation is called on the *Variable* then the *Server* should transfer this request and return the corresponding *StatusCode* even if such a request is rejected. *StatusCodes* are defined in Part 4.

The *SemanticChange* bit of the *AccessLevel Attribute* shall be set when the *Property* describes the semantic of the *Node* that owns the *Property* and changes of the *Property* value will generate *SemanticChangeEvents*. For example, a *Property* describing the engineering unit of a *DataVariable* will have the bit set, whereas a *Property* containing an Icon of the *DataVariable* will not. This behaviour is exactly the same as described by the *SemanticsChanged* bit of the *StatusCode* defined in Part 4. However, if subscribing to a *Variable* then one should look at the *StatusCode* to identify if the semantic has changed in order to receive this information before processing the value of the *Variable*.

The *UserAccessLevel Attribute* indicates the accessibility of the *Value* of a *Variable* taking user access rights into account. If the OPC UA *Server* does not have the ability to get any user access rights related information from the underlying system then it should use the same bit mask as used in the *AccessLevel Attribute*. The *UserAccessLevel Attribute* can restrict the accessibility indicated by the *AccessLevel Attribute*, but not exceed it.

The *MinimumSamplingInterval Attribute* specifies how fast the *Server* can reasonably sample the *value* for changes. The accuracy of this value (the ability of the *Server* to attain "best case" performance) can be greatly affected by system load and other factors.

The *Historizing Attribute* indicates whether the *Server* is actively collecting data for the history of the *Variable*. See Part 11 for details on historizing *Variables*.

Clients may read or write *Variable* values, or monitor them for value changes, as specified in Part 4. Part 8 defines additional rules when using the *Services* for automation data.

To specify its *ModellingRule*, a *Variable* can use at most one *HasModellingRule Reference* pointing to a *ModellingRule Object*. *ModellingRules* are defined in 6.4.4.

If the *Variable* is created based on an *InstanceDeclaration* (see 4.5) it shall have the same *BrowseName* as its *InstanceDeclaration*.

The other *References* are described separately for *Properties* and *DataVariables* in the remainder of 5.6

5.6.3 Properties

Properties are used to define the characteristics of *Nodes*. *Properties* are defined using the *Variable NodeClass*, specified in Table 8. However, they restrict their use.

Properties are the leaf of any hierarchy; therefore they shall not be the *SourceNode* of any *hierarchical References*. This includes the *HasComponent* or *HasProperty Reference*, that is, *Properties* do not contain *Properties* and cannot expose their complex structure. However, they may be the *SourceNode* of any *non-hierarchical References*.

The *HasTypeDefinition Reference* points to the *VariableType* of the *Property*. Since *Properties* are uniquely identified by their *BrowseName*, all *Properties* shall point to the *PropertyType* defined in Part 5.

Properties shall always be defined in the context of another *Node* and shall be the *TargetNode* of at least one *HasProperty Reference*. To distinguish them from *DataVariables*, they shall not be the *TargetNode* of any *HasComponent Reference*. Thus, a *HasProperty Reference* pointing to a *Variable Node* defines this *Node* as a *Property*.

The *BrowseName* of a *Property* is always unique in the context of a *Node*. It is not permitted for a *Node* to refer to two *Variables* using *HasProperty References* having the same *BrowseName*.

5.6.4 DataVariable

DataVariables represent the content of an *Object*. *DataVariables* are defined using the *Variable NodeClass*, specified in Table 8.

DataVariables identify their *Properties* using *HasProperty References*. Complex *DataVariables* use *HasComponent References* to expose their component *DataVariables*.

The *Property NodeVersion* indicates the version of the *DataVariable*. The *Property LocalTime* indicates the difference between the SourceTimestamp of the value and the standard time at the location in which the value was obtained. The *Property DataTypeVersion* is used only for *DataTypeDictionaries* and *DataTypeDescriptions* as defined in 5.8. The Standard *Property DictionaryFragment* is used only for *DataTypeDescriptions* as defined in 5.8. The *Property AllowNulls* indicates if null values are allowed for the *Value Attribute*. The *Property ValueAsText* provides a localized text representation for enumeration values. The *Property MaxStringLength* indicates the maximum allowed length of a string value, the *Property MaxByteStringLength* the maximum allowed length of a byte string value and the *Property MaxArrayLength* the maximum allowed array length of the value. The *Property EngineeringUnits* indicates the engineering units of the value. There are no additional *Properties* defined for *DataVariables* in this part of this document. Additional parts of this series of standards may define additional *Properties* for *DataVariables*. Part 8 defines a set of *Properties* that can be used for *DataVariables*.

DataVariables may use additional *References* to define relationships to other *Nodes*. No restrictions are placed on the types of *References* used or on the *NodeClasses* of the *Nodes* that may be referenced. However, restrictions may be defined by the *ReferenceType* excluding its use for *DataVariables*. Standard *ReferenceTypes* are described in Clause 7.

A *DataVariable* is intended to be defined in the context of an *Object*. However, complex *DataVariables* may expose other *DataVariables*, and *ObjectTypes* and complex *VariableTypes* may also contain *DataVariables*. Therefore each *DataVariable* shall be the *TargetNode* of at least one *HasComponent Reference* coming from an *Object*, an *ObjectType*, a *DataVariable* or a *VariableType*. *DataVariables* shall not be the *TargetNode* of any *HasProperty References*. Therefore, a *HasComponent Reference* pointing to a *Variable Node* identifies it as a *DataVariable*.

The *HasTypeDefinition Reference* points to the *VariableType* used as type definition of the *DataVariable*.

If the *DataVariable* is used as *InstanceDeclaration* (see 4.5) all *Nodes* referenced with *hierarchical References* in the forward direction shall have unique *BrowseNames* in the context of this *DataVariable*.

5.6.5 VariableType NodeClass

VariableTypes are used to provide type definitions for *Variables*. *VariableTypes* are defined using the *VariableType NodeClass*, as specified in Table 9.

Table 9 – VariableType NodeClass

Name	Use	Data Type	Description
Attributes			
Base NodeClass Attributes	M	--	Inherited from the *Base NodeClass*. See 5.2
Value	O	Defined by the *DataType attribute*	The default *Value* for instances of this type.
DataType	M	NodeId	*NodeId* of the data type definition for instances of this type.
ValueRank	M	Int32	This *Attribute* indicates whether the *Value Attribute* of the *VariableType* is an array and how many dimensions the array has. It may have the following values: *n* > 1: the Value is an array with the specified number of dimensions. OneDimension (1): The value is an array with one dimension. OneOrMoreDimensions (0): The value is an array with one or more dimensions. Scalar (−1): The value is not an array. Any (−2): The value can be a scalar or an array with any number of dimensions. ScalarOrOneDimension (−3): The value can be a scalar or a one dimensional array. NOTE All DataTypes are considered to be scalar, even if they have array-like semantics like ByteString and String.
ArrayDimensions	O	UInt32[]	This *Attribute* specifies the length of each dimension for an array value. The Attribute is intended to describe the capability of the *VariableType*, not the current size. The number of elements shall be equal to the value of the *ValueRank Attribute*. Shall be null if *ValueRank* ≤ 0. A value of 0 for an individual dimension indicates that the dimension has a variable length. For example, if a *VariableType* is defined by the following C array: Int32 myArray[346]; then this *VariableType's DataType* would point to an Int32, the *VariableType's ValueRank* has the value 1 and the *ArrayDimensions* is an array with one entry having the value 346.
IsAbstract	M	Boolean	A boolean *Attribute* with the following values: TRUE it is an abstract *VariableType*, i.e. no *Variable* of this type shall exist, only of its subtypes. FALSE it is not an abstract *VariableType*, i.e. *Variables* of this type can exist.
References			
HasProperty	0..*		*HasProperty References* are used to identify the *Properties* of the *VariableType*. The referenced *Nodes* may be instantiated by the instances of this type, depending on the *ModellingRules* defined in 6.4.4.
HasComponent	0..*		*HasComponent References* are used for complex *VariableTypes* to identify their containing *DataVariables*. Complex *VariableTypes* can only be used for *DataVariables*. The referenced *Nodes* may be instantiated by the instances of this type, depending on the *ModellingRules* defined in 6.4.4.
HasSubtype	0..*		*HasSubtype References* identify *VariableTypes* that are subtypes of this type. The inverse *subtype of Reference* identifies the parent type of this type.
GeneratesEvent	0..*		*GeneratesEvent References* identify the type of *Events* instances of this type may generate.
<other References>	0..*		*VariableTypes* may contain other *References* that can be instantiated by *Variables* defined by this *VariableType*. *ModellingRules* are defined in 6.4.4.
Standard Properties			
NodeVersion	O	String	The *NodeVersion Property* is used to indicate the version of a *Node*. The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value changes except for the *DataType Attribute* do not cause the *NodeVersion* to change. *Clients* may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed. Although the relationship of a *VariableType* to its *DataType* is not modelled using *References*, changes to the *DataType Attribute* of a *VariableType* lead to an update of the *NodeVersion Property*.

The *VariableType NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2. The *VariableType NodeClass* also defines a set of *Attributes* that describe the default or initial value of its instance *Variables*. The *Value Attribute* represents the default value. The *DataType*, *ValueRank* and *ArrayDimensions Attributes* provide the capability to describe simple and complex values. The *IsAbstract Attribute* defines if the type can be directly instantiated.

The *VariableType NodeClass* uses *HasProperty References* to define the *Properties* and *HasComponent References* to define *DataVariables*. Whether they are instantiated depends on the *ModellingRules* defined in 6.4.4.

The *Property NodeVersion* indicates the version of the *VariableType*. There are no additional *Properties* defined for *VariableTypes* in this document. Additional parts of this series of standards may define additional *Properties* for *VariableTypes*. Part 8 defines a set of *Properties* that can be used for *VariableTypes*.

HasSubtype References are used to subtype *VariableTypes*. *VariableType* subtypes inherit the general semantics from the parent type. The general rules for subtyping are defined in Clause 6. It is not required to provide the *HasSubtype Reference* for the supertype, but it is required that the subtype provides the inverse *Reference* to its supertype.

GeneratesEvent References identify that *Variables* of the *VariableType* may be the source of an *Event* of the specified *EventType* or one of its subtypes. *Servers* should make *GeneratesEvent References* bidirectional *References*. However, it is allowed to be unidirectional when the *Server* is not able to expose the inverse direction pointing from the *EventType* to each *VariableType* supporting the *EventType.*

GeneratesEvent References are optional, i.e. *Variables* may generate *Events* of an *EventType* that is not exposed by its *VariableType*.

VariableTypes may use any additional *References* to define relationships to other *Nodes*. No restrictions are placed on the types of *References* used or on the *NodeClasses* of the *Nodes* that may be referenced. However, restrictions may be defined by the *ReferenceType* excluding its use for *VariableTypes*. Standard *ReferenceTypes* are described in Clause 7.

All *Nodes* referenced with *hierarchical References* shall have unique *BrowseNames* in the context of the *VariableType* (see 4.5).

5.6.6 Client-side creation of Variables of an VariableType

Variables are always based on a *VariableType*, i.e. they have a *HasTypeDefinition Reference* pointing to its *VariableType*.

Clients can create *Variables* using the *AddNodes Service* defined in Part 4. The *Service* requires specifying the *TypeDefinitionNode* of the *Variable*. A *Variable* created by the *AddNodes Service* contains all components defined by its *VariableType* dependent on the *ModellingRules* specified for the components. However, the *Server* may add additional components and *References* to the *Variable* and its components that are not defined by the *VariableType*. This behaviour is *Server* dependent. The *VariableType* only specifies the minimum set of components that shall exist for each *Variable* of a *VariableType*.

5.7 Method NodeClass

Methods define callable functions. *Methods* are invoked using the *Call Service* defined in Part 4. Method invocations are not represented in the *AddressSpace*. Method invocations always run to completion and always return responses when complete. *Methods* are defined using the *Method NodeClass*, specified in Table 10.

Table 10 – Method NodeClass

Name	Use	Data Type	Description
Attributes			
Base NodeClass Attributes	M	--	Inherited from the *Base NodeClass*. See 5.2.
Executable	M	Boolean	The *Executable Attribute* indicates if the *Method* is currently executable (“False” means not executable, “True” means executable). The *Executable Attribute* does not take any user access rights into account, i.e. although the *Method* is executable this may be restricted to a certain user / user group.
UserExecutable	M	Boolean	The *UserExecutable Attribute* indicates if the *Method* is currently executable taking user access rights into account (“False” means not executable, “True” means executable).
References			
HasProperty	0..*		*HasProperty References* identify the *Properties* for the *Method*.
HasModellingRule	0..1		*Methods* can point to at most one *ModellingRule Object* using a *HasModellingRule Reference* (see 6.4.4 for details on *ModellingRules*).
GeneratesEvent	0..*		*GeneratesEvent References* identify the type of *Events* that will be generated whenever the *Method* is called.
AlwaysGeneratesEvent	0..*		*AlwaysGeneratesEvent References* identify the type of *Events* that shall be generated whenever the *Method* is called.
<other References>	0..*		*Methods* may contain other *References*.
Standard Properties			
NodeVersion	O	String	The *NodeVersion Property* is used to indicate the version of a *Node*. The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value changes do not cause the *NodeVersion* to change. *Clients* may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed.
InputArguments	O	Argument[]	The *InputArguments Property* is used to specify the arguments that shall be used by a client when calling the *Method.*
OutputArguments	O	Argument[]	The *OutputArguments Property* specifies the result returned from the *Method* call.

The *Method NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2. The *Method NodeClass* defines no additional *Attributes*.

The *Executable Attribute* indicates whether the *Method* is executable, not taking user access rights into account. If the OPC UA *Server* cannot get the *Executable* information from the underlying system, it should state that it is executable. If a *Method* is called then the *Server* should transfer this request and return the corresponding *StatusCode* even if such a request is rejected. *StatusCodes* are defined in Part 4.

The *UserExecutable Attribute* indicates whether the *Method* is executable, taking user access rights into account. If the OPC UA *Server* cannot get any user rights related information from the underlying system, it should use the same value as used in the *Executable Attribute*. The *UserExecutable Attribute* can be set to “False”, even if the *Executable Attribute* is set to “True”, but it shall be set to “False” if the *Executable Attribute* is set to “False”.

Properties may be defined for *Methods* using *HasProperty References*. The *Properties InputArguments* and *OutputArguments* specify the input arguments and output arguments of the *Method*. Both contain an array of the *DataType Argument* as specified in 8.6. An empty array or a *Property* that is not provided indicates that there are no input arguments or output arguments for the *Method*. The *Property NodeVersion* indicates the version of the *Method*. There are no additional *Properties* defined for *Methods* in this document. Additional parts of this series of standards may define additional *Properties* for *Methods*.

To specify its *ModellingRule*, a *Method* can use at most one *HasModellingRule Reference* pointing to a *ModellingRule Object*. *ModellingRules* are defined in 6.4.4.

GeneratesEvent References identify that *Methods* may generate an *Event* of the specified *EventType* or one of its subtypes for every call of the *Method*. A *Server* may generate one *Event* for each referenced *EventType* when a *Method* is successfully called.

AlwaysGeneratesEvent References identify that *Methods* will generate an *Event* of the specified *EventType* or one of its subtypes for every call of the *Method*. A *Server* shall always generate one *Event* for each referenced *EventType* when a *Method* is successfully called.

Servers should make *GeneratesEvent References* bidirectional *References*. However, it is allowed to be unidirectional when the *Server* is not able to expose the inverse direction pointing from the *EventType* to each *Method* generating the *EventType.*

GeneratesEvent References are optional, i.e. the call of a *Method* may produce *Events* of an *EventType* that is not referenced with a *GeneratesEvent Reference* by the *Method*.

Methods may use additional *References* to define relationships to other *Nodes*. No restrictions are placed on the types of *References* used or on the *NodeClasses* of the *Nodes* that may be referenced. However, restrictions may be defined by the *ReferenceType* excluding its use for *Methods*. Standard *ReferenceTypes* are described in Clause 7.

A *Method* shall always be the *TargetNode* of at least one *HasComponent Reference*. The *SourceNode* of these *HasComponent References* shall be an *Object* or an *ObjectType*. If a *Method* is called then the *NodeId* of one of those *Nodes* shall be put into the Call *Service* defined in Part 4 as parameter to detect the context of the *Method* operation.

If the *Method* is used as *InstanceDeclaration* (see 4.5) all *Nodes* referenced with *hierarchical References* in forward direction shall have unique *BrowseNames* in the context of this *Method*.

5.8 DataTypes

5.8.1 DataType Model

The DataType Model is used to define simple and structured data types. Data types are used to describe the structure of the *Value Attribute* of *Variables* and their *VariableTypes*. Therefore each *Variable* and *VariableType* is pointing with its *DataType Attribute* to a *Node* of the *DataType NodeClass* as shown in Figure 9.

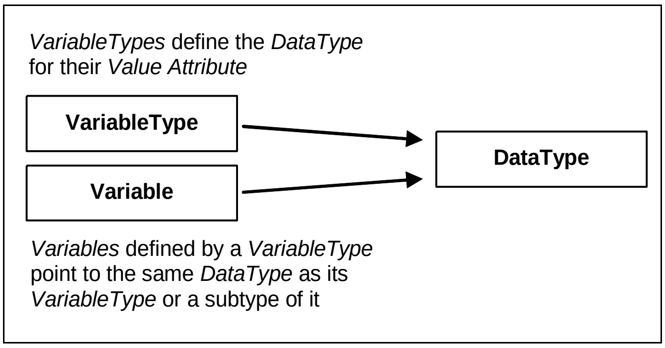


Figure 9 – Variables, VariableTypes and their DataTypes

In many cases, the *NodeId* of the *DataType Node* – the *DataTypeId* – will be well-known to *Clients* and *Servers*. Clause 8 defines *DataTypes* and Part 6 defines their *DataTypeIds*. In addition, other organizations may define *DataTypes* that are well-known in the industry. Well-known *DataTypeIds* provide for commonality across OPC UA *Servers* and allow *Clients* to interpret values without having to read the type description from the *Server*. Therefore, *Servers* may use well-known *DataTypeIds* without representing the corresponding *DataType Nodes* in their *AddressSpaces*.

In other cases, *DataTypes* and their corresponding *DataTypeIds* may be vendor-defined. *Servers* should attempt to expose the *DataType Nodes* and the information about the structure of those *DataTypes* for *Clients* to read, although this information might not always be available to the *Server*.

Figure 10 illustrates the *Nodes* used in the *AddressSpace* to describe the structure of a *DataType*. The *DataType* points to an *Object* of type *DataTypeEncodingType*. Each *DataType* can have several *DataTypeEncoding*, for example “Default”, “UA Binary” and “XML” encoding. Services in Part 4 allow *Clients* to request an encoding or choosing the “Default” encoding.

Each *DataTypeEncoding* is used by exactly one *DataType*, that is, it is not permitted for two *DataTypes* to point to the same *DataTypeEncoding*. The *DataTypeEncoding Object* points to exactly one *Variable* of type *DataTypeDescriptionType*. The *DataTypeDescription Variable* belongs to a *DataTypeDictionary Variable*.

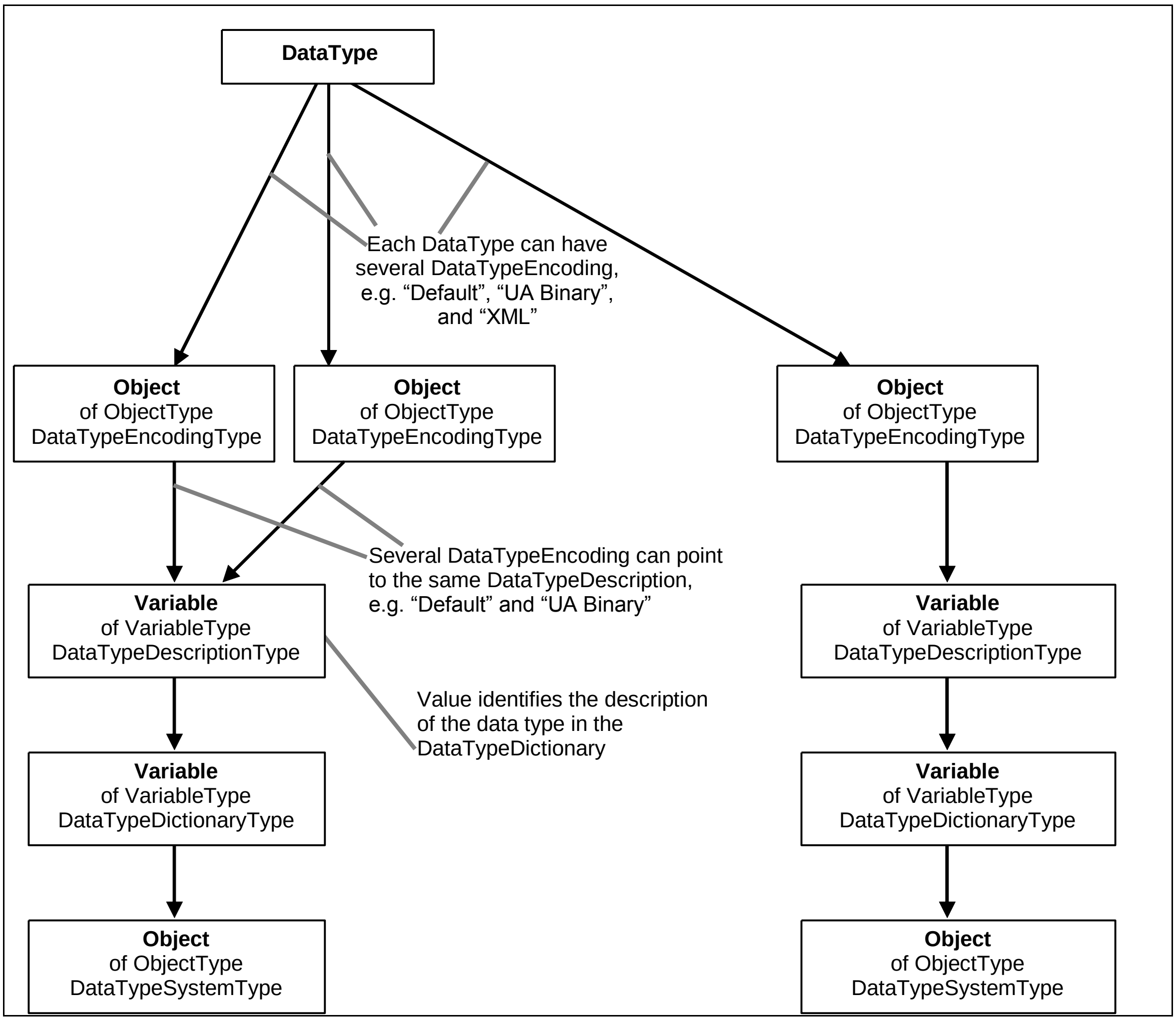


Figure 10 – DataType Model

Since the *NodeId* of the *DataTypeEncoding* will be used in some Mappings to identify the *DataType* and its encoding as defined in Part 6, those *NodeIds* may also be well-known for well-known *DataTypeIds*.

The *DataTypeDictionary* describes a set of *DataTypes* in sufficient detail to allow *Clients* to parse/interpret *Variable Values* that they receive and to construct *Values* that they send. The *DataTypeDictionary* is represented as a *Variable* of type *DataTypeDictionaryType* in the *AddressSpace*, the description about the *DataTypes* is contained in its *Value Attribute*. All containing *DataTypes* exposed in the *AddressSpace* are represented as *Variables* of type *DataTypeDescriptionType*. The *Value* of one of these Variables identifies the description of a *DataType* in the *Value Attribute* of the *DataTypeDictionary*.

The *DataType* of a *DataTypeDictionary Variable* is always a ByteString. The format and conventions for defining *DataTypes* in this ByteString are defined by *DataTypeSystems*. *DataTypeSystems* are identified by *NodeIds*. They are represented in the *AddressSpace* as *Objects* of the *ObjectType DataTypeSystemType*. Each *Variable* representing a *DataTypeDictionary* references a *DataTypeSystem Object* to identify their *DataTypeSystem*.

A client shall recognise the *DataTypeSystem* to parse any of the type description information. OPC UA *Clients* that do not recognise a *DataTypeSystem* will not be able to interpret its type descriptions, and consequently, the values described by them. In these cases, *Clients* interpret these values as opaque ByteStrings.

OPC Binary and W3C XML Schema are examples of *DataTypeSystems*. The OPC Binary *DataTypeSystem* is defined in Annex C. OPC Binary uses XML to describe binary data values. W3C XML Schema is specified in XML Schema Part 1 and XML Schema Part 2

5.8.2 Encoding Rules for different kinds of DataTypes

Different kinds of *DataTypes* are handled differently regarding their encoding and according to whether this encoding is represented in the *AddressSpace*.

Built-in DataTypes are a fixed set of *DataTypes* (see Part 6 for a complete list of *Built-in* DataTypes). They have no encodings visible in the *AddressSpace* since the encoding should be known to all OPC UA products. Examples of *Built-in DataTypes* are *Int32* (see 8.26) and *Double* (see 8.12).

Simple DataTypes are subtypes of the *Built-in DataTypes*. They are handled on the wire like the *Built-in DataType*, i.e. they cannot be distinguished on the wire from their *Built-in* supertypes. Since they are handled like *Built-in DataTypes* regarding the encoding they cannot have encodings defined in the *AddressSpace*. *Clients* can read the *DataType Attribute* of a *Variable* or *VariableType* to identify the *Simple DataType* of the *Value Attribute*. An example of a *Simple DataType* is *Duration*. It is handled on the wire as a *Double* but the Client can read the *DataType Attribute* and thus interpret the value as defined by *Duration* (see 8.13).

Structured DataTypes are *DataTypes* that represent structured data and are not defined as *Built-in DataTypes*. *Structured DataTypes* inherit directly or indirectly from the *DataType Structure* defined in 8.33. *Structured DataTypes* may have several encodings and the encodings are exposed in the *AddressSpace*. How the encoding of *Structured DataTypes* is handled on the wire is defined in Part 6. The encoding of the *Structured DataType* is transmitted with each value, thus *Clients* are aware of the *DataType* without reading the *DataType Attribute*. The encoding has to be transmitted so the Client is able to interpret the data. An example of a *Structured DataType* is *Argument* (see 8.6).

Enumeration DataTypes are *DataTypes* that represent discrete sets of named values. Enumerations are always encoded as Int32 on the wire as defined in Part 6. Enumeration *DataTypes* inherit directly or indirectly from the *DataType Enumeration* defined in 8.14. Enumerations have no encodings exposed in the *AddressSpace*. To expose the human-readable representation of an enumerated value the *DataType Node* may have the *EnumStrings Property* that contains an array of *LocalizedText*. The Integer representation of the enumeration value points to a position within that array. *EnumValues Property* can be used instead of the *EnumStrings* to support integer representation of enumerations that are not zero-based or have gaps. It contains an array of a *Structured DataType* containing the integer representation as well as the human-readable representation. An example of an enumeration *DataType* containing a sparse list of Integers is *NodeClass* which is defined in 8.30.

In addition to the *DataTypes* described above, abstract *DataTypes* are also supported, which do not have any encodings and cannot be exchanged on the wire. *Variables* and *VariableTypes* use abstract *DataTypes* to indicate that their *Value* may be any one of the subtypes of the abstract *DataType*. An example of an abstract *DataType* is Integer which is defined in 8.24.

5.8.3 DataType NodeClass

The *DataType NodeClass* describes the syntax of a *Variable Value*. The *DataTypes* may be simple or complex, depending on the *DataTypeSystem*. *DataTypes* are defined using the *DataType NodeClass*, as specified in Table 11.

Table 11 – DataType NodeClass

Name	Use	Data Type	Description
Attributes			
Base NodeClass Attributes	M	--	Inherited from the *Base NodeClass*. See 5.2.
IsAbstract	M	Boolean	A boolean *Attribute* with the following values: TRUE it is an abstract *DataType*. FALSE it is not an abstract *DataType*.
References			
HasProperty	0..*		*HasProperty References* identify the *Properties* for the *DataType*.
HasSubtype	0..*		*HasSubtype References* may be used to span a data type hierarchy.
HasEncoding	0..*		*HasEncoding References* identify the encodings of the *DataType* represented as *Objects* of type *DataTypeEncodingType*. Only concrete *Structured DataTypes* may use *HasEncoding References*. Abstract, *Built-in, Enumeration,* and *Simple DataTypes* are not allowed to be the *SourceNode* of a *HasEncoding Reference*. Each concrete *Structured DataType* shall point to at least one *DataTypeEncoding Object* with the *BrowseName* “Default Binary” or “Default XML” having the *NamespaceIndex* 0. The *BrowseName* of the *DataTypeEncoding Objects* shall be unique in the context of a *DataType*, i.e. a *DataType* shall not point to two *DataTypeEncodings* having the same *BrowseName*.
Standard Properties			
NodeVersion	O	String	The *NodeVersion Property* is used to indicate the version of a *Node*. The *NodeVersion Property* is updated each time a *Reference* is added or deleted to the *Node* the *Property* belongs to. *Attribute* value changes do not cause the *NodeVersion* to change. Clients may read the *NodeVersion Property* or subscribe to it to determine when the structure of a *Node* has changed.
EnumStrings	O	LocalizedText[]	The *EnumStrings Property* only applies for *Enumeration DataTypes*. It shall not be applied for other *DataTypes*. If the *EnumValues Property* is provided, the *EnumStrings Property* shall not be provided. Each entry of the array of *LocalizedText* in this *Property* represents the human-readable representation of an enumerated value. The Integer representation of the enumeration value points to a position of the array.
EnumValues	O	EnumValueType[]	The *EnumValues Property* only applies for *Enumeration DataTypes*. It shall not be applied for other *DataTypes*. If the *EnumStrings Property* is provided, the *EnumValues Property* shall not be provided. Using the *EnumValues Property* it is possible to represent Enumerations with integers that are not zero-based or have gaps (e.g. 1, 2, 4, 8, 16). Each entry of the array of *EnumValueType* in this *Property* represents one enumeration value with its integer notation, human-readable representation and help information.
OptionSetValues	O	LocalizedText[]	The *OptionSetValues Property* only applies for *OptionSet DataTypes* and *UInteger DataTypes*. An *OptionSet DataType* is used to represent a bit mask and the *OptionSetValues Property* contains the human-readable representation for each bit of the bit mask. The *OptionSetValues Property* provides an array of *LocalizedText* containing the human-readable representation for each bit.

The *DataType NodeClass* inherits the base *Attributes* from the *Base NodeClass* defined in 5.2. The *IsAbstract Attribute* specifies if the *DataType* is abstract or not. Abstract *DataTypes* can be used in the *AddressSpace*, i.e. *Variables* and *VariableTypes* can point with their *DataType Attribute* to an abstract *DataType*. However, concrete values can never be of an abstract *DataType* and shall always be of a concrete subtype of the abstract *DataType*.

HasProperty References are used to identify the *Properties* of a *DataType*. The *Property NodeVersion* is used to indicate the version of the *DataType*. This Version is not affected by the *DataTypeVersion Property* of *DataTypeDictionaries* and *DataTypeDescriptions*. The *Property EnumStrings* contains human-readable representations of enumeration values and is only applied to *Enumeration DataTypes*. Instead of the *EnumStrings Property* an *Enumeration DataType* can also use the *EnumValues Property* to represent *Enumerations* with integer values that are not zero-based or containing gaps. There are no additional *Properties* defined for *DataTypes* in this standard. Additional parts of this series of standards may define additional *Properties* for *DataTypes*.

