# Scope

This [Abbreviations and symbols] specification is part of the overall OPC Unified Architecture (OPC UA) standard series and defines the information model associated with Data Access (DA). It particularly includes additional VariableTypes and complementary descriptions of the NodeClasses and Attributes needed for Data Access, additional Properties, and other information and behaviour.

The complete address space model, including all NodeClasses and Attributes is specified in [Part 3]. The services to detect and access data are specified in [Part 4].

# Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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

Part 3: [OPC UA Specification: Part 3 – Address Space Model]

[http://www.opcfoundation.org/UA/Part3/]

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/]

UN/CEFACT: UNECE Recommendation N° 20, Codes for Units of Measure Used in International Trade, available at [http://www.unece.org/tradewelcome/un-centre-for-trade-facilitation-and-e-business-uncefact/outputs/cefactrecommendationsrec-index/list-of-trade-facilitation-recommendations-n-16-to-20.html]

# Terms, definitions and abbreviations

## Terms and definitions

For the purposes of this document, the terms and definitions given in [Part 1], [Part 3], and [Part 4] as well as the following apply.

DataItem

link to arbitrary, live automation data, that is, data that represents currently valid information

Note [1] to entry: Examples of such data are

* device data (such as temperature sensors),
* calculated data,
* status information (open/closed, moving),
* dynamically-changing system data (such as stock quotes),
* diagnostic data.

AnalogItem

DataItems that represent continuously-variable physical quantities (e.g., length, temperature), in contrast to the digital representation of data in discrete items

Note [1] to entry: Typical examples are the values provided by temperature sensors or pressure sensors. OPC UA defines a specific VariableType to identify an AnalogItem. Properties describe the possible ranges of AnalogItems.

DiscreteItem

DataItems that represent data that may take on only a certain number of possible values (e.g., OPENING, OPEN, CLOSING, CLOSED)

Note [1] to entry: Specific VariableTypes are used to identify DiscreteItems with two states or with multiple states. Properties specify the string values for these states.

ArrayItem

DataItems that represent continuously-variable physical quantities and where each individual data point consists of multiple values represented by an array (e.g., the spectral response of a digital filter)

Note [1] to entry: Typical examples are the data provided by analyser devices. Specific VariableTypes are used to identify ArrayItem variants.

EngineeringUnits

units of measurement for AnalogItems that represent continuously-variable physical quantities (e.g., length, mass, time, temperature)

Note [1] to entry: This standard defines Properties to inform about the unit used for the DataItem value and about the highest and lowest value likely to be obtained in normal operation.

## Abbreviations and symbols

DA Data Access

EU Engineering Unit

UA Unified Architecture

# Concepts

Data Access deals with the representation and use of automation data in Servers.

Automation data can be located inside the Server or on I/O cards directly connected to the Server. It can also be located in sub-servers or on other devices such as controllers and input/output modules, connected by serial links via field buses or other communication links. OPC UA Data Access Servers provide one or more OPC UA Data Access Clients with transparent access to their automation data.

The links to automation data instances are called DataItems. Which categories of automation data are provided is completely vendor-specific. [Figure 1] illustrates how the AddressSpace of a Server might consist of a broad range of different DataItems.



Figure 1 – OPC DataItems are linked to automation data

Clients may read or write DataItems, or monitor them for value changes. The Services needed for these operations are specified in [Part 4]. Changes are defined as a change in status (quality) or a change in value that exceeds a client-defined range called a Deadband. To detect the value change, the difference between the current value and the last reported value is compared to the Deadband.

# Model

## General

The DataAccess model extends the variable model by defining VariableTypes. The DataItemType is the base type. ArrayItemType, AnalogItemType and DiscreteItemType (and its TwoState and MultiState subtypes) are specializations. See [Figure 2]. Each of these VariableTypes can be further extended to form domain or server specific DataItems.



Figure 2 – DataItem VariableType hierarchy

## SemanticsChanged

The StatusCode also contains an informational bit called SemanticsChanged.

Servers that implement Data Access shall set this Bit in notifications if certain Properties defined in this standard change. The corresponding Properties are specified individually for each VariableType.

Clients that use any of these Properties should re-read them before they process the data value.

## Variable Types

### DataItemType

This VariableType defines the general characteristics of a DataItem. All other DataItem Types derive from it. The DataItemType derives from the BaseDataVariableType and therefore shares the variable model as described in [Part 3] and [Part 5]. It is formally defined in [Table 1].