HasSubtype References may be used to expose a data type hierarchy in the *AddressSpace*. This hierarchy shall reflect the hierarchy specified in the *DataTypeDictionary*. The semantic of subtyping depends on the *DataTypeSystem*. *Servers* need not provide *HasSubtype References*, even if their *DataTypes* span a type hierarchy. *Clients* should not make any assumptions about any other semantic with that information than provided by the *DataTypeDictionary*. For example, it might not be possible to cast a value of one data type to its base data type. Some restrictions apply for subtyping enumeration DataTypes as defined in 8.14.

HasEncoding References point from the *DataType* to its *DataTypeEncodings*. Following such a *Reference*, the client can browse to the *DataTypeDictionary* describing the structure of the *DataType* for the used encoding. Each concrete *Structured DataType* can point to many *DataTypeEncodings*, but each *DataTypeEncoding* shall belong to one *DataType*, that is, it is not permitted for two *DataType Nodes* to point to the same *DataTypeEncoding Object* using *HasEncoding References*.

An abstract *DataType* is not the *SourceNode* of a *HasEncoding Reference*. The *DataTypeEncoding* of an abstract *DataType* is provided by its concrete subtypes.

DataType Nodes shall not be the *SourceNode* of other types of *References*. However, they may be the *TargetNode* of other *References*.

5.8.4 DataTypeDictionary, DataTypeDescription, DataTypeEncoding and DataTypeSystem

A *DataTypeDictionary* is an entity that contains a set of type descriptions, such as an XML schema. *DataTypeDictionaries* are defined as *Variables* of the *VariableType DataTypeDictionaryType*.

A *DataTypeSystem* specifies the format and conventions for defining *DataTypes* in *DataTypeDictionaries. DataTypeSystems* are defined as *Objects* of the *ObjectType DataTypeSystemType*.

The *ReferenceType* used to relate *Objects* of the *ObjectType DataTypeSystemType* to *Variables* of the *VariableType DataTypeDictionaryType* is the *HasComponent ReferenceType*. Thus, the *Variable* is always the *TargetNode* of a *HasComponent Reference*; this is a requirement for *Variables*. However, for *DataTypeDictionaries* the *Server* shall always provide the inverse *Reference*, since it is necessary to know the *DataTypeSystem* when processing the *DataTypeDictionary*.

Changes may be a result of a change to a type description, but it is more likely that dictionary changes are a result of the addition or deletion of type descriptions. This includes changes made while the *Server* is offline so that the new version is available when the *Server* restarts. *Clients* may subscribe to the *DataTypeVersion Property* to determine if the *DataTypeDictionary* has changed since it was last read.

The *Server* may, but is not required to, make the *DataTypeDictionary* contents available to *Clients* through the *Value Attribute*. *Clients* should assume that *DataTypeDictionary* contents are relatively large and that they will encounter performance problems if they automatically read the *DataTypeDictionary* contents each time they encounter an instance of a specific *DataType*. The client should use the *DataTypeVersion Property* to determine whether the locally cached copy is still valid. If the client detects a change to the *DataTypeVersion*, then it shall re-read the *DataTypeDictionary*. This implies that the *DataTypeVersion* shall be updated by a *Server* even after restart since *Clients* may persistently store the locally cached copy.

The *Value Attribute* of the *DataTypeDictionary* containing the type descriptions is a ByteString whose formatting is defined by the *DataTypeSystem*. For the “XML Schema” *DataTypeSystem*, the ByteString contains a valid XML Schema document. For the “OPC Binary” *DataTypeSystem*, the ByteString contains a string that is a valid XML document. The *Server* shall ensure that any change to the contents of the ByteString is matched with a corresponding change to the

DataTypeVersion Property. In other words, the client may safely use a cached copy of the *DataTypeDictionary*, as long as the *DataTypeVersion* remains the same.

DataTypeDictionaries are complex *Variables* which expose their *DataTypeDescriptions* as *Variables* using *HasComponent References.* A *DataTypeDescription* provides the information necessary to find the formal description of a *DataType* within the *DataTypeDictionary*. The *Value* of a *DataTypeDescription* depends on the *DataTypeSystem* of the *DataTypeDictionary*. When using “OPC Binary” dictionaries the *Value* shall be the name of the *TypeDescription*. When using “XML Schema” dictionaries the Value shall be an Xpath expression (see XPATH) which points to an XML element in the schema document.

Like *DataTypeDictionaries* each *DataTypeDescription* provides the *Property DataTypeVersion* indicating whether the type description of the *DataType* has changed. Changes to the *DataTypeVersion* may impact the operation of *Subscriptions*. If the *DataTypeVersion* changes for a *Variable* that is being monitored for a *Subscription* and that uses this *DataTypeDescription*, then the next data change *Notification* sent for the *Variable* will contain a status that indicates the change in the *DataTypeDescription*.

DataTypeEncoding Objects of the *DataTypes* reference their *DataTypeDescriptions* of the *DataTypeDictionaries* using *HasDescription* References. *Servers* shall provide the inverse *References* that relate the *DataTypeDescriptions* back to the *DataTypeEncoding Objects*. If a *DataType Node* is exposed in the *AddressSpace*, it shall provide its *DataTypeEncodings* and if a *DataTypeDictionary* is exposed then it should expose all of its *DataTypeDescriptions*. Both of these *References* shall be bi-directional.

The *VariableTypes DataTypeDictionaryType* and *DataTypeDescriptionType* and the *ObjectTypes DataTypeSystemType* and *DataTypeEncodingType* are formally defined in Part 5.

Figure 11 provides an example how *DataTypes* are modelled in the *AddressSpace*.

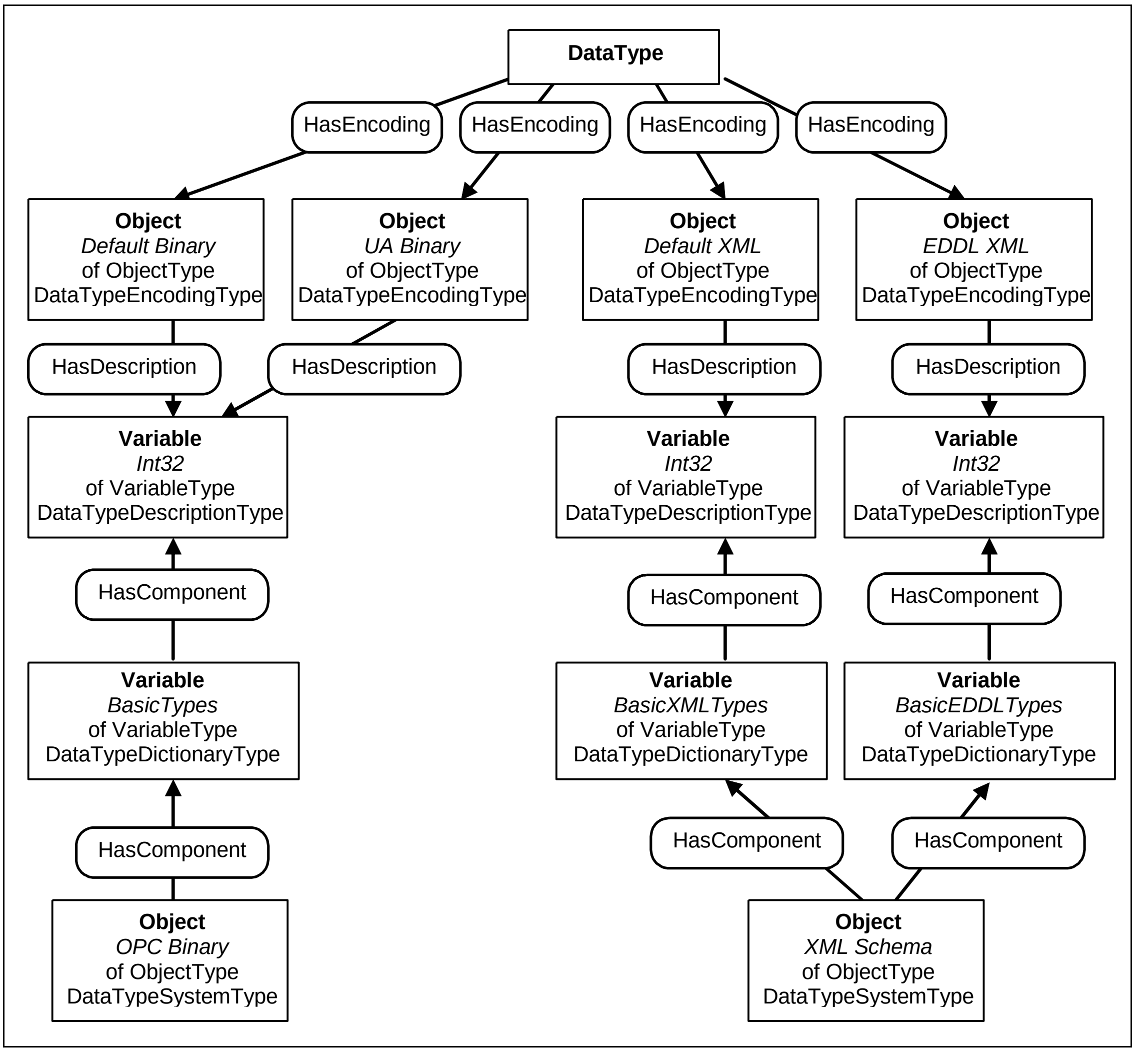


Figure 11 – Example of DataType Modelling

In some scenarios an OPC UA *Server* may have resource limitations which make it impractical to expose large *DataTypeDictionaries*. In these scenarios the *Server* may be able to provide access to descriptions for individual DataTypes even if the entire dictionary cannot be read. For this reason, this standard defines a *Property* for the *DataTypeDescription* called *DictionaryFragment* (see 5.6.2). This *Property* is a ByteString that contains a subset of the *DataTypeDictionary* which describes the format of the *DataType* associated with the *DataTypeDescription*. Thus, the *Server* splits the large *DataTypeDictionary* into several small parts and *Clients* can access without affecting the overall system performance.

However, *Servers* should provide the whole *DataTypeDictionary* at once if this is possible. It is typically more efficient to read the whole *DataTypeDictionary* at once instead of reading individual parts.

5.9 Summary of Attributes of the NodeClasses

Table 12 summarises all *Attributes* defined in this document and points out which *NodeClasses* use them either in an optional (O) or mandatory (M) way.

Table 12 – Overview of Attributes

Attribute	Variable	Variable Type	Object	Object Type	Reference Type	DataType	Method	View
AccessLevel	M							
ArrayDimensions	O	O						
BrowseName	M	M	M	M	M	M	M	M
ContainsNoLoops								M
DataType	M	M						
Description	O	O	O	O	O	O	O	O
DisplayName	M	M	M	M	M	M	M	M
EventNotifier			M					M
Executable							M	
Historizing	M							
InverseName					O			
IsAbstract		M		M	M	M		
MinimumSamplingInterval	O							
NodeClass	M	M	M	M	M	M	M	M
NodeId	M	M	M	M	M	M	M	M
Symmetric					M			
UserAccessLevel	M							
UserExecutable							M	
UserWriteMask	O	O	O	O	O	O	O	O
Value	M	O						
ValueRank	M	M						
WriteMask	O	O	O	O	O	O	O	O

6 Type Model for ObjectTypes and VariableTypes

6.1 Overview

In the remainder of 6 the type model of *ObjectTypes* and *VariableTypes* is defined regarding subtyping and instantiation.

6.2 Definitions

6.2.1 InstanceDeclaration

An *InstanceDeclaration* is an *Object*, *Variable* or *Method* that references a *ModellingRule* with a *HasModellingRule Reference* and is the *TargetNode* of a *hierarchical Reference* from a *TypeDefinitionNode* or another *InstanceDeclaration*.

6.2.2 Instances without ModellingRules

If no *ModellingRule* exists then the *Node* is neither considered for instantiation of a type nor for subtyping.

If a *Node* referenced by a *TypeDefinitionNode* does not reference a *ModellingRule* it indicates that this *Node* only belongs to the *TypeDefinitionNode* and not to the instances. For example, an *ObjectType Node* may contain a *Property* that describes scenarios where the type could be used. This *Property* would not be considered when creating instances of the type. This is also true for subtyping, that is, subtypes of the type definition would not inherit the referenced *Node*.

6.2.3 InstanceDeclarationHierarchy

The *InstanceDeclarationHierarchy* of a *TypeDefinitionNode* contains the *TypeDefinitionNode* and all *InstanceDeclarations* that are directly or indirectly referenced from the *TypeDefinitionNode* using *hierarchical References* in the forward direction.

6.2.4 Similar Node of InstanceDeclaration

A similar *Node* of an *InstanceDeclaration* is a *Node* that has the same *BrowseName* and *NodeClass* as the *InstanceDeclaration* and in cases of *Variables* and *Objects* the same *TypeDefinitionNode* or a subtype of it.

6.2.5 BrowsePath

All targets of forward *hierarchical References* from a *TypeDefinitionNode* shall have a *BrowseName* that is unique within the *TypeDefinitionNode*. The same restriction applies to the targets of *hierarchical References* in forward direction from any *InstanceDeclaration*. This means that any *InstanceDeclaration* within the *InstanceDeclarationHierarchy* can be uniquely identified by a sequence of *BrowseName*s. This sequence of *BrowseNames* is called a *BrowsePath*.

6.2.6 Attribute Handling of InstanceDeclarations

Some restrictions exist regarding the *Attributes* of *InstanceDeclarations* when the *InstanceDeclaration* is overridden or instantiated. The *BrowseName* and the *NodeClass* shall never change and always be the same as the original *InstanceDeclaration*.

In addition, the rules defined in 6.2.7 apply for *InstanceDeclarations* of the *NodeClass Variable*.

6.2.7 Attribute Handling of Variable and VariableTypes

Some restrictions exist regarding the *Attributes* of a *VariableType* or a *Variable* used as an *InstanceDeclaration* with regard to the data type of the *Value Attribute*.

When a *Variable* used as *InstanceDeclaration* or a *VariableType* is overridden or instantiated the following rules apply:

a) The *DataType Attribute* can only be changed to a new *DataType* if the new *DataType* is a subtype of the *DataType* originally used.

b) The *ValueRank Attribute* may only be further restricted

1) ‘Any’ may be set to any other value;
2) ‘ScalarOrOneDimension’ may be set to ‘Scalar’ or ‘OneDimension’;
3) ‘OneOrMoreDimensions’ may be set to a concrete number of dimensions (value > 0).
4) All other values of this *Attribute* shall not be changed.

c) The *ArrayDimensions Attribute* may be added if it was not provided or when modifying the value of an entry in the array from 0 to a different value. All other values in the array shall remain the same.

6.2.8 NodeIds of InstanceDeclarations

InstanceDeclarations are identified by their *BrowsePath*. Different *Servers* might use different *NodeIds* for the *InstanceDeclarations* of common *TypeDefinitionNodes*, unless the definition of the *TypeDefinitionNode* already defines a *NodeId* for the *InstanceDeclaration*. All *TypeDefinitionNodes* defined in Part 5 already define the *NodeIds* for their *InstanceDeclarations* and therefore shall be used in all *Servers*.

6.3 Subtyping of ObjectTypes and VariableTypes

6.3.1 Overview

The *HasSubtype ReferenceType* defines subtypes of types. Subtyping can only occur between *Nodes* of the same *NodeClass*. Rules for subtyping *ReferenceTypes* are described in 5.3.3.3. There is no common definition for subtyping *DataTypes*, as described in 5.8.3. The remainder of 6.3 specify subtyping rules for single inheritance on *ObjectTypes* and *VariableTypes*.

6.3.2 Attributes

Subtypes inherit the parent type’s *Attribute* values, except for the *NodeId*. Inherited *Attribute* values may be overridden by the subtype, the *BrowseName* and *DisplayName* values should be overridden. Special rules apply for some *Attributes* of *VariableTypes* as defined in 6.2.7. Optional *Attributes*, not provided by the parent type, may be added to the subtype.

6.3.3 InstanceDeclarations

6.3.3.1 Overview

Subtypes inherit the fully-inherited parent type's *InstanceDeclarations*.

As long as those *InstanceDeclarations* are not overridden they are not referenced by the subtype. *InstanceDeclarations* can be overridden by adding *References*, changing *References* to reference different *Nodes*, changing *References* to be subtypes of the original *ReferenceType*, changing values of the *Attributes* or adding optional *Attributes*. In order to get the full information about a subtype, the inherited *InstanceDeclarations* have to be collected from all types that can be found by recursively following the inverse *HasSubtype References* from the subtype. This collection of *InstanceDeclarations* is called the fully-inherited *InstanceDeclarationHierarchy* of a subtype.

The remainder of 6.3.3 define how to construct the fully-inherited *InstanceDeclarationHierarchy* and how *InstanceDeclarations* can be overridden.

6.3.3.2 Fully-inherited InstanceDeclarationHierarchy

An instance of a *TypeDefinitionNode* is described by the fully-inherited *InstanceDeclaration-Hierarchy* of the *TypeDefinitionNode*. The fully-inherited *InstanceDeclarationHierarchy* can be created by starting with the *InstanceDeclarationHierarchy* of the *TypeDefinitionNode* and merging the fully-inherited *InstanceDeclarationHierarchy* of its parent type.

The process of merging *InstanceDeclarationHierarchies* is straightforward and can be illustrated with the example shown in Figure 12 which specifies a *TypeDefinitionNode* "BetaType" which is a subtype of "AlphaType". The name in each box is the *BrowseName* and the number is the *NodeId*.

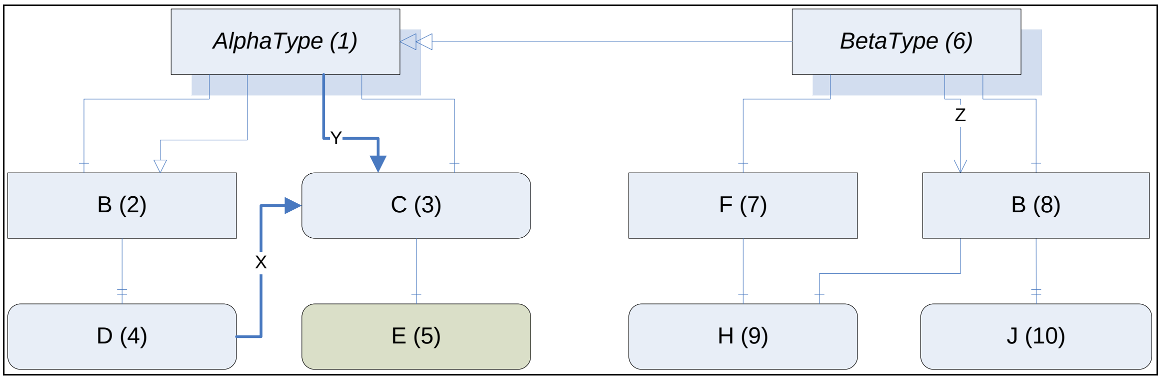


Figure 12 – Subtyping TypeDefinitionNodes

An *InstanceDeclarationHierarchy* can be fully described as a table of *Nodes* identified by their *BrowsePaths* with a corresponding table of *References*. The *InstanceDeclarationHierarchy* for "BetaType" is described in Table 13 where the top half of the table is the table of *Nodes* and the bottom half is the table of *References* (the *HasModellingRule* references have been omitted from the table for the sake of clarity; all Nodes except for 1, 6, and 5 have *ModellingRules*). All *InstanceDeclarations* of the *InstanceDeclarationHierarchy* and all *Nodes* referenced with a non-hierarchical *Reference* from such an *InstanceDeclaration* are added to the table. *Hierarchical References* to *Nodes* without a *ModellingRule* are not considered.

Table 13 – The InstanceDeclarationHierarchy for BetaType

BrowsePath	NodeId		
/	6		
/F	7		
/B	8		
/F/H	9		
/B/J	10		
/B/H	9		
Source Path	**ReferenceType**	**Target Path**	**TargetNodeId**
/	HasComponent	/F	-
/	HasComponent	/B	-
/	Z	/B	-
/	HasTypeDefinition	-	BetaType
/F	HasComponent	/F/H	-
/F	HasTypeDefinition	-	BaseObjectType
/B	HasProperty	/B/J	-
/B	HasTypeDefinition	-	BaseObjectType
/F/H	HasTypeDefinition	-	PropertyType
/B/J	HasTypeDefinition	-	PropertyType
/B	HasComponent	/B/H	-
/B/H	HasTypeDefinition	-	BaseDataVariableType

Multiple *BrowsePaths* to the same *Node* shall be treated as separate *Nodes*. An *Instance* may provide different *Nodes* for each *BrowsePath*.

The fully-inherited *InstanceDeclarationHierarchy* for “BetaType” can now be constructed by merging the *InstanceDeclarationHierarchy* for “AlphaType”. The result is shown in Table 14 where the entries added from “AlphaType” are shaded with grey.

Table 14 – The Fully-Inherited InstanceDeclarationHierarchy for BetaType

BrowsePath	NodeId		
/	6		
/F	7		
/B	8		
/F/H	9		
/B/J	10		
/B/H	9		
/B/D	4		
/C	3		
Source Path	**ReferenceType**	**Target Path**	**TargetNodeId**
/	HasComponent	/F	-
/	HasComponent	/B	-
/	Z	/B	-
/	HasTypeDefinition	-	BetaType
/F	HasComponent	/F/H	-
/F	HasTypeDefinition	-	BaseObjectType
/B	HasProperty	/B/J	-
/B	HasTypeDefinition	-	BaseObjectType
/F/H	HasTypeDefinition	-	PropertyType
/B/J	HasTypeDefinition	-	PropertyType
/B	HasComponent	/B/H	-
/B/H	HasTypeDefinition	-	BaseDataVariableType
/	HasNotifier	/B	-
/B	HasProperty	/B/D	-
/	HasComponent	/C	-
/	Y	/C	-
/C	HasTypeDefinition	-	BaseDataVariableType
/B/D	HasTypeDefinition	-	PropertyType
/B/D	X	/C	-

The *BrowsePath* “/B” already exists in the table so it does not need to be added. However, the *HasNotifier* reference from “/” to “/B” does not exist and was added.

The *Nodes* and *References* defined in Table 14 can be used to create the fully-inherited *InstanceDeclarationHierarchy* shown in Figure 13. The fully-inherited *InstanceDeclarationHierarchy* contains all necessary information about a *TypeDefinitionNode* regarding its complex structure without needing any additional information from its supertypes.

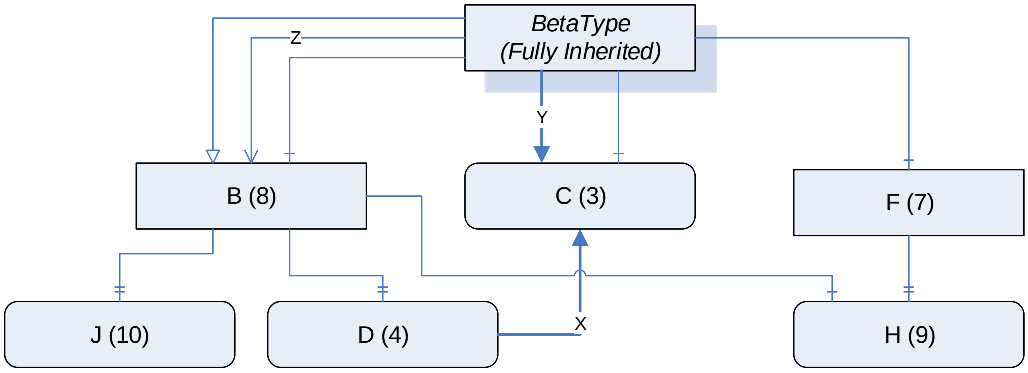


Figure 13 – The Fully-Inherited InstanceDeclarationHierarchy for BetaType

6.3.3.3 Overriding InstanceDeclarations

A subtype overrides an *InstanceDeclaration* by specifying an *InstanceDeclaration* with the same *BrowsePath*. An overridden *InstanceDeclaration* shall have the same *NodeClass* and *BrowseName*. The *TypeDefinitionNode* of the overridden *InstanceDeclaration* shall be the same or a subtype of the *TypeDefinitionNode* specified in the supertype.

When overriding an *InstanceDeclaration* it is necessary to provide *hierarchical References* that link the new *Node* back to the subtype (the *References* are used to determine the *BrowsePath* of the *Node*).

It is only possible to override *InstanceDeclarations* that are directly referenced from the *TypeDefinitionNode*. If an indirect referenced *InstanceDeclaration*, such as “J” in Figure 13, has to be overridden, then the directly referenced *InstanceDeclarations* that includes “J”, in that case “B”, have to be overridden first and then “J” can be overridden in a second step.

A *Reference* is replaced if it goes between two overridden *Nodes* and has the same *ReferenceType* as a *Reference* defined in the supertype. The *Reference* specified in the subtype may be a subtype of the *ReferenceType* used in the parent type.

Any *non-hierarchical References* specified for the overridden *InstanceDeclaration* are treated as new *References* unless the *ReferenceType* only allows a single *Reference* per *SourceNode*. If this situation exists the subtype can change the target of the *Reference* but the new target shall have the same *NodeClass* and for *Objects* and *Variables* also the same type or a subtype of the type specified in the parent.

The overriding *Node* may specify new values for the *Node Attributes* other than the *NodeClass* or *BrowseName*, however, the restrictions on *Attributes* specified in 6.2.6 apply. Any *Attribute* provided by the overridden *InstanceDeclaration* has to be provided by the overriding *InstanceDeclaration*, additional optional *Attributes* may be added.

The *ModellingRule* of the overriding *InstanceDeclaration* may be changed as defined in 6.4.4.3.

Each overriding *InstanceDeclaration* needs its own *HasModellingRule* and *HasTypeDefinition* *References*, even if they have not been changed.

A subtype should not override a *Node* unless it needs to change it.

The semantics of certain *TypeDefinitionNodes* and *ReferenceTypes* may impose additional restrictions with regard to overriding *Nodes*.

6.4 Instances of ObjectTypes and VariableTypes

6.4.1 Overview

Any *Instance* of a *TypeDefinitionNode* will be the root of a hierarchy which mirrors the *InstanceDeclarationHierarchy* for the *TypeDefinitionNode.* Each *Node* in the hierarchy of the Instance will have a *BrowsePath* which may be the same as the *BrowsePath* for one of the *InstanceDeclarations* in the hierarchy of the *TypeDefinitionNode.* The *InstanceDeclaration* with the same *BrowsePath* is called the *InstanceDeclaration* for the *Node*. If a *Node* has an *InstanceDeclaration* then it shall have the same *BrowseName* and *NodeClass* as the *InstanceDeclaration* and, in cases of *Variables* and *Objects*, the same *TypeDefinitionNode* or a subtype of it.

Instances may reference several *Nodes* with the same *BrowsePath*. *Clients* that need to distinguish between the *Nodes* based on the *InstanceDeclarationHierarchy* and the *Nodes* that are not based on the *InstanceDeclarationHierarchy* can accomplish this using the TranslateBrowsePathsToNodeIds service defined in Part 4.

6.4.2 Creating an Instance

Instances inherit the initial values for the *Attributes* that they have in common with the *TypeDefinitionNode* from which they are instantiated, with the exceptions of the *NodeClass* and *NodeId*.

When a *Server* creates an instance of a *TypeDefinitionNode* it shall create the same hierarchy of *Nodes* beneath the new *Object* or *Variable* depending on the *ModellingRule* of each *InstanceDeclaration*. Standard *ModellingRules* are defined in 6.4.4.5. The *Nodes* within the newly created hierarchy may be copies of the *InstanceDeclarations*, the *InstanceDeclaration* itself or another *Node* in the *AddressSpace* that has the same *TypeDefinitionNode* and *BrowseName*. If new copies are created, then the *Attribute* values of the *InstanceDeclarations* are used as the initial values.

Figure 14 provides a simple example of a *TypeDefinitionNode* and an *Instance*. *Nodes* referenced by the *TypeDefinitionNode* without a *ModellingRule* do not appear in the instance. *Instances* may have children with duplicate *BrowseNames*; however, only one of those children will correspond to the *InstanceDeclaration*.

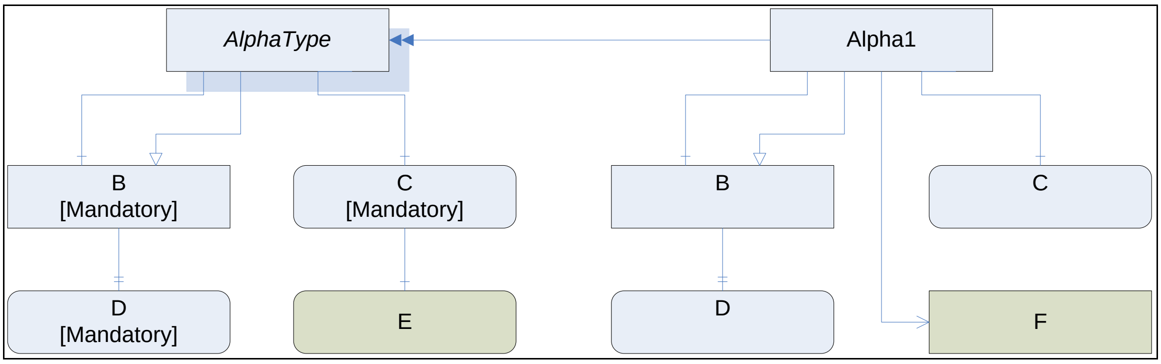


Figure 14 – An Instance and its TypeDefinitionNode

It is up to the *Server* to decide which *InstanceDeclarations* appear in any single instance. In some cases, the *Server* will not define the entire instance and will provide remote references to *Nodes* in another *Server*. The *ModellingRules* described in 6.4.4.5 allow *Servers* to indicate that some *Nodes* are always present; however, the *Client* shall be prepared for the case where the *Node* exists in a different *Server*.

A *Client* can use the information of *TypeDefinitionNodes* to access *Nodes* which are in the hierarchy of the instance. It shall pass the *NodeId* of the instance and the *BrowsePath* of the child *Nodes* based on the *TypeDefinitionNode* to the *TranslateBrowsePathsToNodeIds* service (see Part 4). This *Service* returns the *NodeId* for each of the child *Nodes*. If a child *Node* exists then the *BrowseName* and *NodeClass* shall match the *InstanceDeclaration*. In the case of

Objects or *Variables*, also the *TypeDefinitionNode* shall either match or be a subtype of the original *TypeDefinitionNode*.

6.4.3 Constraints on an Instance

Objects and *Variables* may change their *Attribute* values after being created. Special rules apply for some *Attributes* as defined in 6.2.6.

Additional *References* may be added to the *Nodes*, and *References* may be deleted as long as the *ModellingRules* defined on the *InstanceDeclarations* of the *TypeDefinitionNode* are still fulfilled.

For *Variables* and *Objects* the *HasTypeDefinition Reference* shall always point to the same *TypeDefinitionNode* as the *InstanceDeclaration* or a subtype of it.

If two *InstanceDeclarations* of the fully-inherited *InstanceDeclarationHierarchy* have been connected directly with several *References*, all those *References* shall connect the same *Nodes*. An example is given in Figure 15. The instances A1 and A2 are allowed since B1 references the same *Node* with both *References*, whereas A3 is not allowed since two different *Nodes* are referenced. Note that this restriction only applies for directly connected *Nodes*. For example, A2 references a C1 directly and a different C1 via B1.

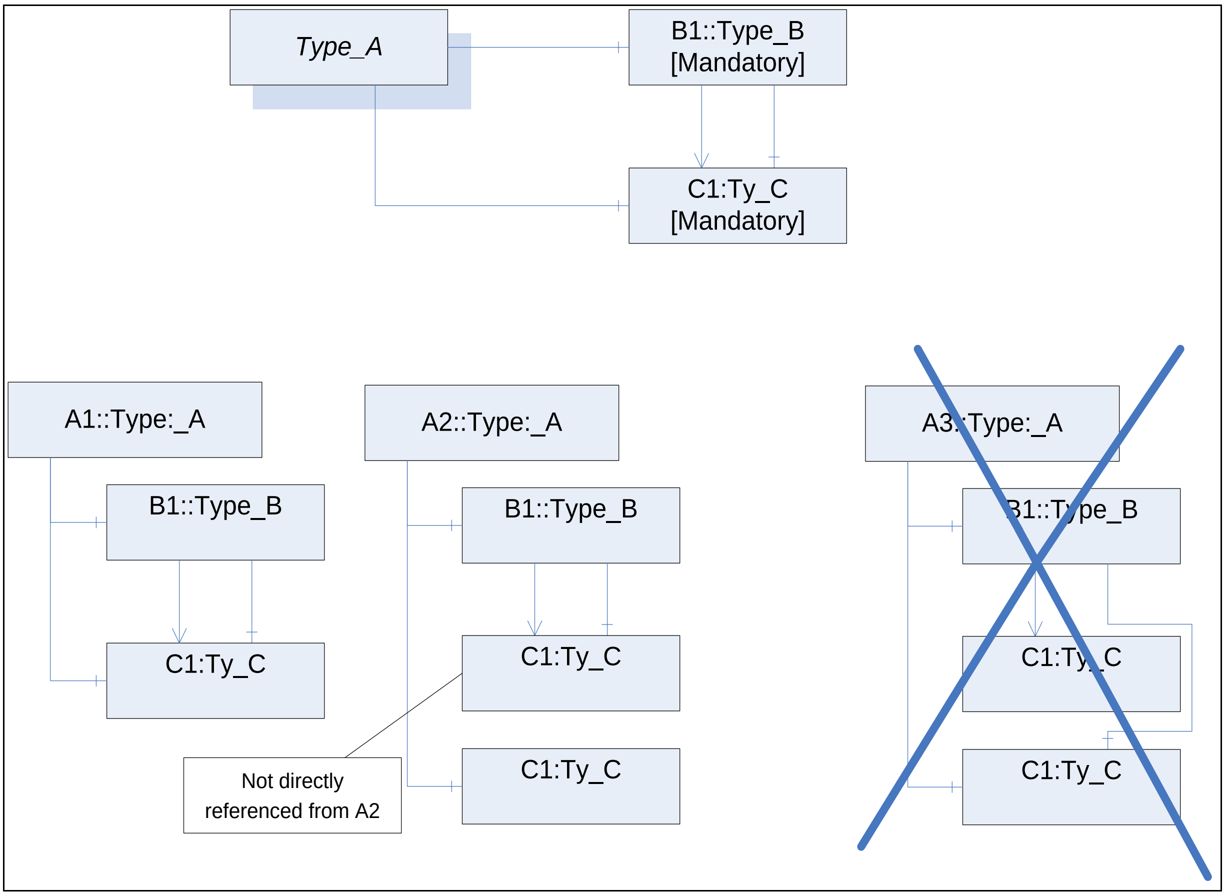


Figure 15 – Example for several References between InstanceDeclarations

6.4.4 ModellingRules

6.4.4.1 General

For a definition of *ModellingRules*, see 6.4.4.5. Other parts of this series of standards may define additional *ModellingRules*. *ModellingRules* are an extendable concept in OPC UA; therefore vendors may define their own *ModellingRules*.

Note that the *ModellingRules* defined in this standard do not define how to deal with non-hierarchical *References* between *InstanceDeclarations*, i.e. it is *Server*-specific if those

References exist in an instance hierarchy or not. Other *ModellingRules* may define behaviour for non-hierarchical *References* between *InstanceDeclaration* as well.

ModellingRules are represented in the *AddressSpace* as *Objects* of the *ObjectType ModellingRuleType*. There are some *Properties* defining common semantic of *ModellingRules.* This edition of this standard only specifies one *Property* for *ModellingRules*. Future editions may define additional *Properties* for *ModellingRules*. Part 5 specifies the representation of the *ModellingRule Objects,* their *Properties* and their type in the *AddressSpace*. The semantic of the *Properties* for *ModellingRules* is defined in 6.4.4.2.

Subclause 6.4.4.4 defines how the *ModellingRule* may be changed when instantiating *InstanceDeclarations* with respect to the *Properties*. Subclause 6.4.4.3 defines how the *ModellingRule* may be changed when overriding *InstanceDeclarations* in subtypes with respect to the *Properties*.

6.4.4.2 Properties describing ModellingRules

6.4.4.2.1 NamingRule

NamingRule is a mandatory *Property* of a *ModellingRule*. It specifies the purpose of an *InstanceDeclaration*. Each *InstanceDeclaration* references a *ModellingRule* and thus the *NamingRule* is defined per *InstanceDeclaration*.

Three values are allowed for the *NamingRule* of a *ModellingRule*: *Optional*, *Mandatory*, and *Constraint*.

The following semantic is valid for the entire life-time of an instance that is based on a *TypeDefinitionNode* having an *InstanceDeclaration*.

For an instance A1 of a *TypeDefinitionNode* AlphaType with an *InstanceDeclaration* B1 having a *ModellingRule* using the *NamingRule Optional* the following rule applies: For each *BrowsePath* from AlphaType to B1 the instance A1 may or may not have a *similar Node* (see 6.2.4) for B1 with the same *BrowsePath*. If such a *Node* exists then the TranslateBrowsePathsToNodeIds *Service* (see Part 4) returns this *Node* as the first entry in the list.

For an instance A1 of a *TypeDefinitionNode* AlphaType with an *InstanceDeclaration* B1 having a *ModellingRule* using the *NamingRule Mandatory* the following rule applies: For each *BrowsePath* from AlphaType to B1 the instance A1 shall have a *similar Node* (see 6.2.4) for B1 using the same *BrowsePath* if all *Nodes* of the *BrowsePath* exist. For example, if a *Node* in the *BrowsePath* has a *NamingRule Optional* and is omitted in the instance, then all children of this *Node* would also be omitted, independent of their *ModellingRules*.

If an *InstanceDeclaration* has a *ModellingRule* using the *NamingRule Constraint* it identifies that the *BrowseName* of the *InstanceDeclaration* is of no significance but other semantic is defined with the *ModellingRule*. The TranslateBrowsePathsToNodeIds *Service* (see Part 4) can typically not be used to access instances based on those *InstanceDeclarations*.

6.4.4.3 Subtyping Rules for Properties of ModellingRules

It is allowed that subtypes override *ModellingRules* on their *InstanceDeclarations*. As a general rule for subtyping, constraints shall only be tightened, not loosened. Therefore, it is not allowed to specify on the supertype that an instance shall exist with the name (*NamingRule Mandatory*) and on the subtype make this optional (*NamingRule Optional*). Table 15 specifies the allowed changes on the *Properties* when exchanging the *ModellingRules* in the subtype.

Table 15 – Rule for ModellingRules Properties when Subtyping

	Value on supertype	Value on subtype
NamingRule	Mandatory	Mandatory
NamingRule	Optional	Mandatory or Optional
NamingRule	Constraint	Constraint

6.4.4.4 Instantiation Rules for Properties of ModellingRules

There are two different use cases when creating an instance 'A' based on a *TypeDefinitionNode* 'A_Type'. Either 'A' is used as normal instance or it is used as *InstanceDeclaration* of another *TypeDefinitionNode*.

In the first case, it is not required that newly created or referenced instances based on *InstanceDeclarations* have a *ModellingRule*, however, it is allowed that they have any *ModellingRule* independent of the *ModellingRule* of their *InstanceDeclaration*.

In Figure 16 an example is given. The instances A1, A2, and A3 are all valid instances of Type_A, although B of A1 has no *ModellingRule* and B of A3 has a different *ModellingRule* than B of Type_A.

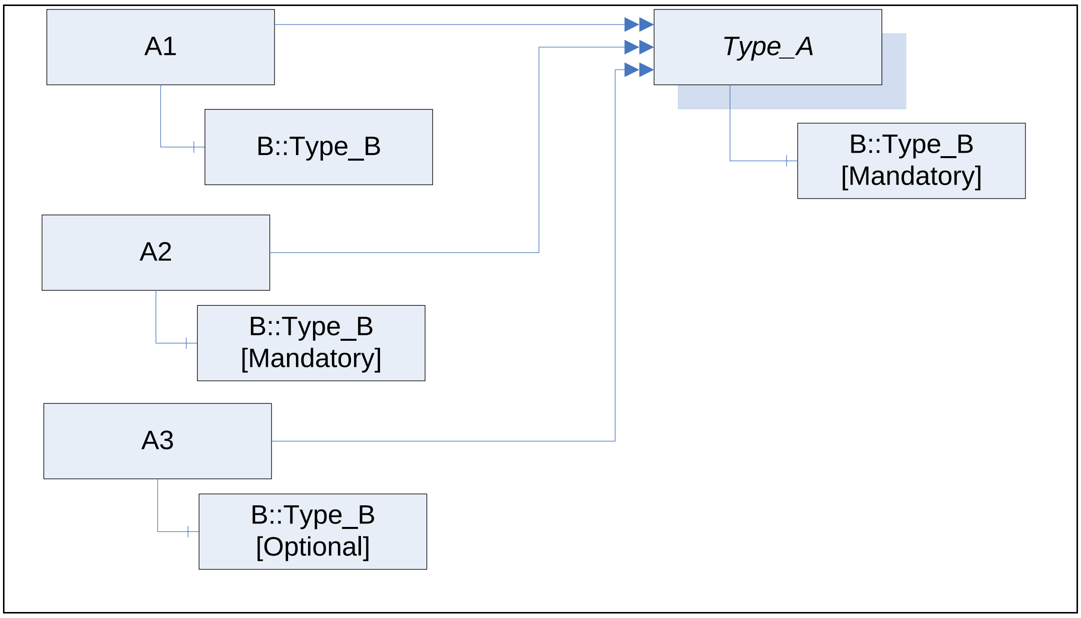


Figure 16 – Example on changing instances based on InstanceDeclarations

In the second case, all instances that are referenced directly or indirectly from 'A' based on *InstanceDeclarations* of 'A_Type' initially maintain the same *ModellingRule* as their *InstanceDeclarations.* The *ModellingRules* may be updated; the allowed changes to the *ModellingRules* of these *Nodes* are the same as those defined for subtyping in 6.4.4.3.

In Figure 17 an example of such a scenario is given. Type_B uses an *InstanceDeclaration* based on Type_A (upper part of the Figure). Later on the *ModellingRule* of the *InstanceDeclaration* A1 is changed (lower part of the Figure). A1 has become the *NamingRule* of *Mandatory* (changed from *Optional*).

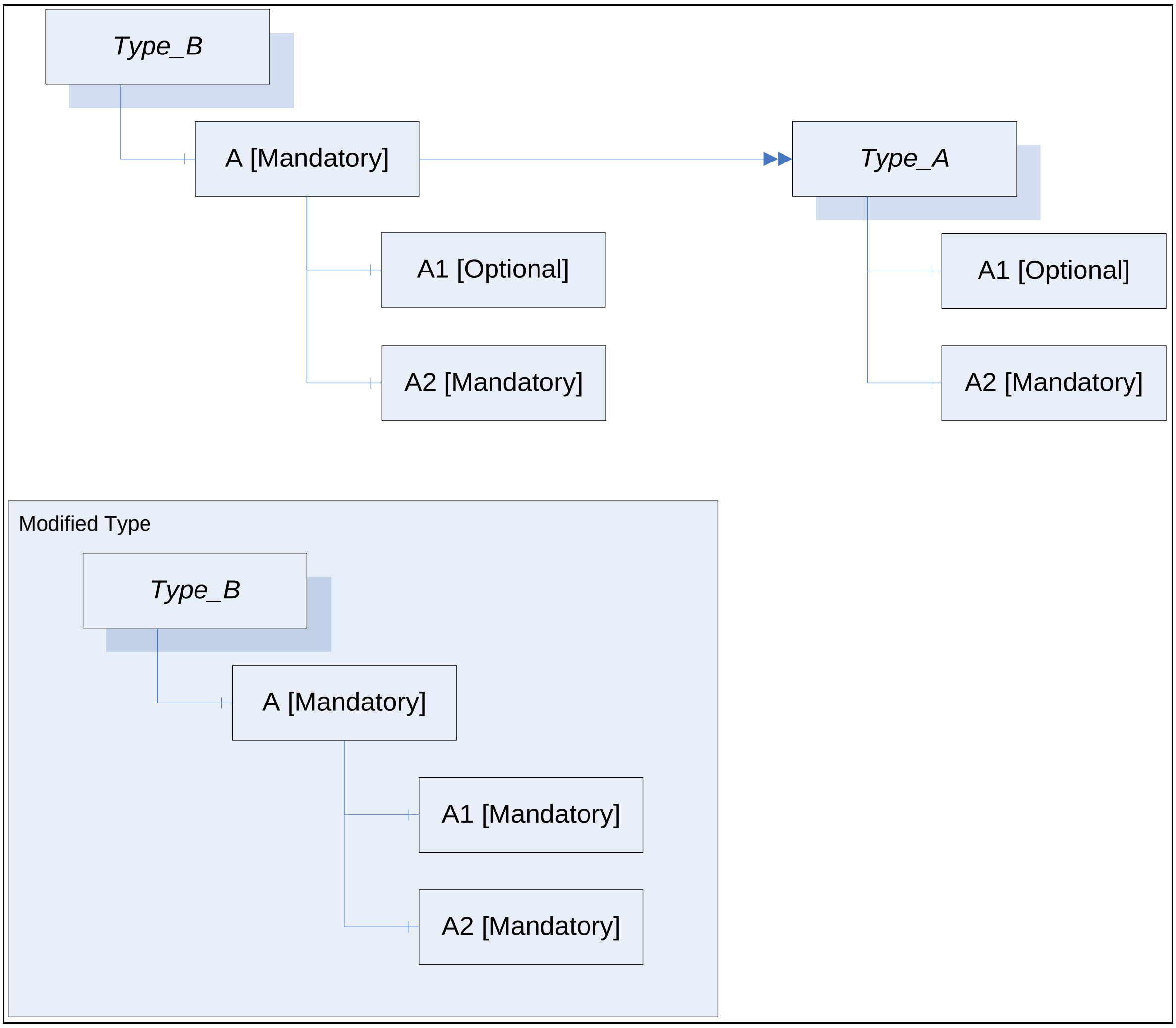


Figure 17 – Example on changing InstanceDeclarations based on an InstanceDeclaration

6.4.4.5 Standard ModellingRules

6.4.4.5.1 Titles of Standard ModellingRules

The remainder of 6.4.4.5 defines *ModellingRules*. In Table 16 the *Properties* of those *ModellingRules* are summarized.

Table 16 – Properties of ModellingRules

Title	NamingRule
Mandatory	Mandatory
Optional	Optional
ExposesItsArray	Constraint
OptionalPlaceholder	Constraint
MandatoryPlaceholder	Constraint

6.4.4.5.2 Mandatory

An *InstanceDeclaration* marked with the *ModellingRule Mandatory* fulfils exactly the semantic defined for the *NamingRule Mandatory*. That means that for each existing *BrowsePath* on the instance a similar *Node* shall exist, but it is not defined whether a new *Node* is created or an existing *Node* is referenced.

For example, the *TypeDefinitionNode* of a functional block “AI_BLK_TYPE” will have a setpoint “SP1”. An instance of this type “AI_BLK_1” will have a newly-created setpoint “SP1 as a similar Node to the *InstanceDeclaration* SP1. Figure 18 illustrates the example.

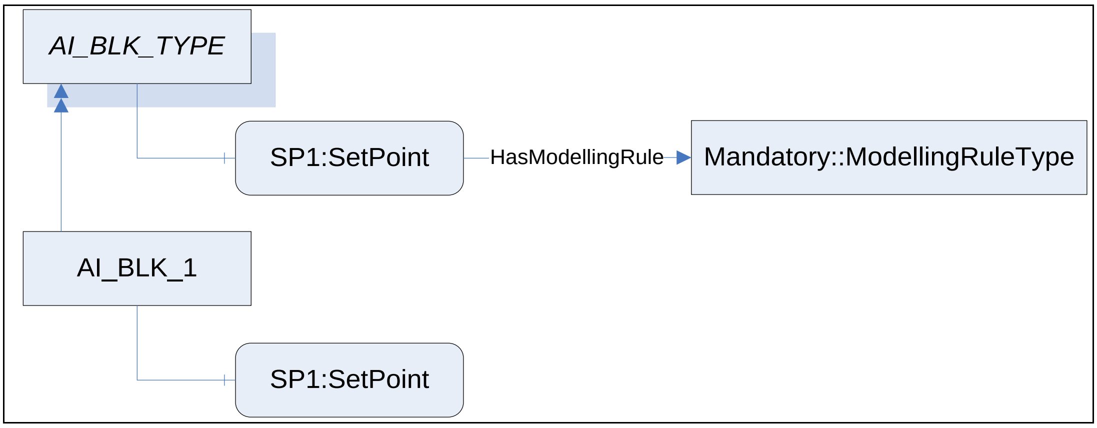


Figure 18 – Use of the Standard ModellingRule New

In 6.4.4.5.3 a complex example combining the *Mandatory* and *Optional ModellingRules* is given.

6.4.4.5.3 Optional

An *InstanceDeclaration* marked with the ModellingRule *Optional* fulfils exactly the semantic defined for the *NamingRule Optional*. That means that for each existing *BrowsePath* on the instance a similar *Node* may exist, but it is not defined whether a new *Node* is created or an existing *Node* is referenced.

In Figure 19 an example using the *ModellingRules Optional* and *Mandatory* is shown. The example contains an *ObjectType* Type_A and all valid combinations of instances named A1 to A13. Note that if the optional B is provided, the mandatory E has to be provided as well, otherwise not. F is referenced by C and D. On the instance, this can be the same *Node* or two different *Nodes* with the same *BrowseName* (similar *Node* to *InstanceDeclaration* F). Not considered in the example is if the instances have *ModellingRules* or not. It is assumed that each F is similar to the *InstanceDeclaration* F, etc.

If there would be a non-hierarchical *Reference* between E and F in the *InstanceDeclaration-Hierarchy*, it is not specified if it occurs in the instance hierarchy or not. In the case of A10, there could be a reference from E to one F but not to the other F, or to both or none of them.

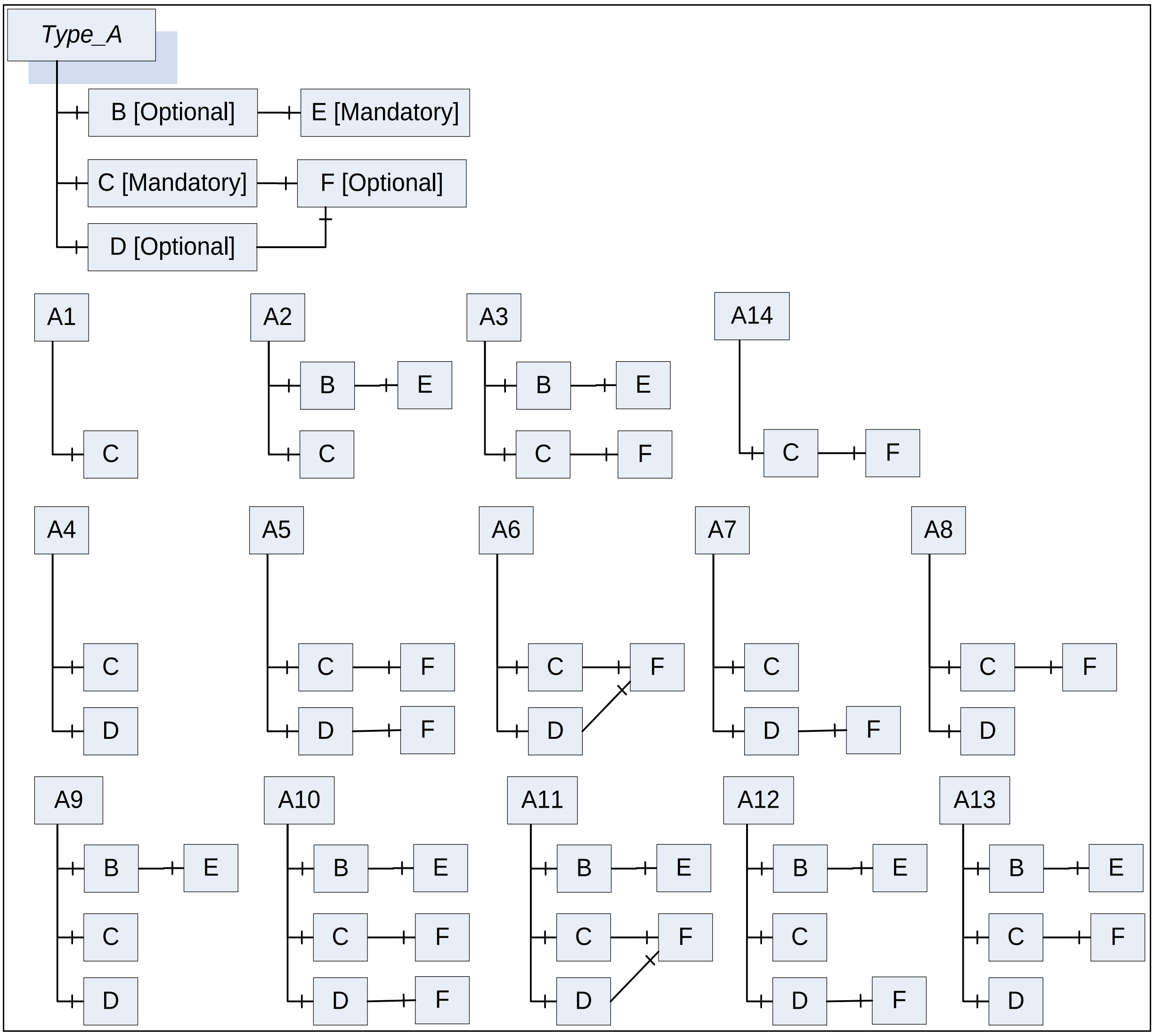


Figure 19 – Example using the Standard ModellingRules Optional and Mandatory

6.4.4.5.4 ExposesItsArray

The *ExposesItsArray ModellingRule* exposes a special semantic on *VariableTypes* having a single- or multidimensional array as the data type. It indicates that each value of the array will also be exposed as a *Variable* in the *AddressSpace*.

The *ExposesItsArray ModellingRule* can only be applied on *InstanceDeclarations* of *NodeClass Variable* that are part of a *VariableType* having a single- or multidimensional array as its data type.

The *Variable* A having this *ModellingRule* shall be referenced by a *hierarchical Reference* in a forward direction from a *VariableType* B. B shall have a *ValueRank* value that is equal to or larger than zero. A should have a data type that reflects at least parts of the data that is managed in the array of B. Each instance of B shall reference one instance of A for each of its array elements. The used *Reference* shall be of the same type as the *hierarchical Reference* that connects B with A or a subtype of it. If there are more than one *hierarchical References* in the forward direction between A and B, then all instances based on B shall be referenced with all those *References*.

Figure 20 gives an example. A is an instance of Type_A having two entries in its value array. Therefore it references two instances of the same type as the *InstanceDeclaration* ArrayExpose. The *BrowseNames* of those instances are not defined by the *ModellingRule*. In general, it is not possible to get a *Variable* representing a specific entry in the array (e.g. the second). *Clients* will typically either get the array or access the *Variables* directly, so there is no need to provide that information.

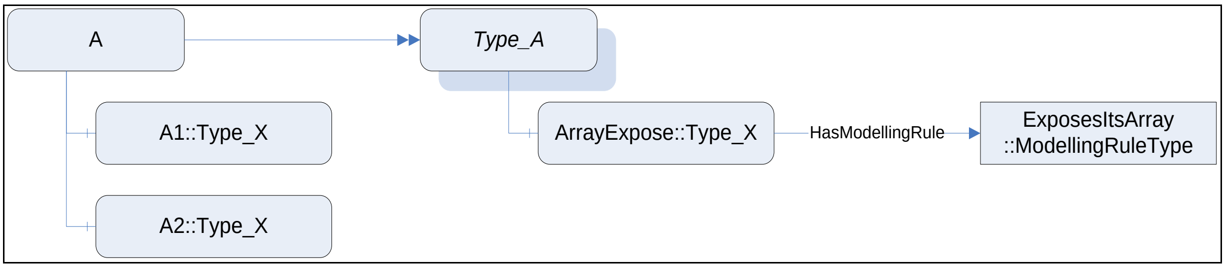


Figure 20 – Example on using ExposesItsArray

It is allowed to reference A by other *InstanceDeclarations* as well. Those *References* have to be reflected on each instance based on A.

Figure 21 gives an example. The *Property* EUUnit is referenced by ArrayExpose and therefore each instance based on ArrayExpose references the instance based on the *InstanceDeclaration* EUUnit.

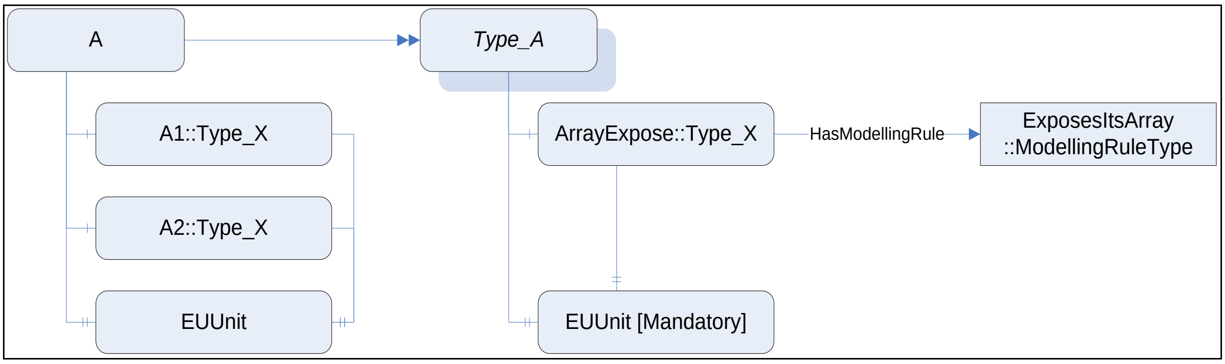


Figure 21 – Complex example on using ExposesItsArray

6.4.4.5.5 OptionalPlaceholder

The intention of the *ModellingRule OptionalPlaceholder* is to expose the information that a complex *TypeDefinition* expects from instances of the *TypeDefinition* to add instances with specific *References* without defining *BrowseNames* for the instances. For example, a Device might have a Folder for DeviceParameters, and the DeviceParameters should be connected with a *HasComponent Reference*. However, the names of the DeviceParameters are specific to the instances. The example is shown in Figure 22, where an instance Device A adds two DeviceParameters in the Folder.

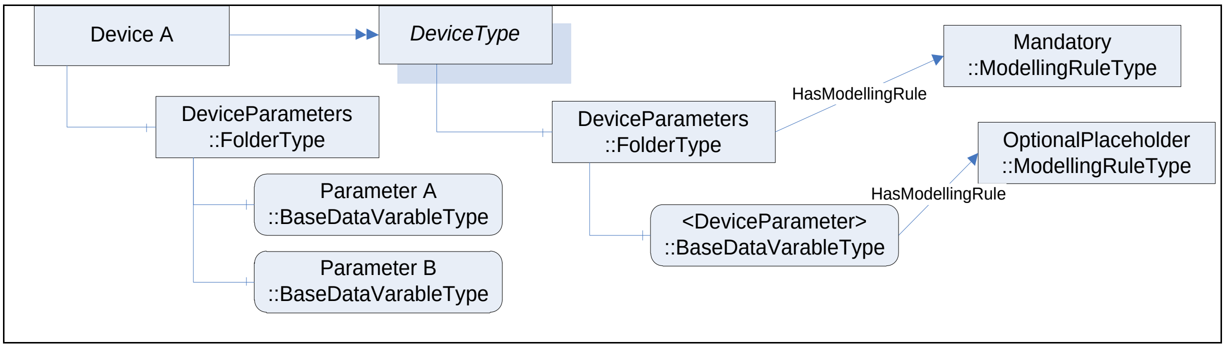


Figure 22 – Example on using OptionalPlaceholder

The *ModellingRule OptionalPlaceholder* adds no additional constraints on instances of the *TypeDefinition*. It just provides useful information when exposing a *TypeDefinition*. When the

InstanceDeclaration is complex, i.e. it references other *InstanceDeclarations* with hierarchical *References*, these *InstanceDeclarations* are not further considered for instantiating the *TypeDefinition*.

It is recommended that the *BrowseName* and the *DisplayName* of *InstanceDeclarations* having the *OptionalPlaceholder ModellingRule* should be enclosed within angle brackets.

When overriding the *InstanceDeclaration,* the *ModellingRule* shall remain *OptionalPlaceholder*.

6.4.4.5.6 MandatoryPlaceholder

The *ModellingRule MandatoryPlaceholder* has a similar intention as the *ModellingRule OptionalPlaceholder*. It exposes the information that a *TypeDefinition* expects of instances of the *TypeDefinition* to add instances defined by the *InstanceDeclaration*. However, *MandatoryPlaceholder* requires that at least one of those instances shall exist.

For example, when the DeviceType requires that at least one DeviceParameter shall exist without specifying the *BrowseName* for it, it uses *MandatoryPlaceholder* as shown in Figure 23. Device A is a valid instance as it has the required DeviceParameter. Device B is not valid as it uses the wrong *ReferenceType* to reference a DeviceParameter (*Organizes* instead of *HasComponent*) and Device C is not valid because it does not provide a DeviceParameter at all.

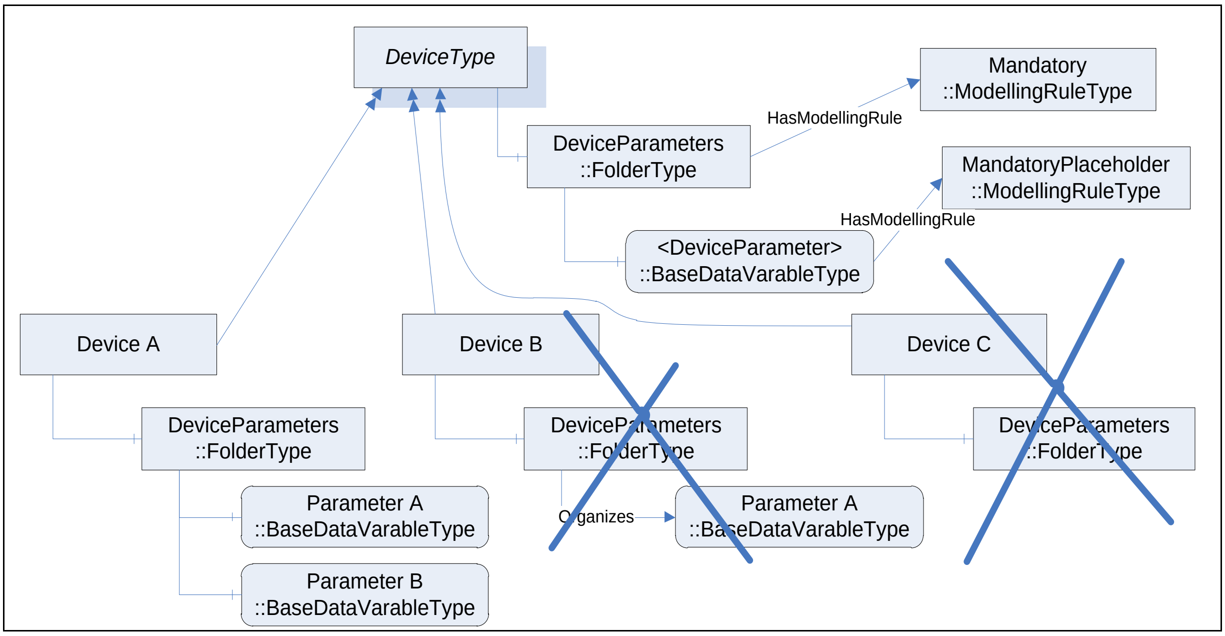


Figure 23 – Example on using MandatoryPlaceholder

The *ModellingRule MandatoryPlaceholder* requires that each instance provides at least one instance with the *TypeDefinition* of the *InstanceDeclaration* or a subtype, and is referenced with the same *ReferenceType* or a subtype as the *InstanceDeclaration*. It does not require a specific *BrowseName* and thus cannot be used for the TranslateBrowsePathsToNodeIds *Service* (see Part 4).

When the *InstanceDeclaration* is complex, i.e. it references other *InstanceDeclarations* with hierarchical *References*, these *InstanceDeclarations* are not further considered for instantiating the *TypeDefinition*.

It is recommended that the *BrowseName* and the *DisplayName* of *InstanceDeclarations* having the *MandatoryPlaceholder ModellingRule* should be enclosed within angle brackets.

When overriding the *InstanceDeclaration,* the *ModellingRule* shall remain *MandatoryPlaceholder*.

6.5 Changing Type Definitions that are already used

There is no behaviour specified regarding subtypes and instances when changing *ObjectTypes* and *VariableTypes*. It is *Server*-dependent, if those changes are reflected on the subtypes and instances of the types. However, all constraints defined for subtypes and instances have to be fulfilled. For example, it is not allowed to add a *Property* using the *ModellingRule Mandatory* on a type if instances of this type exist without the *Property*. In that case, the *Server* either has to add the *Property* to all instances of the type or adding the *Property* on the type has to be rejected.

7 Standard ReferenceTypes

7.1 General

This standard defines *ReferenceTypes* as an inherent part of the OPC UA Address Space Model. Figure 24 informally describes the hierarchy of these *ReferenceTypes*. Other parts of this series of standards may specify additional *ReferenceTypes*. The remainder of 7 defines the *ReferenceTypes*. Part 5 defines their representation in the *AddressSpace*.

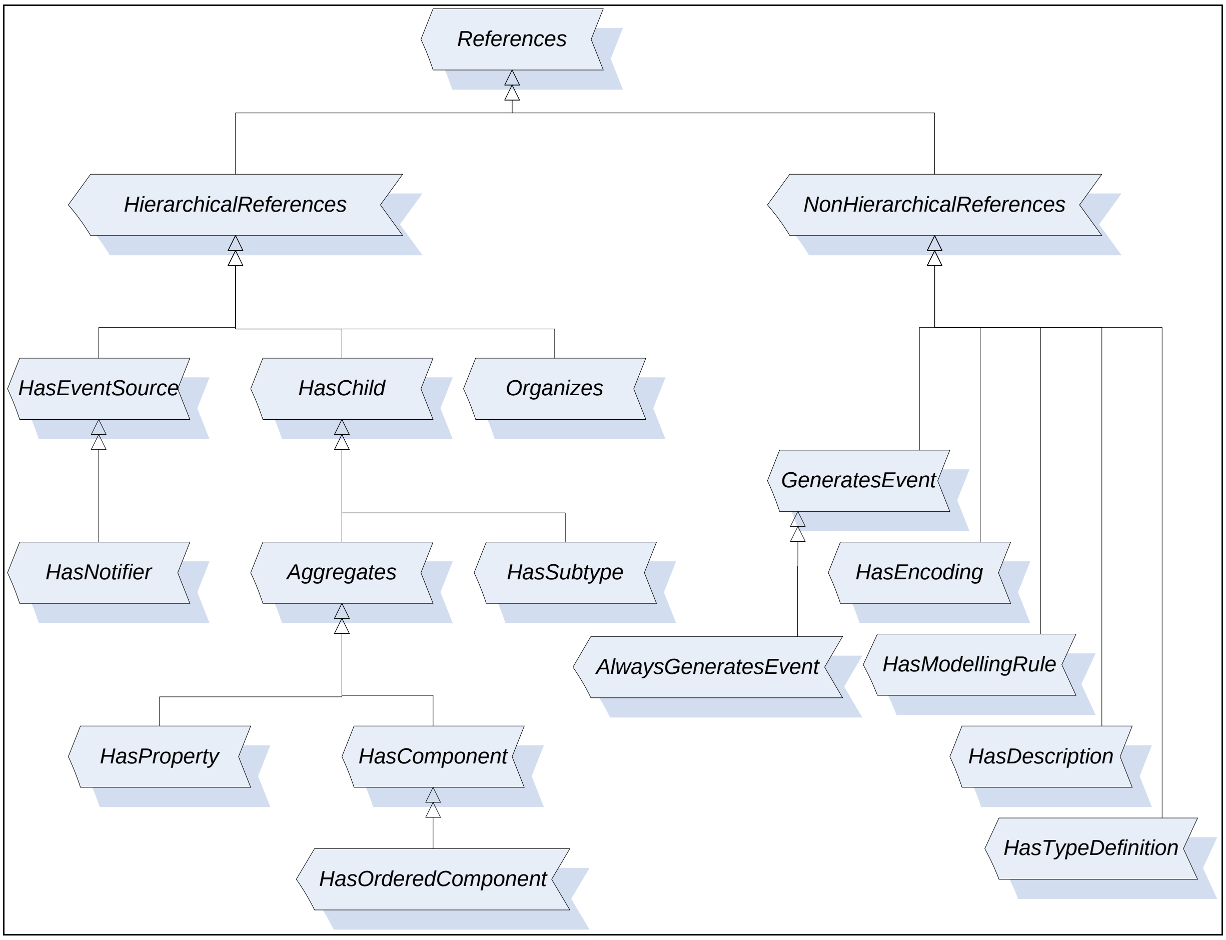


Figure 24 – Standard ReferenceType Hierarchy

7.2 References ReferenceType

The *References ReferenceType* is an abstract *ReferenceType*; only subtypes of it can be used.

There is no semantic associated with this *ReferenceType*. This is the base type of all *ReferenceTypes*. All *ReferenceTypes* shall be a subtype of this base *ReferenceType* – either direct or indirect. The main purpose of this *ReferenceType* is allowing simple filter and queries in the corresponding *Services* of Part 5.

There are no constraints defined for this abstract *ReferenceType*.

7.3 HierarchicalReferences ReferenceType

The *HierarchicalReferences ReferenceType* is an abstract *ReferenceType*; only subtypes of it can be used.

The semantic of *HierarchicalReferences* is to denote that *References* of *HierarchicalReferences* span a hierarchy. It means that it may be useful to present *Nodes* related with *References* of this type in a hierarchical-like way. *HierarchicalReferences* does not forbid loops. For example, starting from *Node* “A” and following *HierarchicalReferences* it may be possible to browse to *Node* “A”, again.

It is not permitted to have a *Property* as *SourceNode* of a *Reference* of any subtype of this abstract *ReferenceType*.

It is not allowed that the *SourceNode* and the *TargetNode* of a *Reference* of the *ReferenceType HierarchicalReferences* are the same, that is, it is not allowed to have self-references using *HierarchicalReferences*.

7.4 NonHierarchicalReferences ReferenceType

The *NonHierarchicalReferences ReferenceType* is an abstract *ReferenceType*; only subtypes of it can be used.

The semantic of *NonHierarchicalReferences* is to denote that its subtypes do not span a hierarchy and should not be followed when trying to present a hierarchy. To distinguish hierarchical and non-hierarchical *References*, all concrete *ReferenceTypes* shall inherit from either *hierarchical References* or *non-hierarchical References*, either direct or indirect.

There are no constraints defined for this abstract *ReferenceType*.

7.5 HasChild ReferenceType

The *HasChild ReferenceType* is an abstract *ReferenceType*; only subtypes of it can be used. It is a subtype of *HierarchicalReferences*.

The semantic is to indicate that *References* of this type span a non-looping hierarchy.

Starting from *Node* “A” and only following *References* of the subtypes of the *HasChild ReferenceType* it shall never be possible to return to “A”. But it is allowed that following the *References* there may be more than one path leading to another *Node* “B”.

7.6 Aggregates ReferenceType

The *Aggregates ReferenceType* is an abstract *ReferenceType*; only subtypes of it can be used. It is a subtype of *HasChild*.

The semantic is to indicate a part (the *TargetNode*) belongs to the *SourceNode*. It does not specify the ownership of the *TargetNode*.

There are no constraints defined for this abstract *ReferenceType*.

7.7 HasComponent ReferenceType

The *HasComponent ReferenceType* is a concrete *ReferenceType* that can be used directly. It is a subtype of the *Aggregates ReferenceType*.

The semantic is a part-of relationship. The *TargetNode* of a *Reference* of the *HasComponent ReferenceType* is a part of the *SourceNode*. This *ReferenceType* is used to relate *Objects* or *ObjectTypes* with their containing *Objects*, *DataVariables*, and *Methods*. This *ReferenceType* is also used to relate complex *Variable*s or *VariableTypes* with their *DataVariables*.

Like all other *ReferenceTypes*, this *ReferenceType* does not specify anything about the ownership of the parts, although it represents a part-of relationship semantic. That is, it is not specified if the *TargetNode* of a *Reference* of the *HasComponent ReferenceType* is deleted when the *SourceNode* is deleted.

The *TargetNode* of this *ReferenceType* shall be a *Variable*, an *Object* or a *Method*.

If the *TargetNode* is a *Variable*, the *SourceNode* shall be an *Object*, an *ObjectType*, a *DataVariable* or a *VariableType*. By using the *HasComponent Reference*, the *Variable* is defined as *DataVariable*.

If the *TargetNode* is an *Object* or a *Method*, the *SourceNode* shall be an *Object* or *ObjectType*.

7.8 HasProperty ReferenceType

The *HasProperty ReferenceType* is a concrete *ReferenceType* that can be used directly. It is a subtype of the *Aggregates ReferenceType*.

The semantic is to identify the *Properties* of a *Node*. *Properties* are described in 4.4.2.

The *SourceNode* of this *ReferenceType* can be of any *NodeClass*. The *TargetNode* shall be a *Variable*. By using the *HasProperty Reference*, the *Variable* is defined as *Property*. Since *Properties* shall not have *Properties*, a *Property* shall never be the *SourceNode* of a *HasProperty Reference*.

7.9 HasOrderedComponent ReferenceType

The *HasOrderedComponent ReferenceType* is a concrete *ReferenceType* that can be used directly. It is a subtype of the *HasComponent ReferenceType*.

The semantic of the *HasOrderedComponent ReferenceType* – besides the semantic of the *HasComponent ReferenceType* – is that when browsing from a *Node* and following *References* of this type or its subtype all *References* are returned in the Browse *Service* defined in Part 4 in a well-defined order. The order is *Server*-specific, but the *Client* can assume that the *Server* always returns them in the same order.

There are no additional constraints defined for this *ReferenceType*.

7.10 HasSubtype ReferenceType

The *HasSubtype ReferenceType* is a concrete *ReferenceType* that can be used directly. It is a subtype of the *HasChild ReferenceType*.

The semantic of *this ReferenceType* is to express a subtype relationship of types. It is used to span the *ReferenceType* hierarchy, whose semantic is specified in 5.3.3.3; a *DataType* hierarchy is specified in 5.8.3, and other subtype hierarchies are specified in Clause 6.

The *SourceNode* of *References* of this type shall be an *ObjectType*, a *VariableType*, a *DataType* or a *ReferenceType* and the *TargetNode* shall be of the same *NodeClass* as the *SourceNode*. Each *ReferenceType* shall be the *TargetNode* of at most one *Reference* of type *HasSubtype*.

7.11 Organizes ReferenceType

The *Organizes ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *HierarchicalReferences*.

The semantic of this *ReferenceType* is to organise *Nodes* in the *AddressSpace*. It can be used to span multiple hierarchies independent of any hierarchy created with the non-looping *Aggregates References*.

The *SourceNode* of *References* of this type shall be an *Object* or a *View.* If it is an *Object* then it should be an *Object* of the *ObjectType FolderType* or one of its subtypes (see 5.5.3).

The *TargetNode* of this *ReferenceType* can be of any *NodeClass*.

7.12 HasModellingRule ReferenceType

The *HasModellingRule ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *NonHierarchicalReferences*.

The semantic of this *ReferenceType* is to bind the *ModellingRule* to an *Object*, *Variable* or *Method*. The *ModellingRule* mechanisms are described in 6.4.4.

The *SourceNode* of this *ReferenceType* shall be an *Object*, *Variable* or *Method*. The *TargetNode* shall be an *Object* of the *ObjectType* “ModellingRule” or one of its subtypes.

Each *Node* shall be the *SourceNode* of at most one *HasModellingRule Reference*.

7.13 HasTypeDefinition ReferenceType

The HasTypeDefinition ReferenceType is a concrete ReferenceType and can be used directly. It is a subtype of NonHierarchicalReferences.

The semantic of this *ReferenceType* is to bind an *Object* or *Variable* to its *ObjectType* or *VariableType*, respectively. The relationships between types and instances are described in 4.5.

The *SourceNode* of this *ReferenceType* shall be an *Object* or *Variable*. If the *SourceNode* is an *Object*, then the *TargetNode* shall be an *ObjectType*; if the *SourceNode* is a *Variable*, then the *TargetNode* shall be a *VariableType*.

Each *Variable* and each *Object* shall be the *SourceNode* of exactly one *HasTypeDefinition Reference*.

7.14 HasEncoding ReferenceType

The *HasEncoding ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *NonHierarchicalReferences*.

The semantic of this *ReferenceType* is to reference *DataTypeEncodings* of a *DataType*.

The *SourceNode* of *References* of this type shall be a *DataType*.

The *TargetNode* of this *ReferenceType* shall be an *Object* of the *ObjectType DataTypeEncodingType* or one of its subtypes (see 5.8.4).

7.15 HasDescription ReferenceType

The *HasDescription ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *NonHierarchicalReferences*.

The semantic of this *ReferenceType* is to reference the *DataTypeDescription* of a *DataTypeEncoding*.

The *SourceNode* of *References* of this type shall be an *Object* of the *ObjectType DataTypeEncodingType* or one of its subtypes.

The *TargetNode* of this *ReferenceType* shall be a *Variable* of the *VariableType DataTypeDescriptionType* or one of its subtypes (see 5.8.4).

7.16 GeneratesEvent

The *GeneratesEvent ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *NonHierarchicalReferences*.

The semantic of this *ReferenceType* is to identify the types of *Events* instances of *ObjectTypes* or *VariableTypes* may generate and *Methods* may generate on each *Method* call.

The *SourceNode* of *References* of this type shall be an *ObjectType*, a *VariableType* or a *Method*.

The *TargetNode* of this *ReferenceType* shall be an *ObjectType* representing *EventTypes*, that is, the *BaseEventType* or one of its subtypes.

7.17 AlwaysGeneratesEvent

The *AlwaysGeneratesEvent ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *GeneratesEvent*.

The semantic of this *ReferenceType* is to identify the types of *Events Methods* have to generate on each *Method* call.

The *SourceNode* of *References* of this type shall be a *Method*.

The *TargetNode* of this *ReferenceType* shall be an *ObjectType* representing *EventTypes*, that is, the *BaseEventType* or one of its subtypes.

7.18 HasEventSource

The *HasEventSource ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *HierarchicalReferences*.

The semantic of this *ReferenceType* is to relate event sources in a hierarchical, non-looping organization. This *ReferenceType* and any subtypes are intended to be used for discovery of *Event* generation in a *Server*. They are not required to be present for a *Server* to generate an *Event* from its source (causing the *Event*) to its notifying *Nodes*. In particular, the root notifier of a *Server*, the *Server Object* defined in Part 5, is always capable of supplying all *Events* from a *Server* and as such has implied *HasEventSource References* to every event source in a *Server*.

The *SourceNode* of this *ReferenceType* shall be an *Object* that is a source of event subscriptions. A source of event subscriptions is an *Object* that has its “SubscribeToEvents” bit set within the *EventNotifier Attribute*.

The *TargetNode* of this *ReferenceType* can be a *Node* of any *NodeClass* that can generate event notifications via a subscription to the reference source.

Starting from *Node* “A” and only following *References* of the *HasEventSource ReferenceType* or of its subtypes it shall never be possible to return to “A”. But it is permitted that, following the *References*, there may be more than one path leading to another *Node* “B”.

7.19 HasNotifier

The *HasNotifier ReferenceType* is a concrete *ReferenceType* and can be used directly. It is a subtype of *HasEventSource*.

The semantic of this *ReferenceType* is to relate *Object Nodes* that are notifiers with other notifier *Object Nodes*. The *ReferenceType* is used to establish a hierarchical organization of event notifying *Objects*. It is a subtype of the *HasEventSource ReferenceType* defined in 7.17.

The *SourceNode* of this *ReferenceType* shall be *Objects* or *Views* that are a source of event subscriptions. The *TargetNode* of this *ReferenceType* shall be *Objects* that are a source of event subscriptions. A source of event subscriptions is an *Object* that has its “SubscribeToEvents” bit set within the *EventNotifier Attribute*.

If the *TargetNode* of a *Reference* of this type generates an *Event*, then this *Event* shall also be provided in the *SourceNode* of the *Reference*.

An example of a possible organization of *Event References* is represented in Figure 25. In this example an unfiltered *Event* subscription directed to the “Pump” *Object* will provide the *Event* sources “Start” and “Stop” to the subscriber. An unfiltered *Event* subscription directed to the “Area 1” *Object* will provide *Event* sources from “Machine B”, “Tank A” and all notifier sources below “Tank A”.

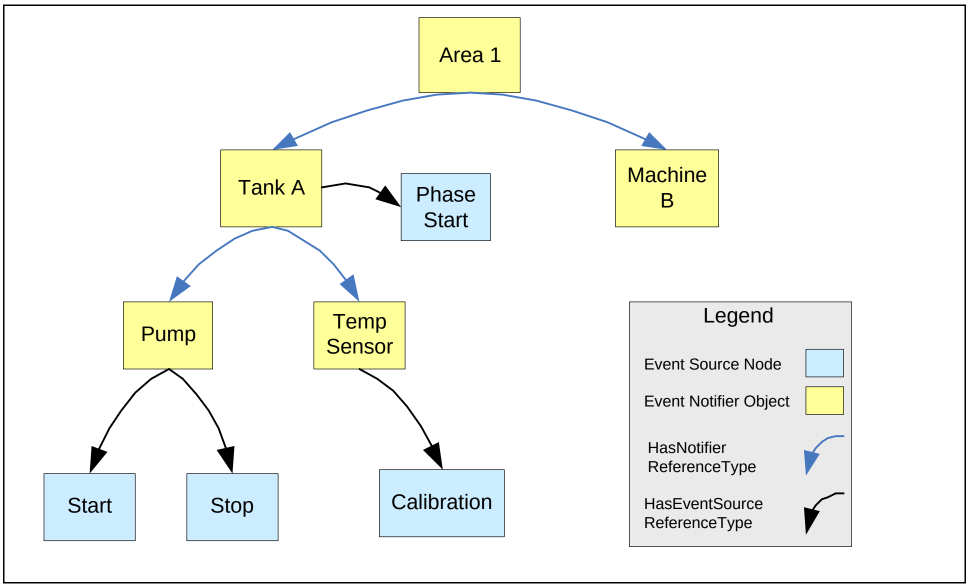


Figure 25 – Event Reference Example

A second example of a more complex organization of *Event References* is represented in Figure 26. In this example, explicit *References* are included from the *Server*'s *Server Object*, which is a source of all *Server Events*. A second *Event* organization has been introduced to collect the *Events* related to "Tank Farm 1". An unfiltered *Event* subscription directed to the "Tank Farm 1" *Object* will provide *Event* sources from "Tank B", "Tank A" and all notifier sources below "Tank B" and "Tank A".

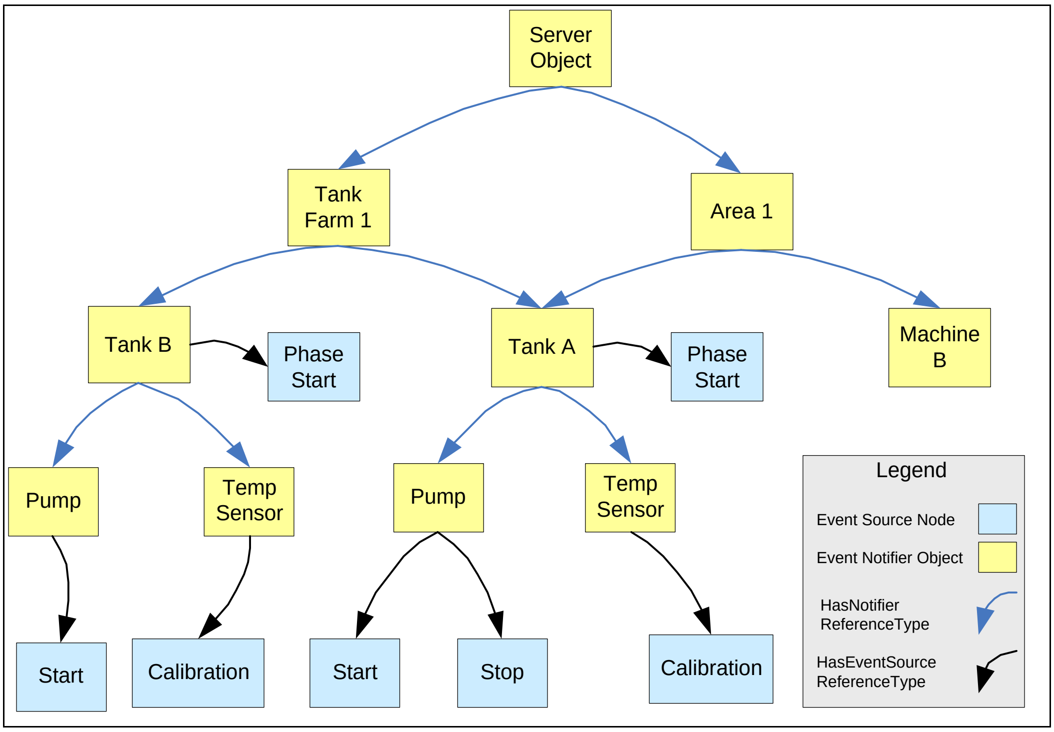


Figure 26 – Complex Event Reference Example

8 Standard DataTypes

8.1 General

The remainder of 8 defines *DataTypes*. Their representation in the *AddressSpace* and the *DataType* hierarchy is specified in Part 5. Other parts of this series of standards may specify additional *DataTypes*.

8.2 NodeId

8.2.1 General

This *Built-in DataType* is composed of three elements that identify a *Node* within a *Server*. They are defined in Table 17.

Table 17 – NodeId Definition

Name	Type	Description
NodeId	structure	
namespaceIndex	UInt16	The index for a namespace URI (see 8.2.2).
identifierType	Enum	The format and data type of the identifier (see 8.2.3).
identifier	*	The identifier for a *Node* in the *AddressSpace* of an OPC UA *Server* (see 8.2.4).

See Part 6 for a description of the encoding of the identifier into OPC UA Messages.

8.2.2 NamespaceIndex

The namespace is a URI that identifies the naming authority responsible for assigning the identifier element of the *NodeId*. Naming authorities include the local *Server*, the underlying system, standards bodies and consortia. It is expected that most *Nodes* will use the URI of the *Server* or of the underlying system.

Using a namespace URI allows multiple OPC UA *Servers* attached to the same underlying system to use the same identifier to identify the same *Object*. This enables *Clients* that connect to those *Servers* to recognise *Objects* that they have in common.

Namespace URIs, like *Server* names, are identified by numeric values in OPC UA *Services* to permit more efficient transfer and processing (e.g. table lookups). The numeric values used to identify namespaces correspond to the index into the *NamespaceArray*. The *NamespaceArray* is a *Variable* that is part of the *Server Object* in the *AddressSpace* (see Part 5 for its definition).

The URI for the OPC UA namespace is:

`"http://opcfoundation.org/UA/"`

Its corresponding index in the namespace table is 0.

The namespace URI is case sensitive.

8.2.3 IdentifierType

The IdentifierType element identifies the type of the *NodeId*, its format and its scope. Its values are defined in Table 18.

Table 18 – IdentifierType Values

Value	Description
NUMERIC_0	Numeric value
STRING_1	String value
GUID_2	Globally Unique Identifier
OPAQUE_3	Namespace specific format

Normally the scope of *NodeIds* is the *Server* in which they are defined. For certain types of *NodeIds*, *NodeIds* can uniquely identify a *Node* within a system, or across systems (e.g. GUIDs). System-wide and globally-unique identifiers allow *Clients* to track *Nodes*, such as work orders, as they move between OPC UA *Servers* as they progress through the system.

Opaque identifiers are identifiers that are free-format byte strings that might or might not be human interpretable.

String identifiers are case sensitive. That is, *Clients* shall consider them case sensitive. *Servers* are allowed to provide alternative *NodeIds* (see 5.2.2) and using this mechanism severs can handle *NodeIds* as case insensitive.

8.2.4 Identifier value

The identifier value element is used within the context of the first three elements to identify the *Node*. Its data type and format is defined by the IdType.

Identifier values of IdType STRING_1 are restricted to 4 096 characters. Identifier values of IdType OPAQUE_3 are restricted to 4 096 bytes.

A null *NodeId* has special meaning. For example, many services defined in Part 4 define special behaviour if a null *NodeId* is passed as a parameter. Each IdType has a set of identifier values that represent a null *NodeId*. These values are summarised in Table 19.

Table 19 – NodeId Null Values

IdType	Identifier
NUMERIC_0	0
STRING_1	A null or Empty String (“”)
GUID_2	A Guid initialised with zeros (e.g. 00000000-0000-0000-0000-000000)
OPAQUE_3	A ByteString with Length=0

A null *NodeId* always has a NamespaceIndex equal to 0.

A *Node* in the *AddressSpace* shall not have a null as its *NodeId*.

8.3 QualifiedName

This *Built-in DataType* contains a qualified name. It is, for example, used as *BrowseName*. Its elements are defined in Table 20. The name part of the *QualifiedName* is restricted to 512 characters.

Table 20 – QualifiedName Definition

Name	Type	Description
QualifiedName	structure	
namespaceIndex	UInt16	Index that identifies the namespace that defines the name. This index is the index of that namespace in the local *Server*’s *NamespaceArray*. The *Client* may read the *NamespaceArray Variable* to access the string value of the namespace.
name	String	The text portion of the QualifiedName.

8.4 LocaleId

This *Simple DataType* is specified as a string that is composed of a language component and a country/region component as specified by IEEE 754-1985, *IEEE Standard for Binary Floating-Point Arithmetic*,http://ieeexplore.ieee.org/servlet/opac?punumber=2355

IETF RFC 3066. The <country/region> component is always preceded by a hyphen. The format of the *LocaleId* string is shown below:

<language>[-<country/region>], where
<language> is the two letter ISO 639 code for a language,
<country/region> is the two letter ISO 3166 code for the country/region.

The rules for constructing *LocaleIds* defined by IEEE 754-1985, *IEEE Standard for Binary Floating-Point Arithmetic*,http://ieeexplore.ieee.org/servlet/opac?punumber=2355

IETF RFC 3066 are restricted as follows:

a) this specification permits only zero or one <country/region> component to follow the <language> component;
b) this specification also permits the “-CHS” and “-CHT” three-letter <country/region> codes for “Simplified” and “Traditional” Chinese locales;

c) this specification also allows the use of other <country/region> codes as deemed necessary by the *Client* or the *Server*.

Table 21 shows examples of OPC UA *LocaleIds*. *Clients* and *Servers* always provide *LocaleIds* that explicitly identify the language and the country/region.

Table 21 –LocaleId Examples

Locale	OPC UA LocaleId
English	en
English (US)	en-US
German	de
German (Germany)	de-DE
German (Austrian)	de-AT

An empty or null string indicates that the LocaleId is unknown.

8.5 LocalizedText

This *Built-in DataType* defines a structure containing a String in a locale-specific translation specified in the identifier for the locale. Its elements are defined in Table 22.

Table 22 – LocalizedText Definition

Name	Type	Description
LocalizedText	structure	
text	String	The localized text.
locale	LocaleId	The identifier for the locale (e.g. “en-US”).

8.6 Argument

This *Structured DataType* defines a *Method* input or output argument specification. It is for example used in the input and output argument *Properties* for *Methods*. Its elements are described in Table 23.

Table 23 – Argument Definition

Name	Type	Description
Argument	structure	
name	String	The name of the argument.
dataType	NodeId	The *NodeId* of the *DataType* of this argument.
valueRank	Int32	Indicates whether the *dataType* is an array and how many dimensions the array has. It may have the following values: *n* > 1: the dataType is an array with the specified number of dimensions. OneDimension (1): The dataType is an array with one dimension. OneOrMoreDimensions (0): The dataType is an array with one or more dimensions. Scalar (−1): The dataType is not an array. Any (−2): The dataType can be a scalar or an array with any number of dimensions. ScalarOrOneDimension (−3): The dataType can be a scalar or a one dimensional array. NOTE All DataTypes are considered to be scalar, even if they have array-like semantics like ByteString and String.
arrayDimensions	UInt32[]	Specifies the length of each dimension for an array dataType. It is intended to describe the capability of the dataType, not the current size. The number of elements shall be equal to the value of the *valueRank*. Shall be null if *valueRank* ≤ 0. A value of 0 for an individual dimension indicates that the dimension has a variable length.
description	LocalizedText	A localised description of the argument.

8.7 BaseDataType

This abstract *DataType* defines a value that can have any valid *DataType*.

It defines a special value null indicating that a value is not present.

8.8 Boolean

This *Built-in DataType* defines a value that is either TRUE or FALSE.

8.9 Byte

This *Built-in DataType* defines a value in the range of 0 to 255.

8.10 ByteString

This *Built-in DataType* defines a value that is a sequence of Byte values.

8.11 DateTime

This *Built-in DataType* defines a Gregorian calendar date. Details about this *DataType* are defined in Part 6.

8.12 Double

This *Built-in DataType* defines a value that adheres to the IEEE 754-1985 double precision data type definition.

8.13 Duration

This *Simple DataType* is a *Double* that defines an interval of time in milliseconds (fractions can be used to define sub-millisecond values). Negative values are generally invalid but may have special meanings where the *Duration* is used.

8.14 Enumeration

This abstract *DataType* is the base *DataType* for all enumeration *DataTypes* like *NodeClass* defined in 8.30. All *DataTypes* inheriting from this *DataType* have special handling for the encoding as defined in Part 6. All enumeration *DataTypes* shall inherit from this *DataType*.

Some special rules apply when subtyping enumerations. Any enumeration *DataType* not directly inheriting from the *Enumeration DataType* can only restrict the enumeration values of its supertype. That is, it shall neither add enumeration values nor change the text associated to the enumeration value. As an example, the enumeration Days having {'Mo', 'Tu', 'We', 'Th', 'Fr', 'Sa', 'Su'} as values can be subtyped to the enumeration Workdays having {'Mo', 'Tu', 'We', 'Th', 'Fr'}. The other direction, subtyping Workdays to Days would not be allowed as Days has values not allowed by Workdays ('Sa' and 'Su').

8.15 Float

This *Built-in DataType* defines a value that adheres to the IEEE 754-1985 single precision data type definition.

8.16 Guid

This *Built-in DataType* defines a value that is a 128-bit Globally Unique Identifier. Details about this *DataType* are defined in Part 6.

8.17 SByte

This *Built-in DataType* defines a value that is a signed integer between −128 and 127 inclusive.

8.18 IdType

This *DataType* is an enumeration that identifies the IdType of a *NodeId*. Its values are defined in Table 18. See 8.2.3 for a description of the use of this *DataType* in *NodeIds*.

8.19 Image

This abstract *DataType* defines a *ByteString* representing an image.

8.20 ImageBMP

This *Simple DataType* defines a *ByteString* representing an image in BMP format.

8.21 ImageGIF

This *Simple DataType* defines a *ByteString* representing an image in GIF format.

8.22 ImageJPG

This *Simple DataType* defines a *ByteString* representing an image in JPG format. JPG is defined in Part 1: OPC UA Specification: Part 1 – Overview and Concepts

http://www.opcfoundation.org/UA/Part1/

Part 2: OPC UA Specification: Part 2 – Security Model

http://www.opcfoundation.org/UA/Part2/

Part 4: OPC UA Specification: Part 4 – Services

http://www.opcfoundation.org/UA/Part4/

Part 5: OPC UA Specification: Part 5 – Information Model

http://www.opcfoundation.org/UA/Part5/

Part 6: OPC UA Specification: Part 6 – Mappings

http://www.opcfoundation.org/UA/Part6/

Part 8: OPC UA Specification: Part 8 – Data Access

http://www.opcfoundation.org/UA/Part8/

Part 9: OPC UA Specification: Part 9 – Alarms and conditions

http://www.opcfoundation.org/UA/Part9/

Part 11: OPC UA Specification: Part 11 – Historical Access

http://www.opcfoundation.org/UA/Part11/

ISO/IEC 10918-1.

8.23 ImagePNG

This *Simple DataType* defines a *ByteString* representing an image in PNG format. PNG is defined in ISO/IEC 15948.

8.24 Integer

This abstract *DataType* defines an integer whose length is defined by its subtypes.

8.25 Int16

This *Built-in DataType* defines a value that is a signed integer between −32 768 and 32 767 inclusive.

8.26 Int32

This *Built-in DataType* defines a value that is a signed integer between −2 147 483 648 and 2 147 483 647 inclusive.

8.27 Int64

This *Built-in DataType* defines a value that is a signed integer between −9 223 372 036 854 775 808 and 9 223 372 036 854 775 807 inclusive.

8.28 TimeZoneDataType

This *Structured DataType* defines the local time that may or may not take daylight saving time into account. Its elements are described in Table 24.

Table 24 – TimeZoneDataType Definition

Name	Type	Description
TimeZoneDataType	structure	
offset	Int16	The offset in minutes from UtcTime
daylightSavingInOffset	Boolean	If TRUE, then daylight saving time (DST) is in effect and *offset* includes the DST correction. If FALSE then the *offset* does not include the DST correction and DST may or may not have been in effect.

8.29 NamingRuleType

This *DataType* is an enumeration that identifies the *NamingRule* (see 6.4.4.2.1). Its values are defined in Table 25.

Table 25 – NamingRuleType Values

Name
MANDATORY_1
OPTIONAL_2
CONSTRAINT_3

8.30 NodeClass

This *DataType* is an enumeration that identifies a *NodeClass*. Its values are defined in Table 26.

Table 26 – NodeClass Values

Name
OBJECT_1
VARIABLE_2
METHOD_4
OBJECT_TYPE_8
VARIABLE_TYPE_16
REFERENCE_TYPE_32
DATA_TYPE_64
VIEW_128

8.31 Number

This abstract *DataType* defines a number. Details are defined by its subtypes.

8.32 String

This *Built-in DataType* defines a Unicode character string that should exclude control characters that are not whitespaces.

8.33 Structure

This abstract *DataType* is the base *DataType* for all *Structured DataTypes* like *Argument* defined in 8.6. All *DataTypes* inheriting from this *DataType* have special handling for the encoding as defined in Part 6.

8.34 UInteger

This abstract *DataType* defines an unsigned integer whose length is defined by its subtypes.

8.35 UInt16

This *Built-in DataType* defines a value that is an unsigned integer between 0 and 65 535 inclusive.

8.36 UInt32

This *Built-in DataType* defines a value that is an unsigned integer between 0 and 4 294 967 295 inclusive.

8.37 UInt64

This *Built-in DataType* defines a value that is an unsigned integer between 0 and 18 446 744 073 709 551 615 inclusive.

8.38 UtcTime

This *simple DataType* is a *DateTime* used to define Coordinated Universal Time (UTC) values. All time values conveyed between OPC UA *Servers* and *Clients* are UTC values. *Clients* shall provide any conversions between UTC and local time.

UTC has the concept of leap seconds. Leap seconds can lead to repeating seconds. Therefore applications are allowed to use TAI[1] (International Atomic Time) instead of UTC in any place where UtcTime is used. Details on time synchronization are discussed in Part 6.

8.39 XmlElement

This *Built-in DataType* is used to define XML elements. Part 6 defines details about this *DataType*.

XML data can always be modelled as a subtype of the *Structure DataType* with a single *DataTypeEncoding* that represents the XML complexType that defines the XML element (it is not necessary to have access to the XML Schema to define a *DataTypeEncoding*). For this reason a *Server* should never define *Variables* that use the *XmlElement DataType* unless the *Server* has no information about the XML elements that might be in the *Variable Value.*

8.40 EnumValueType

This *Structured DataType* is used to represent a human-readable representation of an Enumeration. Its elements are described inTable 27. When this type is used in an array representing human-readable representations of an enumeration, each Value shall be unique in that array.

Table 27 – EnumValueType Definition

Name	Type	Description
EnumValueType	structure	
Value	Int64	The Integer representation of an Enumeration.
DisplayName	LocalizedText	A human-readable representation of the Value of the Enumeration.
Description	LocalizedText	A localized description of the enumeration value. This field can contain an empty string if no description is available.

Note that the *EnumValueType* has been defined with a Int64 Value to meet a variety of usages. When it is used to define the string representation of an Enumeration *DataType*, the value range is limited to Int32, because the Enumeration *DataType* is a subtype of Int32. Part 8 specifies other usages where the actual value might be between 8 and 64 Bit.

[1] TAI = t*emps atomique international.*

8.41 OptionSet

This abstract *DataType* is the base *DataType* for all *DataTypes* representing a bit mask. All *OptionSet DataTypes* representing bit masks shall inherit from this *DataType*. Its elements are described in Table 28.

Table 28 – OptionSet Definition

Name	Type	Description
OptionSet	structure	
value	ByteString	Array of bytes representing the bits in the option set. The length of the ByteString depends on the number of bits.
validBits	ByteString	Array of bytes with same size as value representing the valid bits in the value parameter. When the *Server* returns the value to the *Client*, the *validBits* provides information of which bits in the bit mask have a meaning. When the *Client* passes the value to the *Server*, the *validBits* defines which bits should be written. Only those bits defined in *validBits* are changed in the bit mask, all others stay the same.

The *DataType Nodes* representing concrete subtypes of the *OptionSet* shall have an *OptionSetValues Property* defined in Table 11.

8.42 Union

This abstract *DataType* is the base *DataType* for all union *DataTypes*. The *DataType* is a subtype of *Structure DataType*. All *DataTypes* inheriting from this *DataType* have special handling for the encoding as defined in Part 6. All union *DataTypes* shall inherit from this *DataType*.

8.43 DateString

This *Simple DataType* defines a value which is a day in the Gregorian calendar in string. Lexical representation of the string shall conform to calendar date defined in ISO 8601-2000.

NOTE: According to ISO 8601-2000, 'calendar date representations are in the form [YYYY-MM-DD]. [YYYY] indicates a four-digit year, 0000 through 9999. [MM] indicates a two-digit month of the year, 01 through 12. [DD] indicates a two-digit day of that month, 01 through 31. For example, "the 5th of April 1981" may be represented as either "1981-04-05" in the extended format or "19810405" in the basic format.'

NOTE: ISO 8601-2000 also allows for calendar dates to be written with reduced precision. For example, one may write "1981-04" to mean "1981 April", and one may simply write "1981" to refer to that year or "19" to refer to the century from 1900 to 1999 inclusive.

NOTE: Although ISO 8601-2000 allows both the YYYY-MM-DD and YYYYMMDD formats for complete calendar date representations, if the day [DD] is omitted then only the YYYY-MM format is allowed. By disallowing dates of the form YYYYMM, ISO 8601-2000 avoids confusion with the truncated representation YYMMDD (still often used).

8.44 DecimalString

This *Simple DataType* defines a value that represens a decimal number as a string. Lexical representation of the string shall conform to decimal type defined in W3C XML Schema Definition Language (XSD) 1.1 Part 2: DataTypes.

The *DecimalString* is a numeric string with an optional sign and decimal point.

8.45 DurationString

This *Simple DataType* defines a value that represents a duration of time as a string. It shall conform to duration as defined in ISO 8601-2000.

NOTE: According to ISO 8601—2000 'Durations are represented by the format P[n]Y[n]M[n]DT[n]H[n]M[n]S or P[n]W as shown to the right. In these representations, the [n] is replaced by the value for each of the date and time elements that follow the [n]. Leading zeros are not required, but the maximum number of digits for each element should be agreed to by the communicating parties. The capital letters *P*, *Y*, *M*, *W*, *D*, *T*, *H*, *M*, and *S* are designators for each of the date and time elements and are not replaced.

- *P* is the duration designator (historically called "period") placed at the start of the duration representation.
- *Y* is the year designator that follows the value for the number of years.
- *M* is the month designator that follows the value for the number of months.

- *W* is the week designator that follows the value for the number of weeks.
- *D* is the day designator that follows the value for the number of days.
- *T* is the time designator that precedes the time components of the representation.
- *H* is the hour designator that follows the value for the number of hours.
- *M* is the minute designator that follows the value for the number of minutes.
- *S* is the second designator that follows the value for the number of seconds.

For example, "P3Y6M4DT12H30M5S" represents a duration of "three years, six months, four days, twelve hours, thirty minutes, and five seconds". Date and time elements including their designator may be omitted if their value is zero, and lower order elements may also be omitted for reduced precision. For example, "P23DT23H" and "P4Y" are both acceptable duration representations.'

8.46 NormalizedString

This *Simple DataType* defines a string value that shall be normalized according to Unicode Annex 15, Version 7.0.0, Normalization Form C.

NOTE: Some Unicode characters have multiple equivalent binary representations consisting of sets of combining and/or composite Unicode characters. Unicode defines a process called normalization that returns one binary representation when given any of the equivalent binary representations of a character. The Win32 and the .NET Framework currently support normalization forms C, D, KC, and KD, as defined in Annex 15 of Unicode. *NormalizedString* uses Normalization Form C for all content, because this form avoids potential interoperability problems caused by the use of canonically equivalent, yet different, character sequences in document formats.

8.47 TimeString

This *Simple DataType* defines a value that represents a time as a string. It shall conform to time of day as defined in ISO 8601-2000.

NOTE: ISO 8601-2000 uses the 24-hour clock system. The *basic format* is [hh][mm][ss] and the *extended format* is [hh]:[mm]:[ss].

- [hh] refers to a zero-padded hour between 00 and 24 (where 24 is only used to notate midnight at the end of a calendar day).
- [mm] refers to a zero-padded minute between 00 and 59.
- [ss] refers to a zero-padded second between 00 and 60 (where 60 is only used to notate an added leap second).

So a time might appear as either "134730" in the *basic format* or "13:47:30" in the *extended format*.

It is also acceptable to omit lower order time elements for reduced accuracy: [hh]:[mm], [hh][mm] and [hh] are all used.

Midnight is a special case and can be referred to as both "00:00" and "24:00". The notation "00:00" is used at the beginning of a calendar day and is the more frequently used. At the end of a day use "24:00"

9 Standard EventTypes

9.1 General

The remainder of 9 defines *EventTypes*. Their representation in the *AddressSpace* is specified in Part 5. Other parts of this series of standards may specify additional *EventTypes*. Figure 27 informally describes the hierarchy of these *EventTypes.*

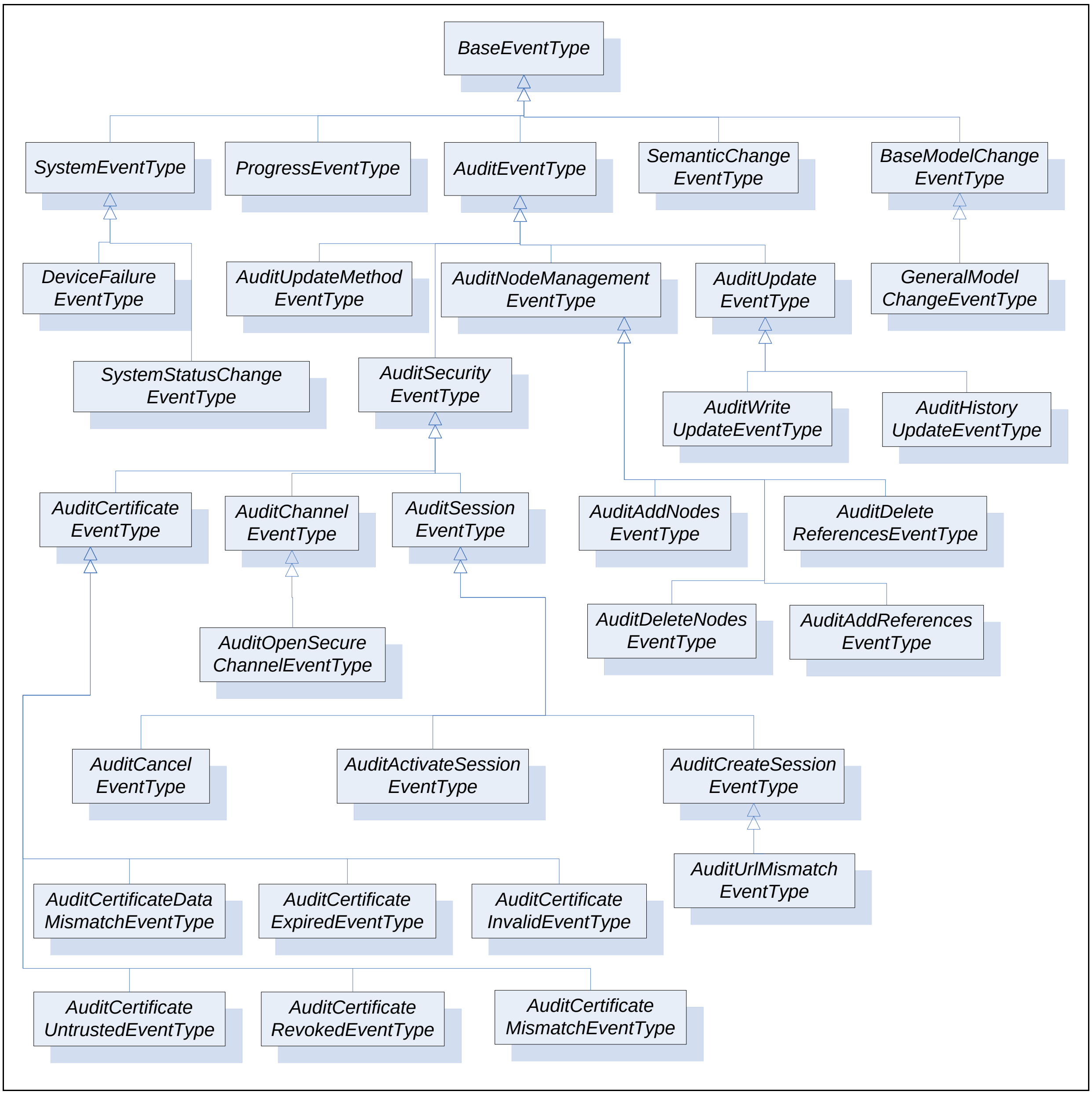


Figure 27 – Standard EventType Hierarchy

9.2 BaseEventType

The *BaseEventType* defines all general characteristics of an *Event*. All other *EventTypes* derive from it. There is no other semantic associated with this type.

9.3 SystemEventType

SystemEvents are *Events* of *SystemEventType* that are generated as a result of some *Event* that occurs within the *Server* or by a system that the *Server* is representing.

9.4 ProgressEventType

ProgressEvents are *Events* of *ProgressEventType* that are generated to identify the progress of an operation. An operation can be a service call or something application specific like a program execution.

9.5 AuditEventType

AuditEvents are *Events* of *AuditEventType* that are generated as a result of an action taken on the *Server* by a *Client* of the *Server*. For example, in response to a *Client* issuing a write to a

Variable, the *Server* would generate an *AuditEvent* describing the *Variable* as the source and the user and *Client* session as the initiators of the *Event*.

Figure 28 illustrates the defined behaviour of an OPC UA *Server* in response to an auditable action request. If the action is accepted, then an action *AuditEvent* is generated and processed by the *Server*. If the action is not accepted due to security reasons, a security *AuditEvent* is generated and processed by the *Server*. The *Server* may involve the underlying device or system in the process but it is the *Server*'s responsibility to provide the *Event* to any interested *Clients*. *Clients* are free to subscribe to *Events* from the *Server* and will receive the *AuditEvents* in response to normal Publish requests.

All action requests include a human readable *AuditEntryId*. The *AuditEntryId* is included in the *AuditEvent* to allow human readers to correlate an *Event* with the initiating action. The *AuditEntryId* typically contains who initiated the action and from where it was initiated.

The *Server* may elect to optionally persist the *AuditEvents* in addition to the mandatory *Event Subscription* delivery to *Clients*.

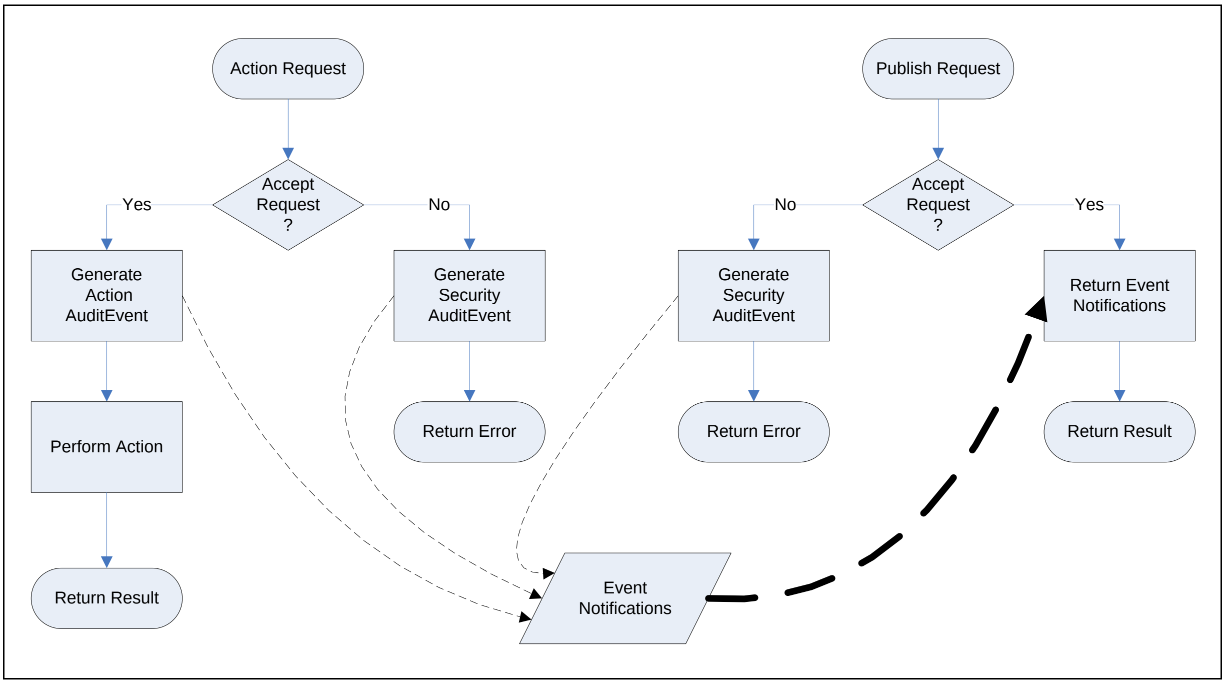


Figure 28 – Audit Behaviour of a Server

Figure 29 illustrates the expected behaviour of an aggregating *Server* in response to an auditable action request. This use case involves the aggregating *Server* passing on the action to one of its aggregated *Servers*. The general behaviour described above is extended by this behaviour and not replaced. That is, the request could fail and generate a security *AuditEvent* within the aggregating *Server*. The normal process is to pass the action down to an aggregated *Server* for processing. The aggregated *Server* will, in turn, follow this behaviour or the general behaviour and generate the appropriate *AuditEvents*. The aggregating *Server* periodically issues publish requests to the aggregated *Servers*. These collected *Events* are merged with self-generated *Events* and made available to subscribing *Clients*. If the aggregating *Server* supports the optional persisting of *AuditEvent*, then the collected *Events* are persisted along with locally-generated *Events*.

The aggregating *Server* may map the authenticated user account making the request to one of its own accounts when passing on the request to an aggregated *Server*. It shall, however, preserve the *AuditEntryId* by passing it on as received. The aggregating *Server* may also generate its own *AuditEvent* for the request prior to passing it on to the aggregated *Server*, in particular, if the aggregating *Server* needs to break a request into multiple requests that are each directed to separate aggregated *Servers* or if part of a request is denied due to security on the aggregating *Server*.

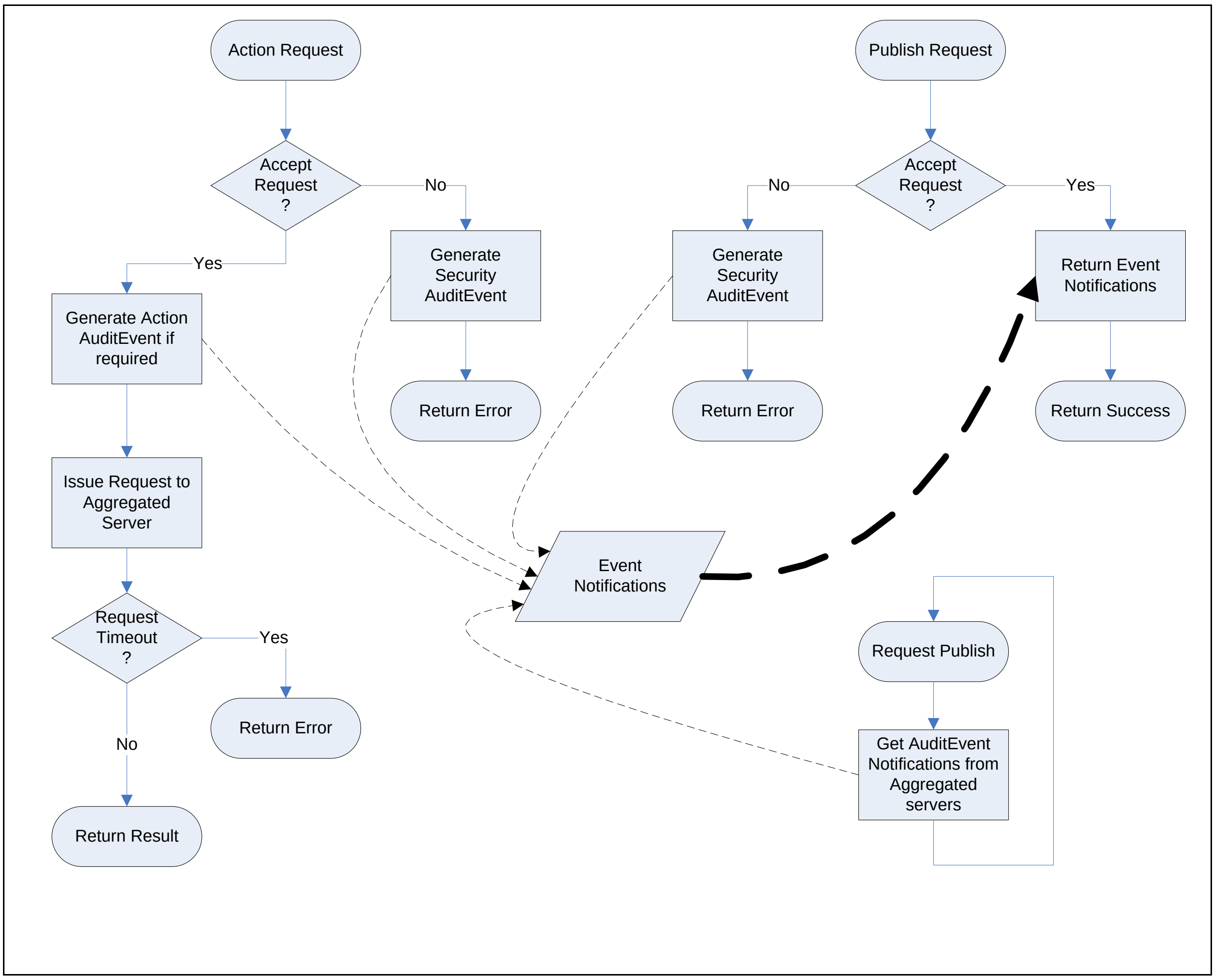


Figure 29 – Audit Behaviour of an Aggregating Server

9.6 AuditSecurityEventType

This is a subtype of *AuditEventType* and is used only for categorization of security-related *Events*. This type follows all behaviour of its parent type.

9.7 AuditChannelEventType

This is a subtype of *AuditSecurityEventType* and is used for categorization of security-related *Events* from the *SecureChannel Service Set* defined in Part 4.

9.8 AuditOpenSecureChannelEventType

This is a subtype of *AuditChannelEventType* and is used for *Events* generated from calling the OpenSecureChannel *Service* defined in Part 4.

9.9 AuditSessionEventType

This is a subtype of *AuditSecurityEventType* and is used for categorization of security-related *Events* from the *Session Service Set* defined in Part 4.

9.10 AuditCreateSessionEventType

This is a subtype of *AuditSessionEventType* and is used for *Events* generated from calling the CreateSession *Service* defined in Part 4.

9.11 AuditUrlMismatchEventType

This is a subtype of *AuditCreateSessionEventType* and is used for *Events* generated from calling the CreateSession *Service* defined in Part 4 if the EndpointUrl used in the service call does not match the *Server*'s *HostNames* (see Part 4 for details).

9.12 AuditActivateSessionEventType

This is a subtype of *AuditSessionEventType* and is used for *Events* generated from calling the ActivateSession *Service* defined in Part 4.

9.13 AuditCancelEventType

This is a subtype of *AuditSessionEventType* and is used for *Events* generated from calling the Cancel *Service* defined in Part 4.

9.14 AuditCertificateEventType

This is a subtype of *AuditSecurityEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. These *AuditEvents* will be generated for Certificate errors in addition to other *AuditEvents* related to service calls.

9.15 AuditCertificateDataMismatchEventType

This is a subtype of *AuditCertificateEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. This *AuditEvent* is generated if the HostName in the URL used to connect to the *Server* is not the same as one of the HostNames specified in the Certificate or if the Application and Software Certificates contain an application or product URI that does not match the URI specified in the ApplicationDescription provided with the Certificate. For more details on Certificates see Part 4.

9.16 AuditCertificateExpiredEventType

This is a subtype of *AuditCertificateEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. This *AuditEvent* is generated if the current time is outside the validity period’s start date and end date.

9.17 AuditCertificateInvalidEventType

This is a subtype of *AuditCertificateEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. This *AuditEvent* is generated if the certificate structure is invalid or if the Certificate has an invalid signature.

9.18 AuditCertificateUntrustedEventType

This is a subtype of *AuditCertificateEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. This *AuditEvent* is generated if the Certificate is not trusted, that is, if the Issuer Certificate is unknown.

9.19 AuditCertificateRevokedEventType

This is a subtype of *AuditCertificateEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. This *AuditEvent* is generated if a Certificate has been revoked or if the revocation list is not available (i.e. a network interruption prevents the Application from accessing the list).

9.20 AuditCertificateMismatchEventType

This is a subtype of *AuditCertificateEventType* and is used only for categorization of Certificate related *Events*. This type follows all behaviours of its parent type. This *AuditEvent* is generated if a Certificate set of uses does not match the requested use for the Certificate (i.e. Application, Software or Certificate Authority).

9.21 AuditNodeManagementEventType

This is a subtype of *AuditEventType* and is used for categorization of node management related *Events*. This type follows all behaviours of its parent type.

9.22 AuditAddNodesEventType

This is a subtype of *AuditNodeManagementEventType* and is used for *Events* generated from calling the AddNodes *Service* defined in Part 4.

9.23 AuditDeleteNodesEventType

This is a subtype of *AuditNodeManagementEventType* and is used for *Events* generated from calling the DeleteNodes *Service* defined in Part 4.

9.24 AuditAddReferencesEventType

This is a subtype of *AuditNodeManagementEventType* and is used for *Events* generated from calling the AddReferences *Service* defined in Part 4.

9.25 AuditDeleteReferencesEventType

This is a subtype of *AuditNodeManagementEventType* and is used for *Events* generated from calling the DeleteReferences *Service* defined in Part 4.

9.26 AuditUpdateEventType

This is a subtype of *AuditEventType* and is used for categorization of update related *Events*. This type follows all behaviours of its parent type.

9.27 AuditWriteUpdateEventType

This is a subtype of *AuditUpdateEventType* and is used for categorization of write update related *Events*. This type follows all behaviours of its parent type.

9.28 AuditHistoryUpdateEventType

This is a subtype of *AuditUpdateEventType* and is used for categorization of history update related *Events*. This type follows all behaviours of its parent type.

9.29 AuditUpdateMethodEventType

This is a subtype of *AuditEventType* and is used for categorization of *Method* related *Events*. This type follows all behaviours of its parent type.

9.30 DeviceFailureEventType

A *DeviceFailureEvent* is an *Event* of *DeviceFailureEventType* that indicates a failure in a device of the underlying system.

9.31 SystemStatusChangeEventType

A *SystemStatusChangeEvent* is an *Event* of *SystemStatusChangeEventType* that indicates a status change in a system. For example, if the status indicates an underlying system is not running, then a *Client* cannot expect any *Events* from the underlying system. A *Server* can identify its own status changes using this *EventType*.

9.32 ModelChangeEvents

9.32.1 General

ModelChangeEvents are generated to indicate a change of the *AddressSpace* structure. The change may consist of adding or deleting a *Node* or *Reference.* Although the relationship of a *Variable* or *VariableType* to its *DataType* is not modelled using *References*, changes to the *DataType Attribute* of a *Variable* or *VariableType* are also considered as model changes and therefore a *ModelChangeEvent* is generated if the *DataType Attribute* changes.

9.32.2 NodeVersion Property

There is a correlation between *ModelChangeEvents* and the *NodeVersion Property* of *Nodes*. Every time a *ModelChangeEvent* is issued for a *Node*, its *NodeVersion* shall be changed, and every time the *NodeVersion* is changed, a *ModelChangeEvent* shall be generated. A *Server* shall support both the *ModelChangeEvent* and the *NodeVersion Property* or neither, but never only one of the two mechanisms.

This relation also implies that only those *Nodes* of the *AddressSpace* having a *NodeVersion* shall trigger a *ModelChangeEvent*. Other *Nodes* shall not trigger a *ModelChangeEvent*.

9.32.3 Views

A *ModelChangeEvent* is always generated in the context of a *View,* including the default *View* where the whole *AddressSpace* is considered. Therefore the only *Notifiers* which report the *ModelChangeEvents* are *View Nodes* and the *Server Object* representing the default *View*. Each action generating a *ModelChangeEvent* may lead to several *Events* since it may affect different *Views*. If, for example, a *Node* was deleted from the *AddressSpace*, and this *Node* was also contained in a View “A”, there would be one *Event* having the *AddressSpace* as context and another having the View “A” as context. If a *Node* would only be removed from *View* “A”, but still exists in the *AddressSpace*, it would generate only a *ModelChangeEvent* for *View* “A”.

If a *Client* does not want to receive duplicates of changes then it shall use the filter mechanisms of the *Event* subscription to filter only for the default *View* and suppress the *ModelChangeEvents* having other *Views* as the context.

When a *ModelChangeEvent* is issued on a *View* and the *View* supports the *ViewVersion Property*, then the *ViewVersion* shall be updated.

9.32.4 Event Compression

An implementation is not required to issue an *Event* for every update as it occurs. An OPC UA *Server* may be capable of grouping a series of transactions or simple updates into a larger unit. This series may constitute a logical grouping or a temporal grouping of changes. A single *ModelChangeEvent* may be issued after the last change of the series, to cover all of the changes. This is referred to as *Event compression*. A change in the *NodeVersion* and the *ViewVersion* may thus reflect a group of changes and not a single change.

9.32.5 BaseModelChangeEventType

BaseModelChangeEvents are *Events* of the *BaseModelChangeEventType*. The *BaseModelChangeEventType* is the base type for *ModelChangeEvents* and does not contain information about the changes but only indicates that changes occurred. Therefore the *Client* shall assume that any or all of the *Nodes* may have changed.

9.32.6 GeneralModelChangeEventType

GeneralModelChangeEvents are *Events* of the *GeneralModelChangeEventType*. The *GeneralModelChangeEventType* is a subtype of the *BaseModelChangeEventType*. It contains information about the *Node* that was changed and the action that occurred to cause the *ModelChangeEvent* (e.g. add a *Node*, delete a *Node*, etc.). If the affected *Node* is a *Variable* or *Object*, then the *TypeDefinitionNode* is also present.

To allow *Event* compression, a *GeneralModelChangeEvent* contains an array of changes.

9.32.7 Guidelines for ModelChangeEvents

Two types of *ModelChangeEvents* are defined: the *BaseModelChangeEvent* that does not contain any information about the changes and the *GeneralModelChangeEvent* that identifies the changed *Nodes* via an array. The precision used depends on both the capability of the OPC UA *Server* and the nature of the update. An OPC UA *Server* may use either *ModelChangeEvent* type depending on circumstances. It may also define subtypes of these *EventTypes* adding additional information.

To ensure interoperability, the following guidelines for *Events* should be observed.

- If the array of the *GeneralModelChangeEvent* is present, then it should identify every *Node* that has changed since the preceding *ModelChangeEvent*.
- The OPC UA *Server* should emit exactly one *ModelChangeEvent* for an update or series of updates. It should not issue multiple types of *ModelChangeEvent* for the same update.
- Any *Client* that responds to *ModelChangeEvents* should respond to any *Event* of the *BaseModelChangeEventType* including its subtypes like the *GeneralModelChangeEventType*.

If a *Client* is not capable of interpreting additional information of the subtypes of the *BaseModelChangeEventType*, it should treat *Events* of these types the same way as *Events* of the *BaseModelChangeEventType*.

9.33 SemanticChangeEventType

9.33.1 General

SemanticChangeEvents are *Events* of *SemanticChangeEventType* that are generated to indicate a change of the *AddressSpace* semantics. The change consists of a change to the *Value Attribute* of a *Property*.

The *SemanticChangeEvent* contains information about the *Node* owning the *Property* that was changed. If this is a *Variable* or *Object*, the *TypeDefinitionNode* is also present.

The SemanticChange bit of the *AccessLevel Attribute* of a *Property* indicates whether changes of the *Property* value are considered for *SemanticChangeEvents* (see 5.6.2).

9.33.2 ViewVersion and NodeVersion Properties

The *ViewVersion* and *NodeVersion Properties* do not change due to the publication of a *SemanticChangeEvent*.

There is no standard way to identify which *Nodes* trigger a *SemanticChange Event* and which *Nodes* do not.

9.33.3 Views

SemanticChangeEvents are handled in the context of a *View* the same way as *ModelChangeEvents*. This is defined in 9.32.3.

9.33.4 Event Compression

SemanticChangeEvents can be compressed the same way as *ModelChangeEvents*. This is defined in 9.32.4.

Annex A
(informative)

How to use the Address Space Model

A.1 Overview

Annex A points out some general considerations on how the Address Space Model can be used. Annex A is for information only, that is, each *Server* vendor can model its data in the appropriate way that fits its needs. However, it gives some hints the *Server* vendor may consider.

Typically OPC UA *Servers* will offer data provided by an underlying system like a device, a configuration database, an OPC COM *Server*, etc. Therefore the modelling of the data depends on the model of the underlying system as well as the requirements of the *Clients* accessing the OPC UA *Server*. It is also expected that companion specifications will be developed on top of OPC UA with additional rules on how to model the data. However, the remainder of Annex Aill give some general considerations about the different concepts of OPC UA to model data and when they should be used, and when not.

Part 5:–, Annex A, provides an overview of the design decisions made when modelling the information about the *Server* defined in Part 5.

A.2 Type definitions

Type definitions should be used whenever it is expected that the type information may be used more than once in the same system or for interoperability between different systems supporting the same type definitions.

A.3 ObjectTypes

Subclause 5.5.1 states: "*Objects* are used to represent systems, system components, real-world objects, and software objects." Therefore *ObjectTypes* should be used if a type definition of those *ObjectTypes* is useful (see A.2).

From a more abstract point of view *Objects* are used to group *Variables* and other *Objects* in the *AddressSpace*. Therefore *ObjectTypes* should be used when some common structures/groups of *Objects* and/or *Variables* should be described. *Clients* can use this knowledge to program against the *ObjectType* structure and use the TranslateBrowsePathsToNodeIds *Service* defined in Part 4 on the instances.

Simple objects only having one value (e.g. a simple heat sensor) can also be modelled as *VariableTypes*. However, extensibility mechanisms should be considered (e.g. a complex heat sensor subtype could have several values) and whether that object should be exposed as an object in the *Client*'s GUI or just as a value. Whenever a modeller is in doubt as to which solution to use the *ObjectType* having one *Variable* should be preferred.

A.4 VariableTypes

A.4.1 General

VariableTypes are only used for *DataVariables*[2] and should be used when there are several *Variables* having the same semantic (e.g. set point). It is not necessary to define a *VariableType* that only reflects the *DataType* of a *Variable*, e.g. an "Int32VariableType".

A.4.2 Properties or DataVariables

Besides the semantic differences of *Properties* and *DataVariables* described in Clause 4 there are also syntactical differences. A *Property* is identified by its *BrowseName*, that is, if *Properties*

[2] *VariableTypes* other than the *PropertyType* which is used for all *Properties.*

having the same semantic are used several times, they should always have the same *BrowseName*. The same semantic of *DataVariables* is captured in the *VariableType*.

If it is not clear which concept to use based on the semantic described in Clause 4, then the different syntax can help. The following points identify when it shall be a *DataVariable*.

- If it is a complex *Variable* or it should contain additional information in the form of *Properties*.
- If the type definition may be refined (subtyping).
- If the type definition should be made available so the *Client* can use the AddNodes *Service* defined in Part 4 to create new instances of the type definition.
- If it is a component of a complex *Variable* exposing a part of the value of the complex *Variable*.

A.4.3 Many Variables and / or structured DataTypes

When structured data structures should be made available to the *Client* there are basically three different approaches:

a) Create several simple *Variables* using simple *DataTypes* always reflecting parts of the simple structure. *Objects* are used to group the *Variables* according to the structure of the data.
b) Create a structured *DataType* and a simple *Variable* using this *DataType*.
c) Create a structured *DataType* and a complex *Variable* using this *DataType* and also exposing the structured data structure as *Variables* of the complex *Variable* using simple *DataTypes*.

The advantages of the first approach are that the complex structure of the data is visible in the *AddressSpace*. A generic *Client* can easily access the data without knowledge of user-defined *DataTypes* and the *Client* can access individual parts of the structured data. The disadvantages of the first approach are that accessing the individual data does not provide any transactional context and for a specific *Client* the *Server* first has to convert the data and the *Client* has to convert the data, again, to get the data structure the underlying system provides.

The advantages of the second approach are, that the data is accessed in a transactional context and the structured *DataType* can be constructed in a way that the *Server* does not have to convert the data and can pass directly to the specific *Client* that can directly use them. The disadvantages are that the generic *Client* might not be able to access and interpret the data or has at least the burden to read the *DataTypeDescription* to interpret the data. The structure of the data is not visible in the *AddressSpace*; additional *Properties* describing the data structure cannot be added to the adequate places since they do not exist in the *AddressSpace*. Individual parts of the data cannot be read without accessing the whole data structure.

The third approach combines the other two approaches. Therefore a specific *Client* can access data in its native format in a transactional context, whereas a generic *Client* can access simple *DataTypes* of the components of the complex *Variable*. The disadvantage is that the *Server* must be able to provide the native format and also interpret it to be able to provide the information in simple *DataTypes*.

It is recommended to use the first approach. When a transactional context is needed or the *Client* should be able to get a large amount of data instead of subscribing to several individual values, then the third approach is suitable. However, the *Server* might not always have the knowledge to interpret the structured data of the underlying system and therefore has to use the second approach just passing the data to the specific *Client* who is able to interpret the data.

A.5 Views

Server-defined *Views* can be used to present an excerpt of the *AddressSpace* suitable for a special class of *Clients*, for example maintenance *Clients*, engineering *Clients*, etc. The *View* only provides the information needed for the purpose of the *Client* and hides unnecessary information.

A.6 Methods

Methods should be used whenever some input is expected and the *Server* delivers a result. One should avoid using *Variables* to write the input values and other *Variables* to get the output results as it was necessary to do in OPC COM since there was no concept of a *Method* available. However, a simple OPC COM wrapper might not be able to do this.

Methods can also be used to trigger some execution in the *Server* that does not require input and / or output parameters.

Global *Methods*, that is, *Methods* that cannot directly be assigned to a special *Object*, should be assigned to the *Server Object* defined in Part 5.

A.7 Defining ReferenceTypes

Defining new *ReferenceTypes* should only be done if the predefined *ReferenceTypes* are not suitable. Whenever a new *ReferenceType* is defined, the most appropriate *ReferenceType* should be used as its supertype.

It is expected that *Servers* will have new defined hierarchical *ReferenceTypes* to expose different hierarchies, and new non-hierarchical *References* to expose relationships between *Nodes* in the *AddressSpace*.

A.8 Defining ModellingRules

New *ModellingRules* have to be defined if the predefined *ModellingRules* are not appropriate for the model exposed by the *Server*.

Depending on the model used by the underlying system the *Server* may need to define new *ModellingRules*, since the OPC UA *Server* may only pass the data to the underlying system and this system may use its own internal rules for instantiation, subtyping, etc.

Beside this, the predefined *ModellingRules* might not be sufficient to specify the required behaviour for instantiation and subtyping.

Annex B
(informative)

OPC UA Meta Model in UML

B.1 Background

The OPC UA Meta Model (the OPC UA Address Space Model) is represented by UML classes and UML objects marked with the stereotype <<TypeExtension>>. Those stereotyped UML objects represent *DataTypes* or *ReferenceTypes*. The domain model can contain user-defined *ReferenceTypes* and *DataTypes*, also marked as <<TypeExtension>>. In addition, the domain model contains *ObjectTypes*, *VariableTypes* etc. represented as UML objects (see Figure B.1).

The OPC Foundation specifies not only the OPC UA Meta Model, but also defines some *Nodes* to organise the *AddressSpace* and to provide information about the *Server* as specified in Part 5.

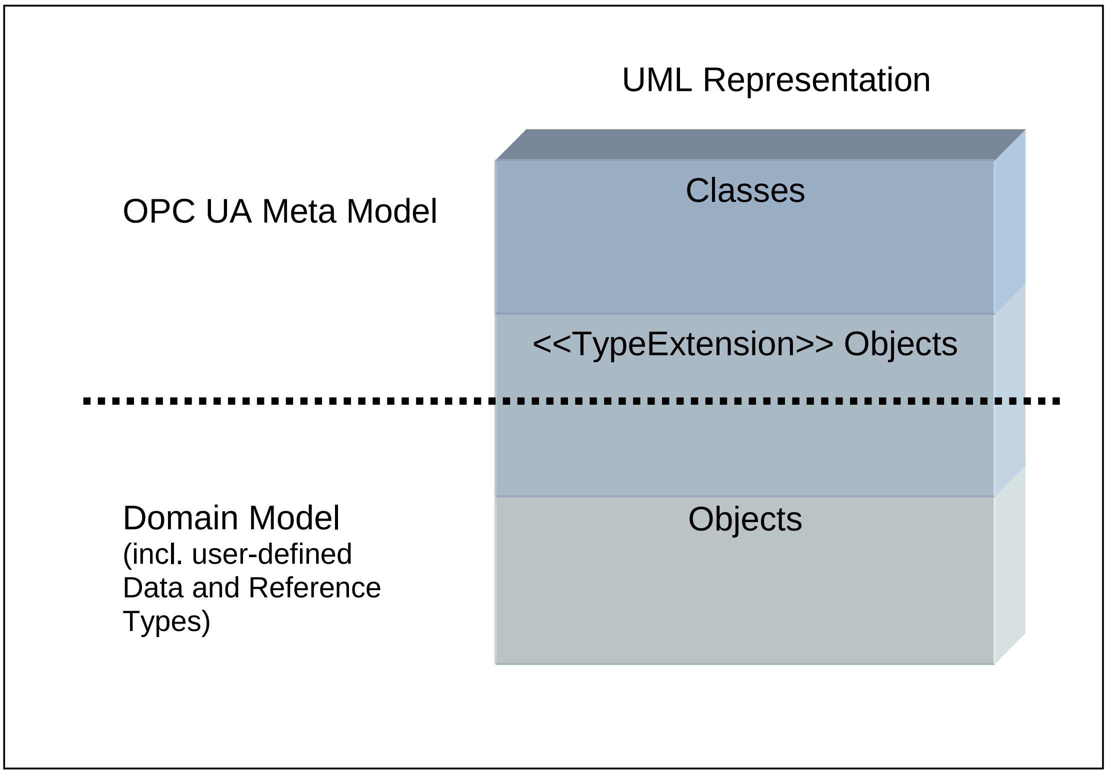


Figure B.1 – Background of OPC UA Meta Model

B.2 Notation

An example of a UML class representing the OPC UA concept *Base* is given in the UML class diagram in Figure B.2. OPC Attributes inherit from the abstract class Attribute and have a value identifying their data type. They are composed of a *Node* which is either optional (0..1) or required (1), such as *BrowseName* to *Base* in Figure B.2.

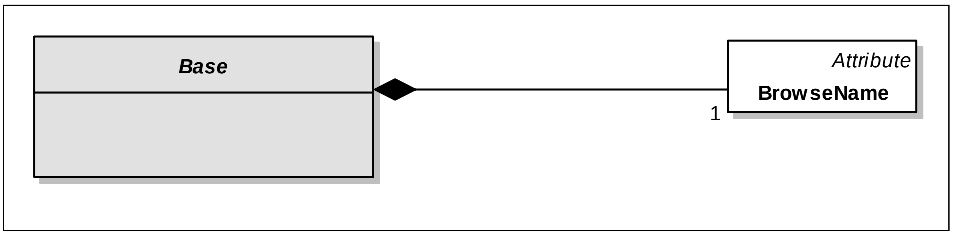


Figure B.2 – Notation (I)

UML object diagrams are used to display <<TypeExtension>> objects (e.g. *HasComponent* in Figure B.3). In object diagrams, OPC *Attributes* are represented as UML attributes without data types and marked with the stereotype <<Attribute>>, like *InverseName* in the UML object *HasComponent*. They have values, like *InverseName =ComponentOf* for *HasComponent*. To keep the object diagrams simple, not all *Attributes* are shown (e.g. the *NodeId* of *HasComponent*).

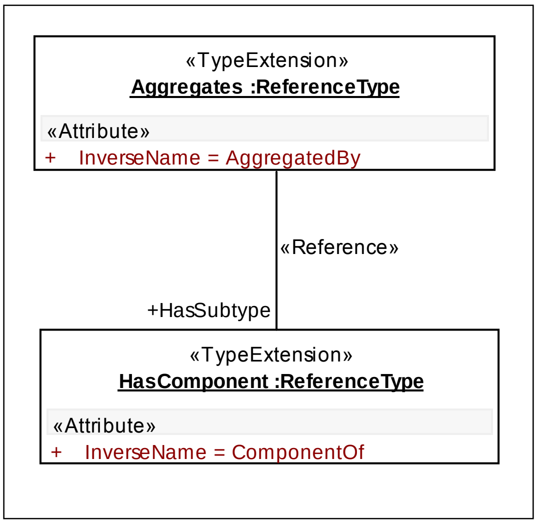


Figure B.3 – Notation (II)

OPC *References* are represented as UML associations marked with the stereotype <<Reference>>. If a particular *ReferenceType* is used, its name is used as the role name, identifying the direction of the *Reference* (e.g. *Aggregates* has the subtype *HasComponent*). For simplicity, the inverse role name is not shown (in the example *SubtypeOf*). When no role name is provided, it means that any *ReferenceType* can be used (only valid for class diagrams).

There are some special *Attributes* in OPC UA containing a *NodeId* and thereby referencing another *Node*. Those *Attributes* are represented as associations marked with the stereotype <<Attribute>>. The name of the *Attribute* is displayed as the role name of the *TargetNode*.

The value of the OPC *Attribute BrowseName* is represented by the UML object name, for example the *BrowseName* of the UML object *HasComponent* in Figure B.3 is “HasComponent”.

To highlight the classes explained in a class diagram, they are marked in grey (e.g. *Base* in Figure B.2). Only those classes have all of their relationships to other classes and attributes shown in the diagram. For the other classes, we provide only those attributes and relationships needed to understand the main classes of the diagram.

B.3 Meta Model

NOTE: Other parts of this series of standards can extend the OPC UA Meta Model by adding *Attributes* and defining new *ReferenceTypes*.

B.3.1 Base

Base is shown in Figure B.4.

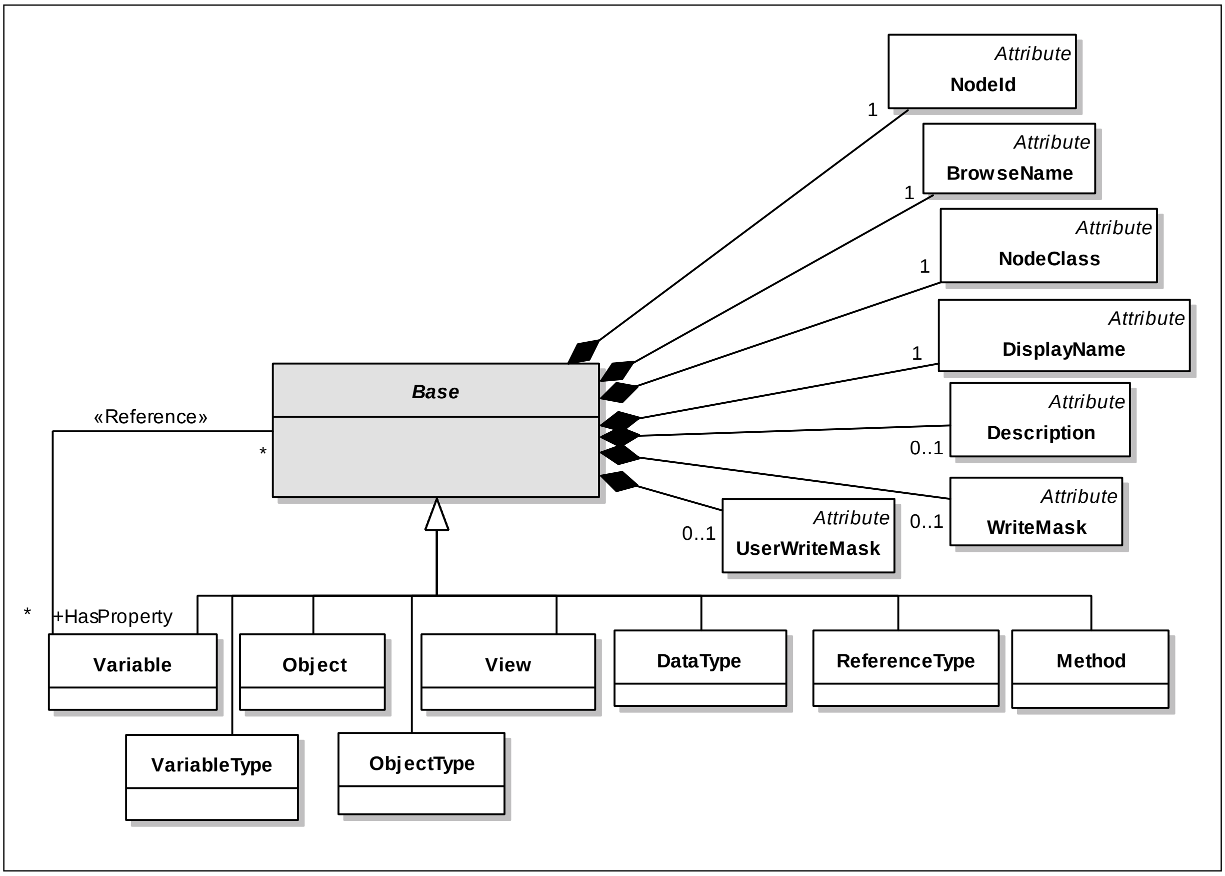


Figure B.4 – Base

B.3.2 ReferenceType

ReferenceType is shown in Figure B.5 and predefined *ReferenceTypes* in Figure B.6.

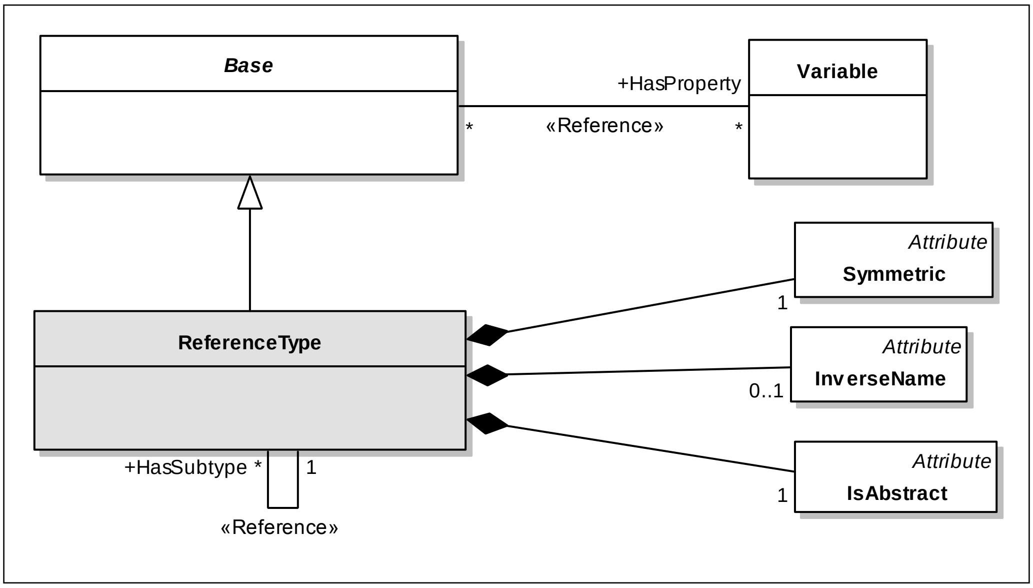


Figure B.5 – Reference and ReferenceType

If *Symmetric* is “false” and *IsAbstract* is “false” an *InverseName* shall be provided.

B.3.3 Predefined ReferenceTypes

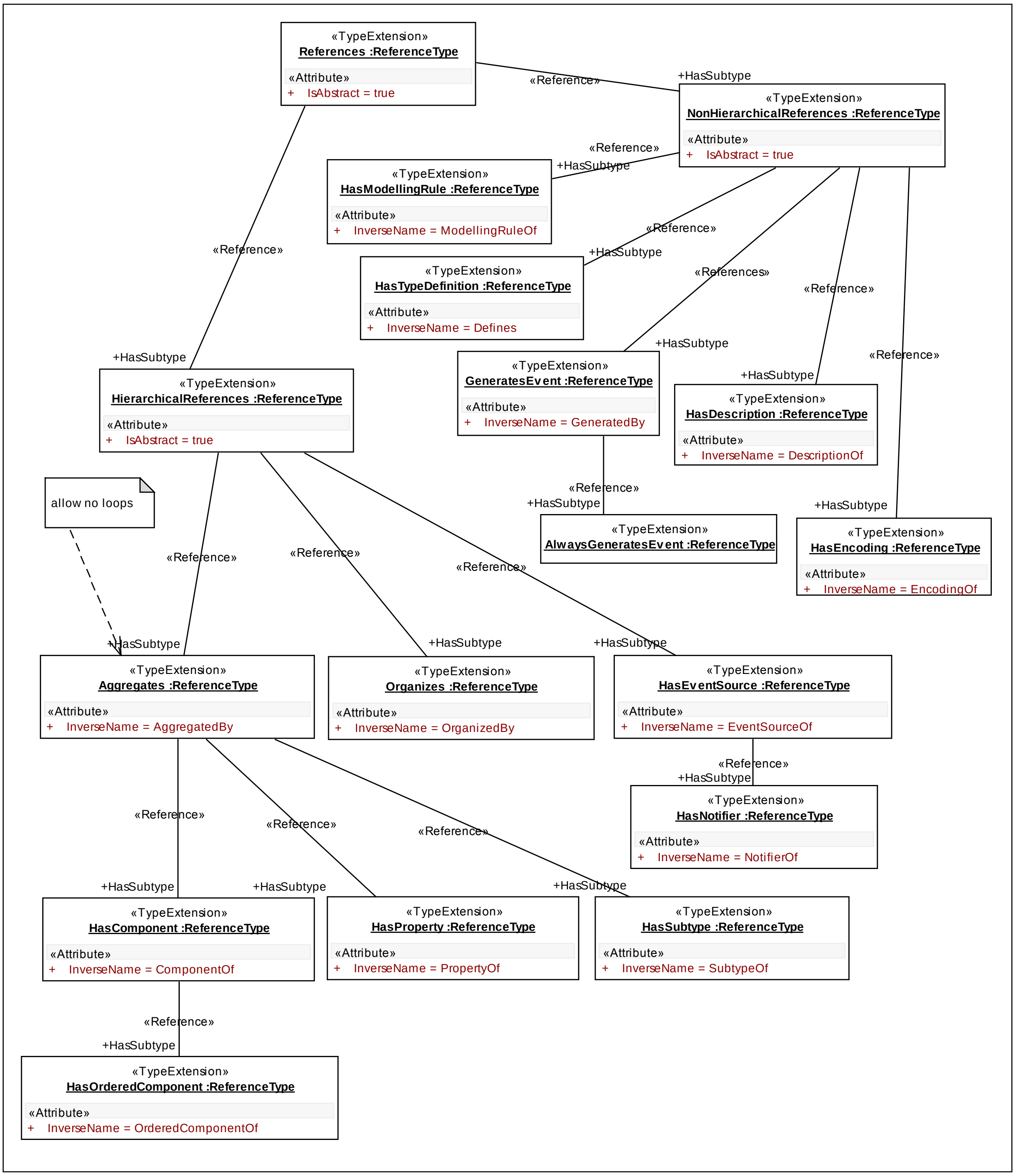


Figure B.6 – Predefined ReferenceTypes

B.3.4 Attributes

Attributes are shown in Figure B.7.

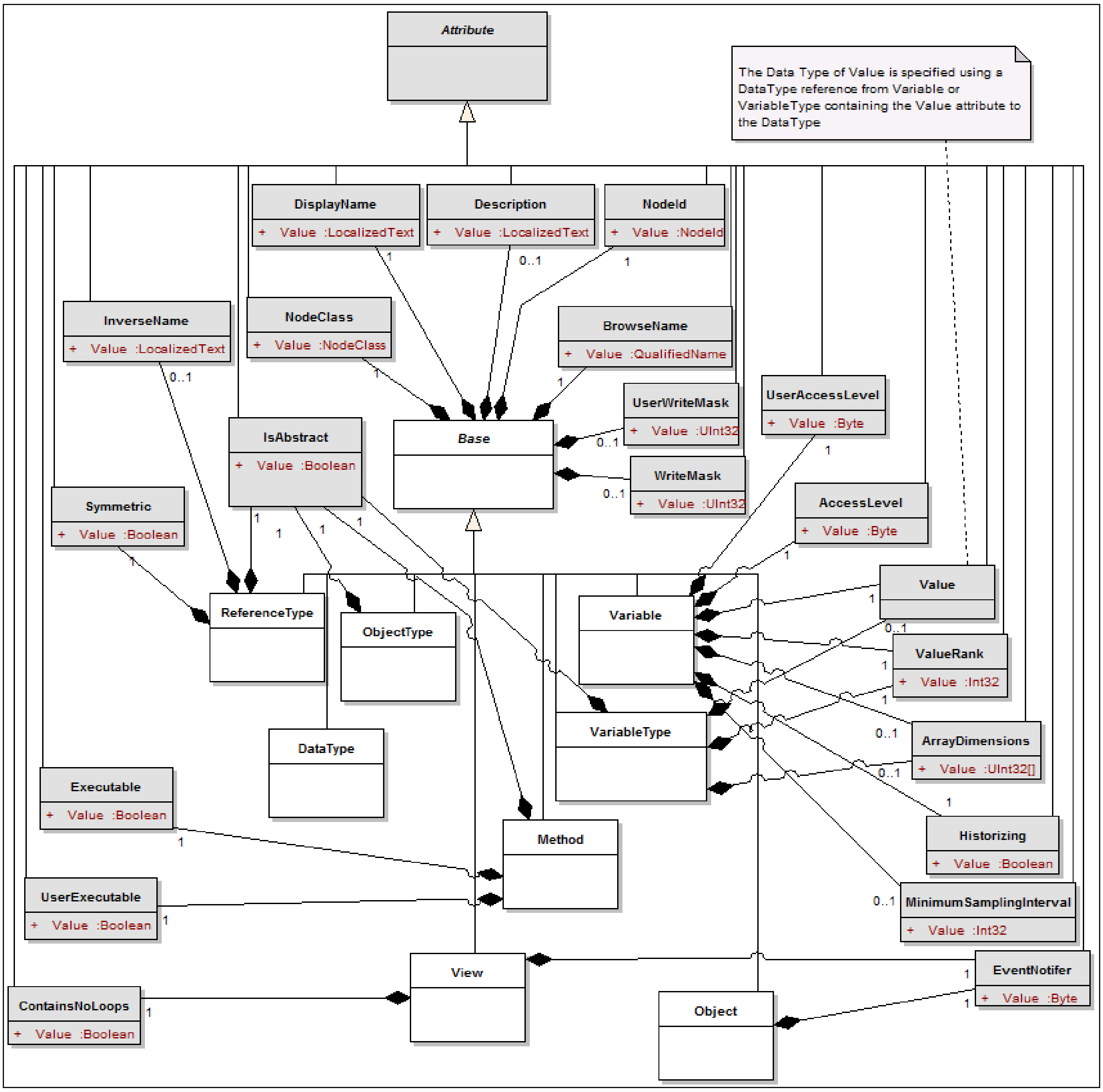


Figure B.7 – Attributes

There may be more *Attributes* defined in other parts of this series of standards.

Attributes used for references, which have a *NodeId* as *DataType*, are not shown in this diagram but are shown as stereotyped associations in the other diagrams.

B.3.5 Object and ObjectType

Objects and *ObjectTypes* are shown in Figure B.8.

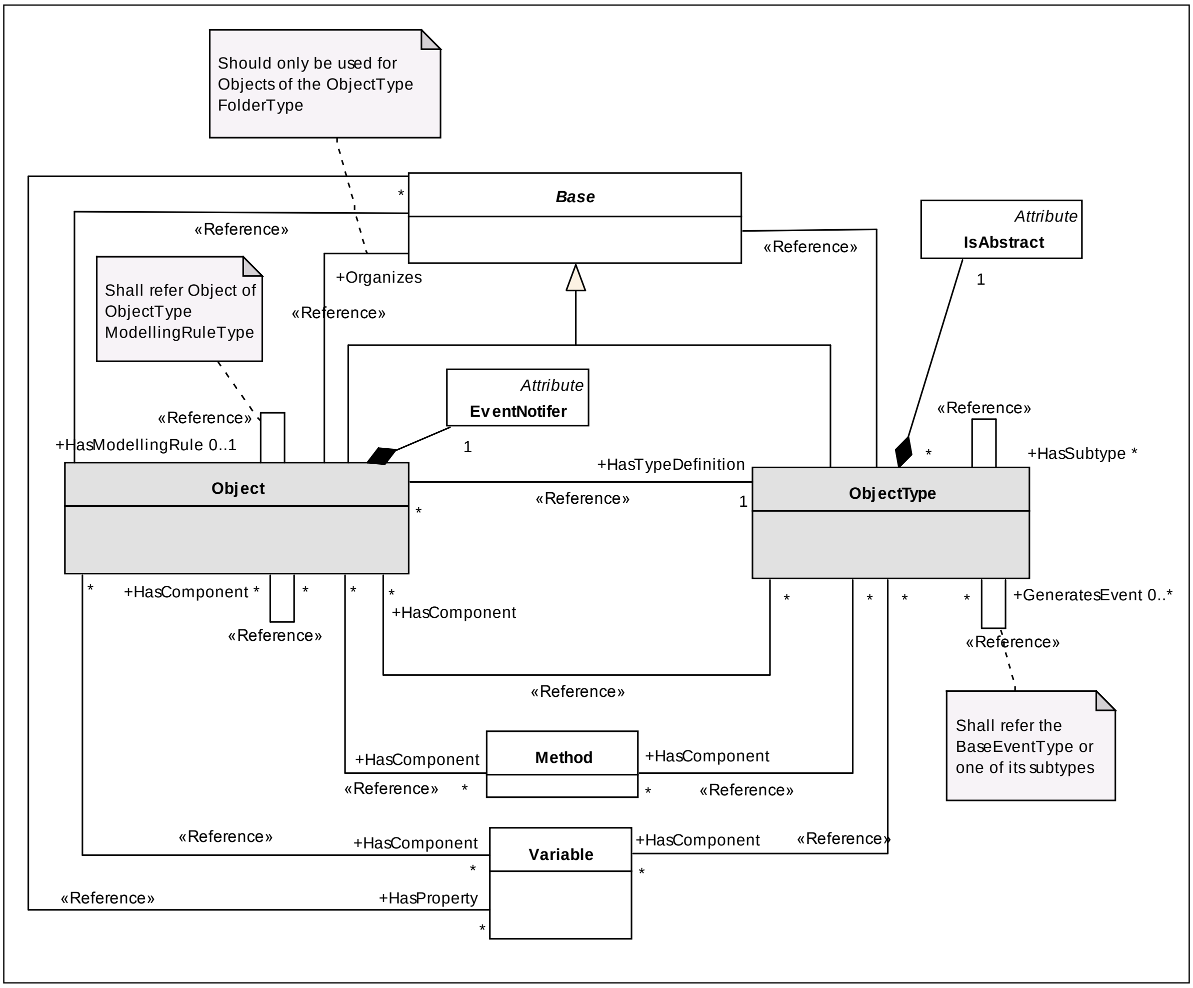


Figure B.8 – Object and ObjectType

B.3.6 EventNotifier

EventNotifier are shown in Figure B.9.

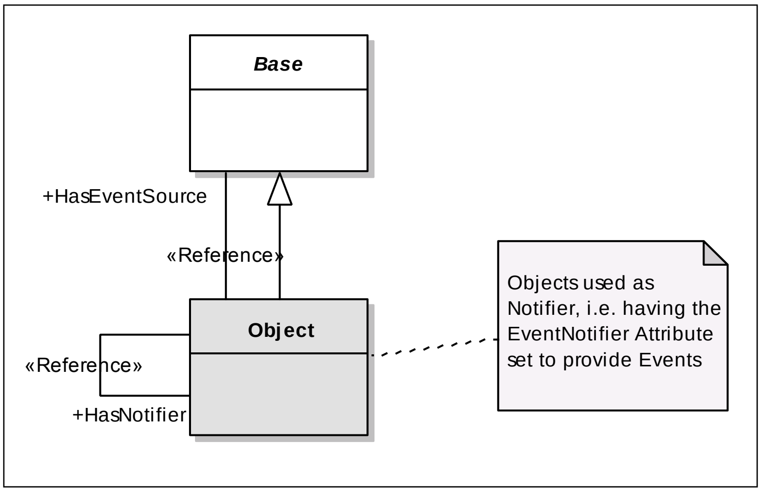


Figure B.9 – EventNotifier

B.3.7 Variable and VariableType

Variable and VariableType are shown in Figure B.10.

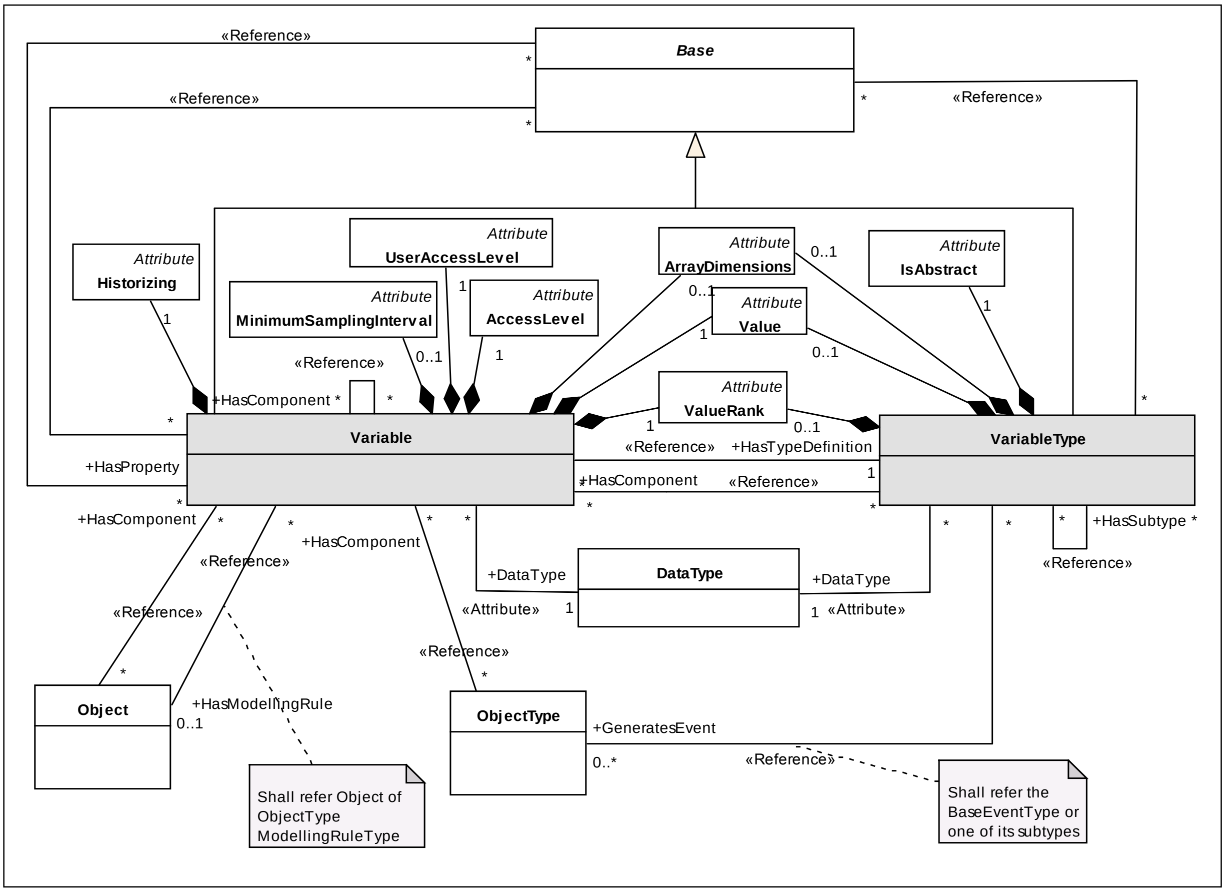


Figure B.10 – Variable and VariableType

The *DataType* of a *Variable* shall be the same as or a subtype of the *DataType* of its *VariableType* (referred with *HasTypeDefinition*).

If a *HasProperty* points to a *Variable* from a *Base* “A” then the following constraints apply:

- The Variable shall not be the SourceNode of a HasProperty or any other HierarchicalReferences Reference.
- All *Variables* having “A” as the *SourceNode* of a *HasProperty Reference* shall have a unique *BrowseName* in the context of “A”.

B.3.8 Method

Method is shown in Figure B.11

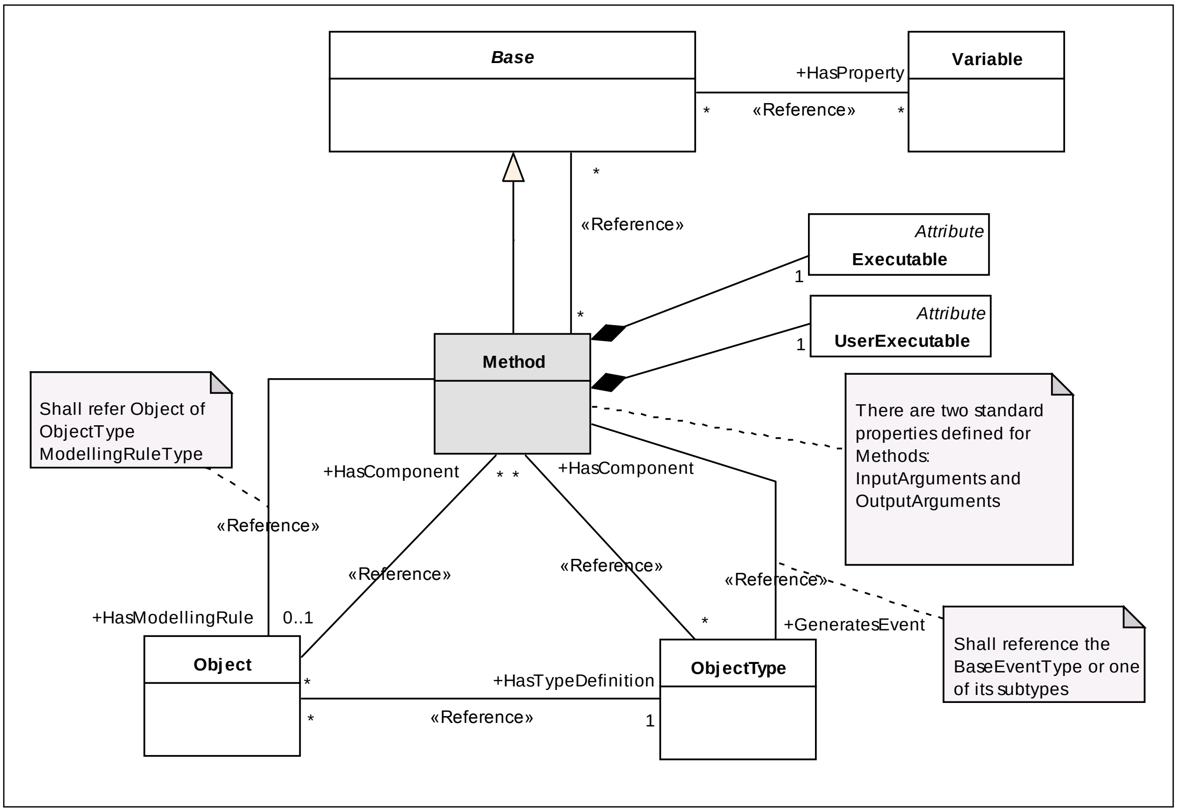


Figure B.11 – Method

B.3.9 DataType

DataType is shown in Figure B.12.

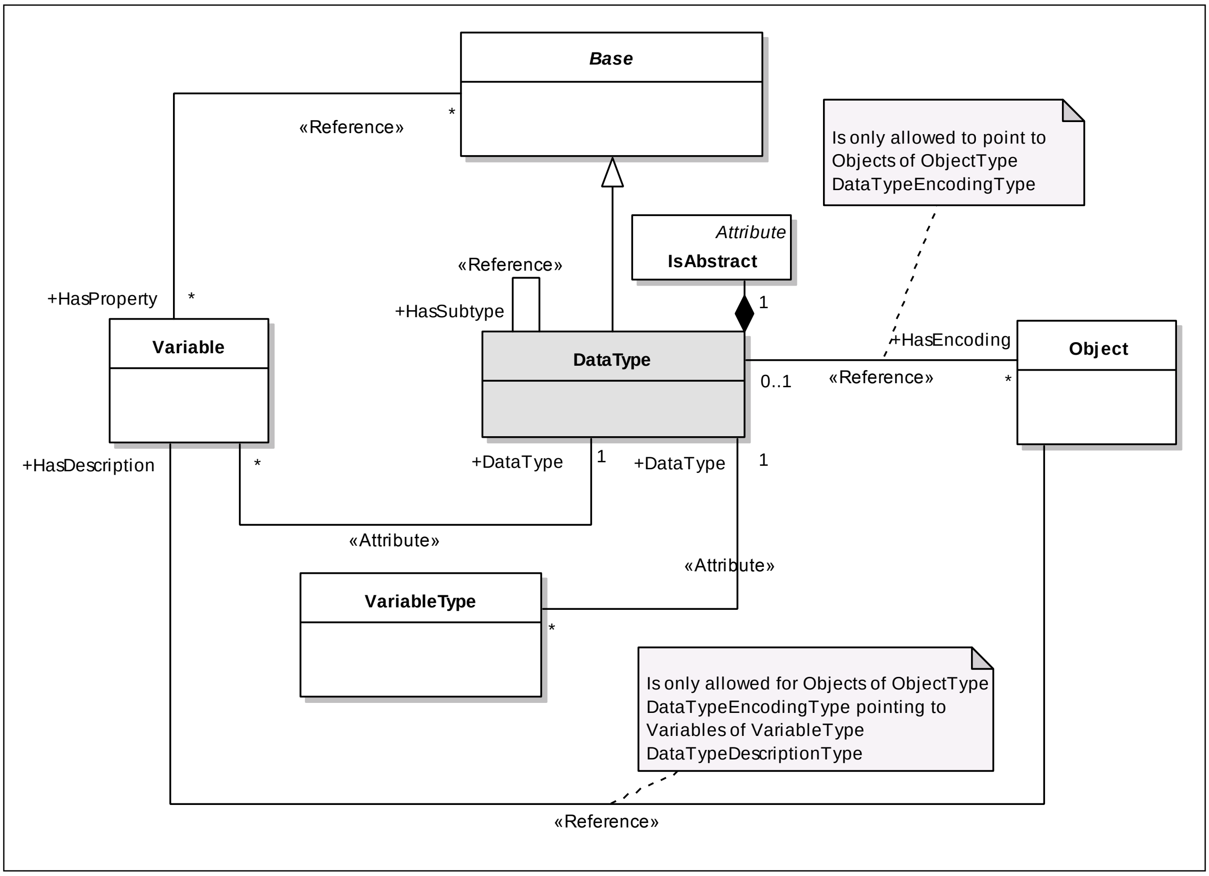


Figure B.12 – DataType

B.3.10 View

View is shown in Figure B.13.

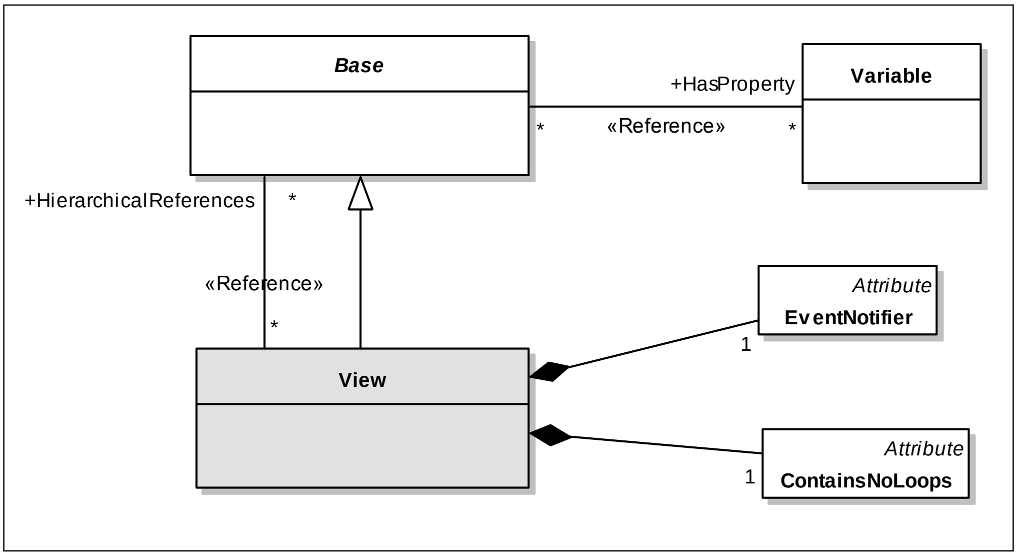


Figure B.13 – View

Annex C
(normative)

OPC Binary Type Description System

C.1 Concepts

The OPC Binary XML Schema defines the format of OPC Binary *TypeDictionaries*. Each OPC Binary *TypeDictionary* is an XML document that contains one or more *TypeDescriptions* that describe the format of a binary-encoded value. Applications that have no advanced knowledge of a particular binary encoding can use the OPC Binary *TypeDescription* to interpret or construct a value.

The OPC Binary Type Description System does not define a standard mechanism to *encode* data in binary. It only provides a standard way to describe an existing binary encoding. Many binary encodings will have a mechanism to describe types that could be encoded; however, these descriptions are useful only to applications that have knowledge of the type description system used with each binary encoding. The OPC Binary Type Description System is a generic syntax that can be used by any application to interpret any binary encoding.

The OPC Binary Type Description System was originally defined in the OPC Complex Data Specification. The OPC Binary Type Description System described in Annex C is quite different and is correctly described as the OPC Binary Type Description System Version 2.0.

Each *TypeDescription* is identified by a *TypeName* which shall be unique within the *TypeDictionary* that defines it. Each *TypeDictionary* also has a *TargetNamespace* which should be unique among all OPC Binary *TypeDictionaries*. This means that the *TypeName* qualified with the *TargetNamespace* for the dictionary should be a globally-unique identifier for a *TypeDescription.*

Figure C.1 below illustrates the structure of an OPC Binary *TypeDictionary*.

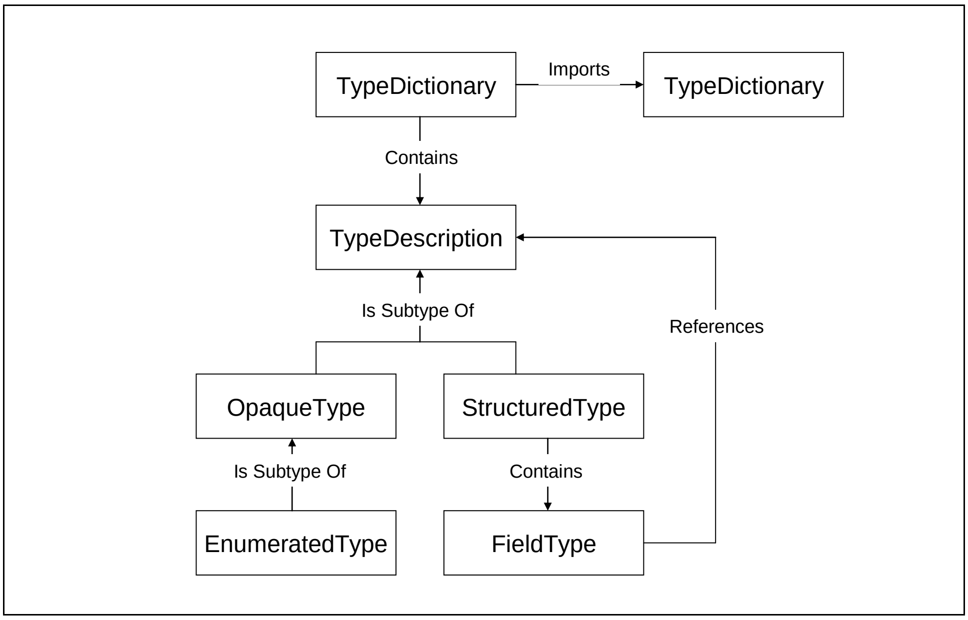


Figure C.1 – OPC Binary Dictionary Structure

Each binary encoding is built from a set of opaque building blocks that are either primitive types with a fixed length or variable-length types with a structure that is too complex to describe properly in an XML document. These building blocks are described with an *OpaqueType*. An instance of one of these building blocks is a binary-encoded value.

The OPC Binary Type Description System defines a set of standard *OpaqueTypes* that all OPC Binary *TypeDictionaries* should use to build their *TypeDescriptions*. These standard type descriptions are described in Clause C.3.

In some cases, the binary encoding described by an *OpaqueType* may have a fixed size which would allow an application to skip an encoded value that it does not understand. If that is the case, then the *LengthInBits* attribute should be specified for the *OpaqueType.* If authors of *TypeDictionaries* need to define new *OpaqueTypes* that do not have a fixed size then they should use the documentation elements to describe how to encode binary values for the type. This description should provide enough detail to allow a human to write a program that can interpret instances of the type.

A *StructuredType* breaks a complex value into a sequence of values that are described by a *FieldType*. Each *FieldType* has a name, type and a number of qualifiers that specify when the field is used and how many instances of the type exist. A *FieldType* is described completely in C.2.6.

An *EnumeratedType* describes a numeric value that has a limited set of possible values, each of which has a descriptive name. *EnumeratedTypes* provide a convenient way to capture semantic information associated with what would otherwise be an opaque numeric value.

C.2 Schema Description

C.2.1 TypeDictionary

The *TypeDictionary* element is the root element of an OPC Binary Dictionary. The components of this element are described in Table C.1.

Table C.1 – TypeDictionary Components

Name	Type	Description
Documentation	Documentation	An element that contains human-readable text and XML that provides an overview of what is contained in the dictionary.
Import	ImportDirective[]	Zero or more elements that specify other *TypeDictionaries* that are referenced by *StructuredTypes* defined in the dictionary. Each import element specifies the *NamespaceUri* of the *TypeDictionary* being imported. The *TypeDictionary* element shall declare an XML namespace prefix for each imported namespace.
TargetNamespace	xs:string	Specifies the URI that qualifies all *TypeDescriptions* defined in the dictionary.
DefaultByteOrder	ByteOrder	Specifies the default *ByteOrder* for all *TypeDescriptions* that have the *ByteOrderSignificant* attribute set to “true”. This value overrides the setting in any imported *TypeDictionary*. This value is overridden by the *DefaultByteOrder* specified on a *TypeDescription*.
TypeDescription	TypeDescription[]	One or more elements that describe the structure of a binary encoded value. A TypeDescription is an abstract type. A dictionary may only contain the *OpaqueType*, *EnumeratedType* and *StructuredType* elements.

C.2.2 TypeDescription

A *TypeDescription* describes the structure of a binary encoded value. A *TypeDescription* is an abstract base type and only instances of subtypes may appear in a *TypeDictionary*. The components of a *TypeDescription* are described in Table C.2.

Table C.2 – TypeDescription Components

Name	Type	Description
Documentation	Documentation	An element that contains human readable text and XML that describes the type. This element should capture any semantic information that would help a human to understand what is contained in the value.
Name	xs: NCName	An attribute that specifies a name for the *TypeDescription* that is unique within the dictionary. The fields of structured types reference *TypeDescriptions* by using this name qualified with the dictionary namespace URI.
DefaultByteOrder	ByteOrder	An attribute that specifies the default *ByteOrder* for the type description. This value overrides the setting in any *TypeDictionary* or in any *StructuredType* that references the type description.
anyAttribute	*	Authors of a *TypeDictionary* may add their own attributes to any *TypeDescription* that shall be qualified with a namespace defined by the author. Applications should not be required to understand these attributes in order to interpret a binary encoded instance of the type.

C.2.3 OpaqueType

An *OpaqueType* describes a binary encoded value that is either a primitive fixed length type or that has a structure too complex to capture in an OPC Binary type dictionary. Authors of type dictionaries should avoid defining *OpaqueTypes* that do not have a fixed length because it would prevent applications from interpreting values that use these types without having built-in knowledge of the *OpaqueType.* The OPC Binary Type Description System defines many standard *OpaqueTypes* that should allow authors to describe most binary encoded values as *StructuredTypes*.

The components of an *OpaqueType* are described in Table C.3.

Table C.3 – OpaqueType Components

Name	Type	Description
TypeDescription	TypeDescription	An *OpaqueType* inherits all elements and attributes defined for a *TypeDescription* in Table C.2.
LengthInBits	xs:string	An attribute which specifies the length of the *OpaqueType* in bits. This value should always be specified. If this value is not specified the *Documentation* element should describe the encoding in a way that a human understands.
ByteOrderSignificant	xs:boolean	An attribute that indicates whether byte order is significant for the type. If byte order is significant then the application shall determine the byte order to use for the current context before interpreting the encoded value. The application determines the byte order by looking for the *DefaultByteOrder* attribute specified for containing *StructuredTypes* or the *TypeDictionary*. If *StructuredTypes* are nested the inner *StructuredTypes* override the byte order of the outer descriptions. If the *DefaultByteOrder* attribute is specified for the *OpaqueType*, then the *ByteOrder* is fixed and does not change according to context. If this attribute is “true”, then the *LengthInBits* attribute shall be specified and it shall be an integer multiple of 8 bits.

C.2.4 EnumeratedType

An *EnumeratedType* describes a binary-encoded numeric value that has a fixed set of valid values. The encoded binary value described by an *EnumeratedType* is always an unsigned integer with a length specified by the *LengthInBits* attribute.

The names for each of the enumerated values are not required to interpret the binary encoding, however, they form part of the documentation for the type.

The components of an *EnumeratedType* are described in Table C.4.

Table C.4 – EnumeratedType Components

Name	Type	Description
OpaqueType	OpaqueTypeDescription	An *EnumeratedType* inherits all elements and attributes defined for a *TypeDescription* in Table C.2 and for an *OpaqueType* defined in Table C.3. The *LengthInBits* attribute shall always be specified.
EnumeratedValue	EnumeratedValue	One or more elements that describe the possible values for the instances of the type.

C.2.5 StructuredType

A *StructuredType* describes a type as a sequence of binary-encoded values. Each value in the sequence is called a *Field*. Each *Field* references a *TypeDescription* that describes the binary-encoded value that appears in the field. A *Field* may specify that zero, one or multiple instances of the type appear within the sequence described by the *StructuredType*.

Authors of type dictionaries should use *StructuredTypes* to describe a variety of common data constructs including arrays, unions and structures.

Some fields have lengths that are not multiples of 8 bits. Several of these fields may appear in a sequence in a structure, however, the total number of bits used in the sequence shall be fixed and it shall be a multiple of 8 bits. Any field which does not have a fixed length shall be aligned on a byte boundary.

A sequence of fields which do not line up on byte boundaries are specified from the least significant bit to the most significant bit. Sequences which are longer than one byte overflow from the most significant bit of the first byte into the least significant bit of the next byte.

The components of a *StructuredType* are described in Table C.5.

Table C.5 – StructuredType Components

Name	Type	Description
TypeDescription	TypeDescription	A *StructuredType* inherits all elements and attributes defined for a *TypeDescription* in Table C.2.
Field	FieldType	One or more elements that describe the fields of the structure. Each field shall have a name that is unique within the *StructuredType*. Some fields may reference other fields in the *StructuredType* by using this name.

C.2.6 FieldType

A *FieldType* describes a binary encoded value that appears in sequence within a *StructuredType*. Every *FieldType* shall reference a *TypeDescription* that describes the encoded value for the field.

A *FieldType* may specify an array of encoded values.

Fields may be optional and they reference other *FieldTypes*, which indicate if they are present in any specific instance of the type.

The components of a *FieldType* are described in Table C.6.

Table C.6 – FieldType Components

Name	Type	Description
Documentation	Documentation	An element that contains human readable text and XML that describes the field. This element should capture any semantic information that would help a human to understand what is contained in the field.
Name	xs:string	An attribute that specifies a name for the *Field* that is unique within the *StructuredType*. Other fields in the structured type reference a *Field* by using this name.
TypeName	xs:QName	An attribute that specifies the *TypeDescription* that describes the contents of the field. A field may contain zero or more instances of this type depending on the settings for the other attributes and the values in other fields.
Length	xs:unsignedInt	An attribute that indicates the length of the field. This value may be the total number of encoded bytes or it may be the number of instances of the type referenced by the field. The *IsLengthInBytes* attributes specifies which of these definitions applies.
LengthField	xs:string	An attribute that indicates which other field in the *StructuredType* specifies the length of the field. The length of the field may be in bytes or it may be the number of instances of the type referenced by the field. The *IsLengthInBytes* attributes specify which of these definitions applies. If this attribute refers to a field that is not present in an encoded value, then the default value for the length is 1. This situation could occur if the field referenced is an optional field (see the *SwitchField* attribute). The length field shall be a fixed length Base-2 representation of an integer. If the length field is one of the standard signed integer types and the value is a negative integer, then the field is not present in the encoded stream. The *FieldType* referenced by this attribute shall precede the field with the *StructuredType*.
IsLengthInBytes	xs:boolean	An attribute that indicates whether the *Length* or *LengthField* attributes specify the length of the field in bytes or in the number of instances of the type referenced by the field.
SwitchField	xs:string	If this attribute is specified, then the field is optional and may not appear in every instance of the encoded value. This attribute specifies the name of another *Field* that controls whether this field is present in the encoded value. The field referenced by this attribute shall be an integer value (see the *LengthField* attribute). The current value of the switch field is compared to the *SwitchValue* attribute using the *SwitchOperand.* If the condition evaluates to true then the field appears in the stream. If the *SwitchValue* attribute is not specified, then this field is present if the value of the switch field is non-zero. The *SwitchOperand* field is ignored if it is present. If the *SwitchOperand* attribute is missing, then the field is present if the value of the switch field is equal to the value of the *SwitchValue* attribute*.* The *Field* referenced by this attribute shall precede the field with the *StructuredType*.
SwitchValue	xs:unsignedInt	This attribute specifies when the field appears in the encoded value. The value of the field referenced by the *SwitchField* attribute is compared using the *SwitchOperand* attribute to this value. The field is present if the expression evaluates to true. The field is not present otherwise.
SwitchOperand	xs:string	This attribute specifies how the value of the switch field should be compared to the switch value attribute. This field is an enumeration with the following values: Equal *SwitchField* is equal to the *SwitchValue*. GreaterThan *SwitchField* is greater than the *SwitchValue*. LessThan *SwitchField* is less than the *SwitchValue*. GreaterThanOrEqual *SwitchField* is greater than or equal to the *SwitchValue*. LessThanOrEqual *SwitchField* is less than or equal to the *SwitchValue*. NotEqual *SwitchField* is not equal to the *SwitchValue*. In each case the field is present if the expression is true.
Terminator	xs:hexBinary	This attribute indicates that the field contains one or more instances of *TypeDescription* referenced by this field and that the last value has the binary encoding specified by the value of this attribute. If this attribute is specified then the *TypeDescription* referenced by this field shall either have a fixed byte order (i.e. byte order is not significant or explicitly specified) or the containing *StructuredType* shall explicitly specify the byte order. Examples:

Name	Type	Description
		Field Data Type Terminator Byte Order Hexadecimal String Char tab character not applicable 09 WideChar: tab character BigEndian 0009 WideChar: tab character LittleEndian 0900 Int16 1 BigEndian 0001 Int16 1 LittleEndian 0100
anyAttribute	*	Authors of a *TypeDictionary* may add their own attributes to any *FieldType* which shall be qualified with a namespace defined by the authors. Applications should not be required to understand these attributes in order to interpret a binary encoded field value.

C.2.7 EnumeratedValue

An *EnumeratedValue* describes a possible value for an *EnumeratedType*.

The components of an *EnumeratedValue* are described in Table C.7.

Table C.7 – EnumeratedValue Components

Name	Type	Description
Name	xs:string	This attribute specifies a descriptive name for the enumerated value.
Value	xs:unsignedInt	This attribute specifies the numeric value that could appear in the binary encoding.

C.2.8 ByteOrder

A *ByteOrder* is an enumeration that describes a possible value byte orders for *TypeDescriptions* that allow different byte orders to be used. There are two possible values: BigEndian and LittleEndian. BigEndian indicates the most significant byte appears first in the binary encoding. LittleEndian indicates that the least significant byte appears first.

C.2.9 ImportDirective

An *ImportDirective* specifies a *TypeDictionary* that is referenced by types defined in the current dictionary.

The components of an *ImportDirective* are described in Table C.8.

Table C.8 – ImportDirective Components

Name	Type	Description
Namespace	xs:string	This attribute specifies the *TargetNamespace* for the *TypeDictionary* being imported. This may be a well-known URI which means applications need not have access to the physical file to recognise types that are referenced.
Location	xs:string	This attribute specifies the physical location of the XML file containing the *TypeDictionary* to import. This value could be a URL for a network resource, a NodeId in an OPC UA *Server* address space or a local file path.

C.3 Standard Type Descriptions

The OPC Binary Type Description System defines a number of standard type descriptions that can be used to describe many common binary encodings using a *StructuredType*. The standard type descriptions are described in Table C.9.

Table C.9 – Standard Type Descriptions

Type name	Description
Bit	A single bit value.
Boolean	A two-state logical value represented as an 8-bit value.
SByte	An 8-bit signed integer.
Byte	An 8-bit unsigned integer.
Int16	A 16-bit signed integer.
UInt16	A 16-bit unsigned integer.
Int32	A 32-bit signed integer.
UInt32	A 32-bit unsigned integer.
Int64	A 64-bit signed integer.
UInt64	A 64-bit unsigned integer.
Float	An IEEE 754-1985 single precision floating point value.
Double	An IEEE 754-1985 double precision floating point value.
Char	An 8-bit UTF-8 character value.
WideChar	A 16-bit UTF-16 character value.
String	A null terminated sequence of UTF-8 characters.
CharArray	A sequence of UTF-8 characters preceded by the number of characters.
WideString	A null terminated sequence of UTF-16 characters.
WideCharArray	A sequence of UTF-16 characters preceded by the number of characters.
DateTime	A 64-bit signed integer representing the number of 100 nanoseconds intervals since 1601-01-01 00:00:00. This is the same as the WIN32 FILETIME type.
ByteString	A sequence of bytes preceded by its length in bytes.
Guid	A 128-bit structured type that represents a WIN32 GUID value.

C.4 Type Description Examples

1. A 128-bit signed integer.

```
<opc:OpaqueType Name="Int128" LengthInBits="128" ByteOrderSignificant="true">
  <opc:Documentation>A 128-bit signed integer.</opc:Documentation>
</opc:OpaqueType>
```

2. A 16-bit value divided into several fields.

```
<opc:StructuredType Name="Quality">
  <opc:Documentation>An OPC COM-DA quality value.</opc:Documentation>
  <opc:Field Name="LimitBits" TypeName="opc:Bit" Length="2" />
  <opc:Field Name="QualityBits" TypeName="opc:Bit" Length="6"/>
  <opc:Field Name="VendorBits" TypeName="opc:Byte" />
</opc:StructuredType>
```

When using bit fields, the least significant bits within a byte shall appear first.

3. A structured type with optional fields.

```
<opc:StructuredType Name="DataValue">
  <opc:Documentation>A value with an associated timestamp, and quality.</opc:Documentation>
  <opc:Field Name="ValueSpecified" TypeName="Bit" />
  <opc:Field Name="StatusCodeSpecified" TypeName="Bit" />
  <opc:Field Name="TimestampSpecified" TypeName="Bit" />
  <opc:Field Name="Reserved1" TypeName="Bit" Length="5" />
  <opc:Field Name="Value" TypeName="Variant" SwitchField="ValueSpecified" />
  <opc:Field Name="Quality" TypeName="Quality" SwitchField="StatusCodeSpecified" />
  <opc:Field Name="Timestamp" TypeName="opc:DateTime" SwitchField="SourceTimestampSpecified" />
</opc:StructuredType>
```

It is necessary to explicitly specify any padding bits required to ensure subsequent fields line up on byte boundaries.

4. An array of integers.

```
<opc:StructuredType Name="IntegerArray">
  <opc:Documentation>An array of integers prefixed by its length.</opc:Documentation>
  <opc:Field Name="Size" TypeName="opc:Int32" />
```

```
  <opc:Field Name="Array" TypeName="opc:Int32" LengthField="Size" />
</opc:StructuredType>
```

Nothing is encoded for the Array field if the Size field has a value ≤ 0.

5. An array of integers with a terminator instead of a length prefix.

```
<opc:StructuredType Name="IntegerArray" DefaultByteOrder="LittleEndian">
  <opc:Documentation>An array of integers terminated with a known value.</opc:Documentation>
  <opc:Field Name="Value" TypeName="opc:Int16" Terminator="FF7F" />
</opc:StructuredType>
```

The terminator is 32,767 converted to hexadecimal with LittleEndian byte order.

6. A simple union.

```
<opc:StructuredType Name="Variant">
  <opc:Documentation>A union of several types.</opc:Documentation>
  <opc:Field Name="ArrayLengthSpecified" TypeName="opc:Bit" Length="1"/>
  <opc:Field Name="VariantType" TypeName="opc:Bit" Length="7" />
  <opc:Field Name="ArrayLength" TypeName="opc:Int32"
      SwitchField="ArrayLengthSpecified" />
  <opc:Field Name="Int32" TypeName="opc:Int32" LengthField="ArrayLength"
      SwitchField="VariantType" SwitchValue="1" />
  <opc:Field Name="String" TypeName="opc:String" LengthField="ArrayLength"
      SwitchField="VariantType" SwitchValue="2" />
  <opc:Field Name="DateTime" TypeName="opc:DateTime" LengthField="ArrayLength"
      SwitchField="VariantType" SwitchValue="3" />
</opc:StructuredType>
```

The *ArrayLength* field is optional. If it is not present in an encoded value, then the length of all fields with *LengthField* set to “ArrayLength” have a length of 1.

It is valid for the *VariantType* field to have a value that has no matching field defined. This simply means all optional fields are not present in the encoded value.

7. An enumerated type.

```
<opc:EnumeratedType Name="TrafficLight" LengthInBits="32">
  <opc:Documentation>The possible colours for a traffic signal.</opc:Documentation>
  <opc:EnumeratedValue Name="Red" Value="4">
    <opc:Documentation>Red says stop immediately.</opc:Documentation>
  </opc:EnumeratedValue>
  <opc:EnumeratedValue Name="Yellow" Value="3">
    <opc:Documentation>Yellow says prepare to stop.</opc:Documentation>
  </opc:EnumeratedValue>
  <opc:EnumeratedValue Name="Green" Value="2">
    <opc:Documentation>Green says you may proceed.</opc:Documentation>
  </opc:EnumeratedValue>
</opc:EnumeratedType>
```

The documentation element is used to provide human readable description of the type and values.

8. A nillable array.

```
<opc:StructuredTypen Name="NillableArray">
  <opc:Documentation>An array where a length of -1 means null.</opc:Documentation>
  <opc:Field Name="Length" TypeName="opc:Int32" />
  <opc:Field
      Name="Int32"
      TypeName="opc:Int32"
      LengthField="Length"
      SwitchField="Length"
      SwitchValue="0"
      SwitchOperand="GreaterThanOrEqual" />
</opc:StructuredType>
```

If the length of the array is −1 then the array does not appear in the stream.

C.5 OPC Binary XML Schema

```
<?xml version="1.0" encoding="utf-8" ?>
<xs:schema
  targetNamespace="http://opcfoundation.org/BinarySchema/"
```

```
  elementFormDefault="qualified"
  xmlns="http://opcfoundation.org/BinarySchema/"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
>
  <xs:element name="Documentation">
    <xs:complexType mixed="true">
      <xs:choice minOccurs="0" maxOccurs="unbounded">
        <xs:any minOccurs="0" maxOccurs="unbounded"/>
      </xs:choice>
      <xs:anyAttribute/>
    </xs:complexType>
  </xs:element>

  <xs:complexType name="ImportDirective">
    <xs:attribute name="Namespace" type="xs:string" use="optional" />
    <xs:attribute name="Location" type="xs:string" use="optional" />
  </xs:complexType>

  <xs:simpleType name="ByteOrder">
    <xs:restriction base="xs:string">
      <xs:enumeration value="BigEndian" />
      <xs:enumeration value="LittleEndian" />
    </xs:restriction>
  </xs:simpleType>

  <xs:complexType name="TypeDescription">
    <xs:sequence>
      <xs:element ref="Documentation" minOccurs="0" maxOccurs="1" />
    </xs:sequence>
    <xs:attribute name="Name" type="xs:NCName" use="required" />
    <xs:attribute name="DefaultByteOrder" type="ByteOrder" use="optional" />
    <xs:anyAttribute processContents="lax" />
  </xs:complexType>

  <xs:complexType name="OpaqueType">
    <xs:complexContent>
      <xs:extension base="TypeDescription">
        <xs:attribute name="LengthInBits" type="xs:int" use="optional" />
        <xs:attribute name="ByteOrderSignificant" type="xs:boolean" default="false" />
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:complexType name="EnumeratedValue">
    <xs:sequence>
      <xs:element ref="Documentation"  minOccurs="0" maxOccurs="1" />
    </xs:sequence>
    <xs:attribute name="Name" type="xs:string" use="optional" />
    <xs:attribute name="Value" type="xs:unsignedInt" use="optional" />
  </xs:complexType>

  <xs:complexType name="EnumeratedType">
    <xs:complexContent>
      <xs:extension base="OpaqueTypeDescription">
        <xs:sequence>
       <xs:element       name="EnumeratedValue"       type="EnumeratedValueDescription"
maxOccurs="unbounded" />
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:simpleType name="SwitchOperand">
    <xs:restriction base="xs:string">
      <xs:enumeration value="Equals" />
      <xs:enumeration value="GreaterThan" />
      <xs:enumeration value="LessThan" />
      <xs:enumeration value="GreaterThanOrEqual" />
      <xs:enumeration value="LessThanOrEqual" />
      <xs:enumeration value="NotEqual" />
    </xs:restriction>
  </xs:simpleType>

  <xs:complexType name="FieldType">
    <xs:sequence>
      <xs:element ref="Documentation" minOccurs="0" maxOccurs="1" />
    </xs:sequence>
    <xs:attribute name="Name" type="xs:string" use="required" />
```

```
    <xs:attribute name="TypeName" type="xs:QName" use="optional" />
    <xs:attribute name="Length" type="xs:unsignedInt" use="optional" />
    <xs:attribute name="LengthField" type="xs:string" use="optional" />
    <xs:attribute name="IsLengthInBytes" type="xs:boolean" default="false" />
    <xs:attribute name="SwitchField" type="xs:string" use="optional" />
    <xs:attribute name="SwitchValue" type="xs:unsignedInt" use="optional" />
    <xs:attribute name="SwitchOperand" type="SwitchOperand" use="optional" />
    <xs:attribute name="Terminator" type="xs:hexBinary" use="optional" />
    <xs:anyAttribute processContents="lax" />
  </xs:complexType>

  <xs:complexType name="StructuredType">
    <xs:complexContent>
      <xs:extension base="TypeDescription">
        <xs:sequence>
          <xs:element name="Field" type="FieldType" minOccurs="0" maxOccurs="unbounded"
/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:element name="TypeDictionary">
    <xs:complexType>
      <xs:sequence>
        <xs:element ref="Documentation"  minOccurs="0" maxOccurs="1" />
        <xs:element       name="Import"       type="ImportDirective"       minOccurs="0"
maxOccurs="unbounded" />
        <xs:choice minOccurs="0" maxOccurs="unbounded">
          <xs:element name="OpaqueType" type="OpaqueType" />
          <xs:element name="EnumeratedType" type="EnumeratedType" />
          <xs:element name="StructuredType" type="StructuredType" />
        </xs:choice>
      </xs:sequence>
      <xs:attribute name="TargetNamespace" type="xs:string" use="required" />
      <xs:attribute name="DefaultByteOrder" type="ByteOrder" use="optional" />
    </xs:complexType>
  </xs:element>

</xs:schema>
```

C.6 OPC Binary Standard TypeDictionary

```
<?xml version="1.0" encoding="utf-8"?>
<opc:TypeDictionary
  xmlns="http://opcfoundation.org/BinarySchema/"
  xmlns:opc="http://opcfoundation.org/BinarySchema/"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  TargetNamespace="http://opcfoundation.org/BinarySchema/"
>
  <opc:Documentation>This dictionary defines the standard types used by the OPC Binary
type description system.</opc:Documentation>

  <opc:OpaqueType Name="Bit" LengthInBits="1">
    <opc:Documentation>A single bit.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Boolean" LengthInBits="8">
    <opc:Documentation>A   two   state   logical   value   represented   as   a   8-bit
value.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="SByte" LengthInBits="8">
    <opc:Documentation>An 8-bit signed integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Byte" LengthInBits="8">
    <opc:Documentation>A 8-bit unsigned integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Int16" LengthInBits="16" ByteOrderSignificant="true">
    <opc:Documentation>A 16-bit signed integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="UInt16" LengthInBits="16" ByteOrderSignificant="true">
    <opc:Documentation>A 16-bit unsigned integer.</opc:Documentation>
  </opc:OpaqueType>
```

```xml
  <opc:OpaqueType Name="Int32" LengthInBits="32" ByteOrderSignificant="true">
    <opc:Documentation>A 32-bit signed integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="UInt32" LengthInBits="32" ByteOrderSignificant="true">
    <opc:Documentation>A 32-bit unsigned integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Int64" LengthInBits="32" ByteOrderSignificant="true">
    <opc:Documentation>A 64-bit signed integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="UInt64" LengthInBits="64" ByteOrderSignificant="true">
    <opc:Documentation>A 64-bit unsigned integer.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Float" LengthInBits="32" ByteOrderSignificant="true">
    <opc:Documentation>An IEEE-754 single precision floating point value.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Double" LengthInBits="64" ByteOrderSignificant="true">
    <opc:Documentation>An IEEE-754 double precision floating point value.</opc:Documentation>
  </opc:OpaqueType>

  <opc:OpaqueType Name="Char" LengthInBits="8">
    <opc:Documentation>A 8-bit character value.</opc:Documentation>
  </opc:OpaqueType>

  <opc:StructuredType Name="String">
    <opc:Documentation>A UTF-8 null terminated string value.</opc:Documentation>
    <opc:Field Name="Value" TypeName="Char" Terminator="00" />
  </opc:StructuredType>

  <opc:StructuredType Name="CharArray">
    <opc:Documentation>A UTF-8 string prefixed by its length in characters.</opc:Documentation>
    <opc:Field Name="Length" TypeName="Int32" />
    <opc:Field Name="Value" TypeName="Char" LengthField="Length" />
  </opc:StructuredType>

  <opc:OpaqueType Name="WideChar" LengthInBits="16" ByteOrderSignificant="true">
    <opc:Documentation>A 16-bit character value.</opc:Documentation>
  </opc:OpaqueType>

  <opc:StructuredType Name="WideString">
    <opc:Documentation>A UTF-16 null terminated string value.</opc:Documentation>
    <opc:Field Name="Value" TypeName="WideChar" Terminator="0000" />
  </opc:StructuredType>

  <opc:StructuredType Name="WideCharArray">
    <opc:Documentation>A UTF-16 string prefixed by its length in characters.</opc:Documentation>
    <opc:Field Name="Length" TypeName="Int32" />
    <opc:Field Name="Value" TypeName="WideChar" LengthField="Length" />
  </opc:StructuredType>

  <opc:StructuredType Name="ByteString">
    <opc:Documentation>An array of bytes prefixed by its length.</opc:Documentation>
    <opc:Field Name="Length" TypeName="Int32" />
    <opc:Field Name="Value" TypeName="Byte" LengthField="Length" />
  </opc:StructuredType>

  <opc:OpaqueType Name="DateTime" LengthInBits="64" ByteOrderSignificant="true">
    <opc:Documentation>The number of 100 nanosecond intervals since January 01, 1601.</opc:Documentation>
  </opc:OpaqueType>

  <opc:StructuredType Name="Guid">
    <opc:Documentation>A 128-bit globally unique identifier.</opc:Documentation>
    <opc:Field Name="Data1" TypeName="UInt32" />
    <opc:Field Name="Data2" TypeName="UInt16" />
    <opc:Field Name="Data3" TypeName="UInt16" />
    <opc:Field Name="Data4" TypeName="Byte" Length="8" />
  </opc:StructuredType>

</opc:TypeDictionary>
```

Annex D
(normative)

Graphical Notation

D.1 General

Annex D defines a graphical notation for OPC UA data. Annex D is normative, that is, the notation is used in this standard to expose examples of OPC UA data. However, it is not required to use this notation to expose OPC UA data.

The graphical notation is able to expose all structural data of OPC UA. *Nodes*, their *Attributes* including their current value and *References* between the *Nodes* including the *ReferenceType* can be exposed. The graphical notation provides no mechanism to expose events or historical data.

D.2 Notation

D.2.1 Overview

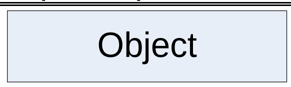
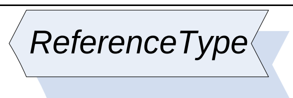
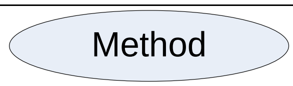
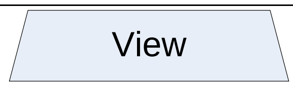
The notation is divided into two parts. The simple notation only provides a simplified view on the data hiding some details like *Attributes*. The extended notation allows exposing all structure information of OPC UA, including *Attribute* values. The simple and the extended notation can be combined to expose OPC UA data in one figure.

Common to both notations is that neither any colour nor the thickness or style of lines is relevant for the notation. Those effects can be used to highlight certain aspects of a figure.

D.2.2 Simple Notation

Depending on their *NodeClass Nodes* are represented by different graphical forms as defined in Table D.1.

Table D.1 – Notation of Nodes depending on the NodeClass

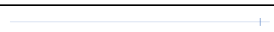
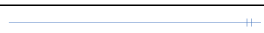
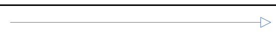
NodeClass	Graphical Representation	Comment
Object		Rectangle including text representing the string-part of the *DisplayName* of the *Object*. The font shall not be set to italic.
ObjectType		Shadowed rectangle including text representing the string-part of the *DisplayName* of the *ObjectType*. The font shall be set in italic.
Variable		Rectangle with rounded corners including text representing the string-part of the *DisplayName* of the *Variable*. The font shall not be set in italic.
VariableType		Shadowed rectangle with rounded corners including text representing the string-part of the *DisplayName* of the *VariableType*. The font shall be set in italic.
DataType		Shadowed hexagon including text representing the string-part of the *DisplayName* of the *DataType*.
ReferenceType		Shadowed six-sided polygon including text representing the string-part of the *DisplayName* of the *ReferenceType*.
Method		Oval including text representing the string-part of the *DisplayName* of the *Method*.
View		Trapezium including text representing the string-part of the *DisplayName* of the *View*.

References are represented as lines between *Nodes* as exemplified in Figure D.1. Those lines can vary in their form. They do not have to connect the *Nodes* with a straight line; they can have angles, arches, etc.

Figure D.1 – Example of a Reference connecting two Nodes

Table D.2 defines how symmetric and asymmetric *References* are represented in general, and also defines shortcuts for some *ReferenceTypes*. Although it is recommended to use those shortcuts, it is not required. Thus, instead of using the shortcut, the generic solution can also be used.

Table D.2 – Simple Notation of Nodes depending on the NodeClass

ReferenceType	Graphical Representation	Comment
Any symmetric ReferenceType	 ReferenceType	Symmetric *ReferenceTypes* are represented as lines between *Nodes* with closed and filled arrows on both sides pointing to the connected *Nodes*. Near the line has to be a text containing the string-part of the *BrowseName* of the *ReferenceType*.
Any asymmetric ReferenceType	 ReferenceType	Asymmetric *ReferenceTypes* are represented as lines between *Nodes* with a closed and filled arrow on the side pointing to the *TargetNode*. Near the line has to be a text containing the string-part of the *BrowseName* of the *ReferenceType*.
Any hierarchical ReferenceType	 ReferenceType	Asymmetric *ReferenceTypes* that are subtypes of *HierarchicalReferences* should be exposed the same way as asymmetric *ReferenceTypes* except that an open arrow is used.
HasComponent		The notation provides a shortcut for *HasComponent References* shown on the left. The single hashed line has to be near the *TargetNode*.
HasProperty		The notation provides a shortcut for *HasProperty References* shown on the left. The double hashed lines have to be near the *TargetNode*.
HasTypeDefinition		The notation provides a shortcut for *HasTypeDefinition References* shown on the left. The double closed and filled arrows have to point to the *TargetNode*.
HasSubtype		The notation provides a shortcut for *HasSubtype References* shown on the left. The double closed arrows have to point to the *SourceNode*.
HasEventSource		The notation provides a shortcut for *HasEventSource References* shown on the left. The closed arrow has to point to the *TargetNode*.

D.2.3 Extended Notation

In the extended notation some additional concepts are introduced. It is allowed only to use some of those concepts on elements of a figure.

The following rules define some special handling of structures.

- In general, values of all *DataTypes* should be represented by an appropriate string representation. Whenever a *NamespaceIndex* or *LocaleId* is used in those structures they can be omitted.
- The *DisplayName* contains a *LocaleId* and a *String*. Such a structure can be exposed as [<LocaleId>:]<String> where the *LocaleId* is optional. For example, a *DisplayName* can be "en:MyName". Instead of that, "MyName" can also be used. This rule applies whenever a *DisplayName* is shown, including the text used in the graphical representation of a *Node*.
- The *BrowseName* contains the *NamespaceIndex* and a *String*. Such a structure can be exposed as [<NamespaceIndex>:]<String> where the *NamespaceIndex* is optional. For example, a *BrowseName* can be "1:MyName". Instead of that, "MyName" can also be used. This rule applies whenever a *BrowseName* is shown, including the text used in the graphical representation of a *Node*.

Instead of using the *HasTypeDefinition* reference to point from an *Object* or *Variable* to its *ObjectType* or *VariableType* the name of the *TypeDefinition* can be added to the text used in the *Node*. The *TypeDefinition* shall either be prefixed with “::” or it is put in italic as the top line. Figure D.3 gives an example, where “Node1” uses a *Reference* and “Node2” the shortcut in both notation variants. A figure can contain *HasTypeDefinition References* for some *Nodes* and the shortcut for other *Nodes*. It is not allowed that a *Node* uses the shortcut and additionally is the *SourceNode* of a *HasTypeDefinition*.

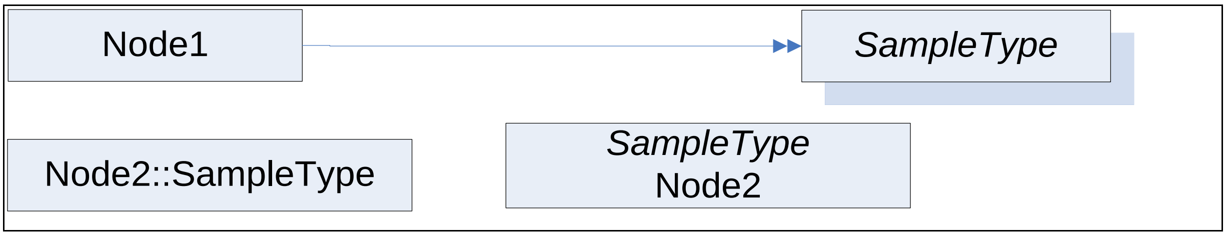


Figure D.3 – Example of using a TypeDefinition inside a Node

To display *Attributes* of a *Node* additional text can be put inside the form representing the *Node* under the text representing the *DisplayName*. The *DisplayName* and the text describing the *Attributes* have to be separated using a horizontal line. Each *Attribute* has to be set into a new text line. Each text line shall contain the *Attribute* name followed by an “=” and the value of the *Attribute*. On top of the first text line containing an *Attribute* shall be a text line containing the underlined text “Attribute”. It is not required to expose all *Attributes* of a *Node*. It is allowed to show only a subset of *Attributes*. If an optional *Attribute* is not provided, the *Attribute* can be marked by a strike-through line, for example “~~Description~~”. Examples of exposing *Attributes* are shown in Figure D.4.

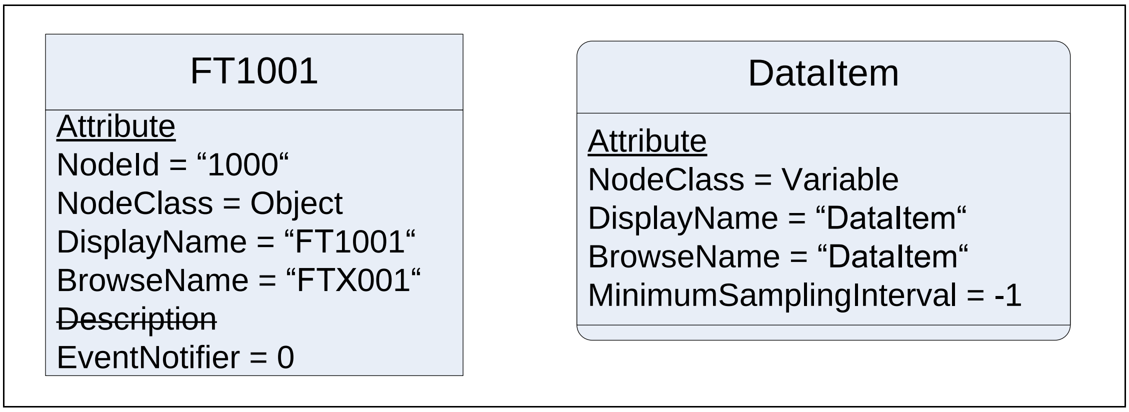


Figure D.4 – Example of exposing Attributes

To avoid too many *Nodes* in a figure it is allowed to expose *Properties* inside a *Node*, similar to *Attributes*. Therefore, the text field used for exposing *Attributes* is extended. Under the last text line containing an *Attribute* a new text line containing the underlined text “Property” has to be added. If no *Attribute* is provided, the text has to start with this text line. After this text line, each new text line shall contain a *Property*, starting with the *BrowseName* of the *Property* followed by “=” and the value of the *Value Attribute* of the *Property*. Figure D.5 shows some examples exposing *Properties* inline. It is allowed to expose some *Properties* of a *Node* inline, and other *Properties* as *Nodes*. It is not allowed to show a *Property* inline as well as an additional *Node*.

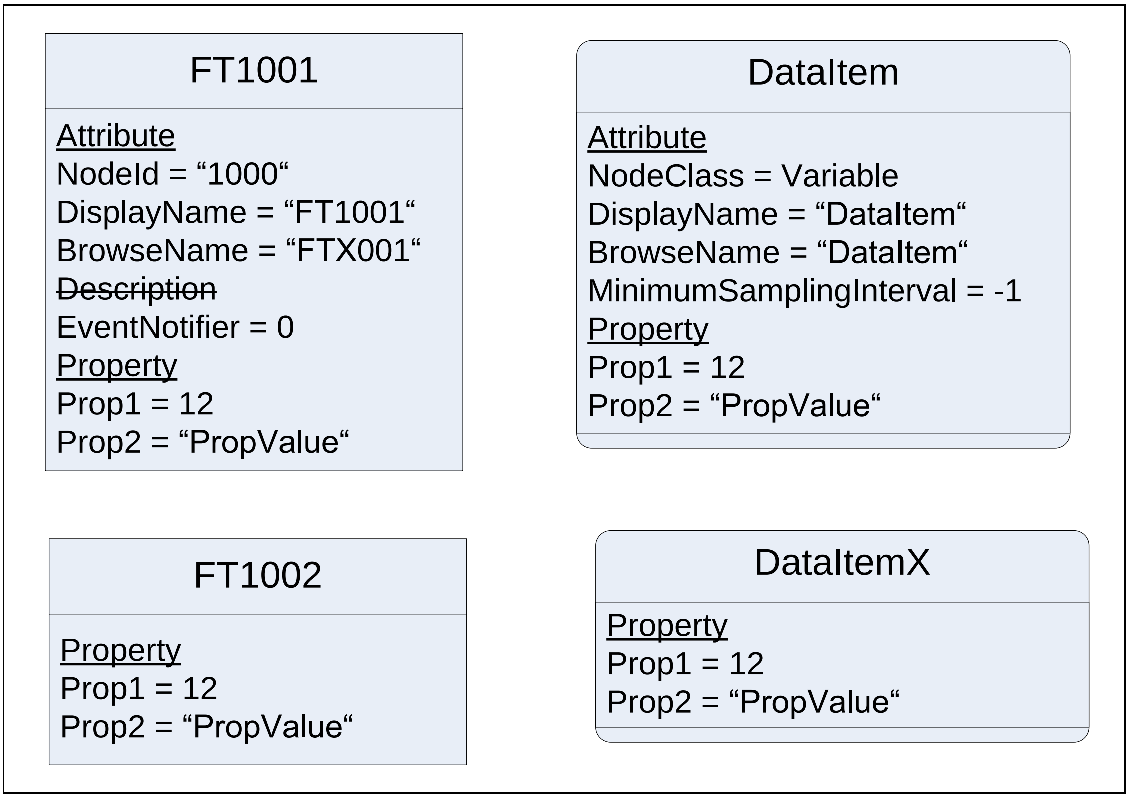


Figure D.5 – Example of exposing Properties inline

It is allowed to add additional information to a figure using the graphical representation, for example callouts.