Table 1 – DataItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | DataItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | −2 (−2 = ‘Any’) | | | | |
| DataType | BaseDataType | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the BaseDataVariableType defined in [Part 5]; i.e the Properties of that type are inherited. | | | | | |
| HasSubtype | VariableType | AnalogItemType | Defined in [AnalogItemType] | | |
| HasSubtype | VariableType | DiscreteItemType | Defined in [DiscreteItemType] | | |
| HasSubtype | VariableType | ArrayItemType | Defined in [ArrayItemType] | | |
| HasProperty | Variable | Definition | String | PropertyType | Optional |
| HasProperty | Variable | ValuePrecision | Double | PropertyType | Optional |

Definition is a vendor-specific, human readable string that specifies how the value of this DataItem is calculated. Definition is non-localized and will often contain an equation that can be parsed by certain clients.

Example: Definition::= “(TempA – 25) + TempB”

ValuePrecision specifies the maximum precision that the Server can maintain for the item based on restrictions in the target environment.

ValuePrecision can be used for the following DataTypes:

* For Float and Double values it specifies the number of digits after the decimal place.
* For DateTime values it indicates the minimum time difference in nanoseconds. For example, a ValuePrecision of 20 000 000 defines a precision of 20 ms.

The ValuePrecision Property is an approximation that is intended to provide guidance to a Client. A Server is expected to silently round any value with more precision that it supports. This implies that a Client may encounter cases where the value read back from a Server differs from the value that it wrote to the Server. This difference shall be no more than the difference suggested by this Property.

### AnalogItemType

This VariableType defines the general characteristics of an AnalogItem. All other AnalogItem Types derive from it. The AnalogItemType derives from the DataItemType. It is formally defined in [Table 2].

Table 2 – AnalogItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | AnalogItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | −2 (−2 = ‘Any’) | | | | |
| DataType | Number | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the DataItemType defined in [DataItemType] i.e the Properties of that type are inherited. | | | | | |
| HasProperty | Variable | InstrumentRange | Range | PropertyType | Optional |
| HasProperty | Variable | EURange | Range | PropertyType | Mandatory |
| HasProperty | Variable | EngineeringUnits | EUInformation | PropertyType | Optional |

The following paragraphs describe the Properties of this VariableType. If the analog item’s Value contains an array, the Properties shall apply to all elements in the array.

InstrumentRange defines the value range that can be returned by the instrument.

Example: InstrumentRange::= {-9999.9, 9999.9}

Although defined as optional, it is strongly recommended for Servers to support this Property. Without an InstrumentRange being provided, Clients will commonly assume the full range according to the DataType.

The Range Data Type is specified in [Range].

EURange defines the value range likely to be obtained in normal operation. It is intended for such use as automatically scaling a bar graph display.

Sensor or instrument failure or deactivation can result in a returned item value which is actually outside of this range. Client software must be prepared to deal with this possibility. Similarly a Client may attempt to write a value that is outside of this range back to the server. The exact behaviour (accept, reject, clamp, etc.) in this case is Server-dependent. However, in general Servers shall be prepared to handle this.

Example: EURange::= {-200.0,1400.0}

See also [PercentDeadband] for a special monitoring filter (PercentDeadband) which is based on the engineering unit range.

EngineeringUnits specifies the units for the DataItem’s value (e.g., DEGC, hertz, seconds). The EUInformation type is specified in [EUInformation].

Important note: Understanding the units of a measurement value is essential for a uniform system. In an open system in particular where servers from different cultures might be used, it is essential to know what the units of measurement are. Based on such knowledge, values can be converted if necessary before being used. Therefore, although defined as optional, support of the EngineeringUnits Property is strongly advised.

OPC UA recommends using the “Codes for Units of Measurement” (see [UN/CEFACT: UNECE Recommendation N° 20]). The mapping to the EngineeringUnits Property is specified in [EUInformation].

Examples for unit mixup: In 1999, the Mars Climate Orbiter crashed into the surface of Mars. The main reason was a discrepancy over the units used. The navigation software expected data in newton second; the company who built the orbiter provided data in pound-force seconds. Another, less expensive, disappointment occurs when people used to British pints order a pint in the USA, only to be served what they consider a short measure.

The StatusCode SemanticsChanged bit shall be set if any of the EURange (could change the behaviour of a Subscription if a PercentDeadband filter is used) or EngineeringUnits (could create problems if the client uses the value to perform calculations) Properties are changed (see section [SemanticsChanged] for additional information).

### DiscreteItemType

#### General

This VariableType is an abstract type. That is, no instances of this type can exist. However, it might be used in a filter when browsing or querying. The DiscreteItemType derives from the DataItemType and therefore shares all of its characteristics. It is formally defined in [Table 3].

Table 3 – DiscreteItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | DiscreteItemType | | | | |
| IsAbstract | True | | | | |
| ValueRank | −2 (−2 = ‘Any’) | | | | |
| DataType | BaseDataType | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the DataItemType defined in [SemanticsChanged]; i.e the Properties of that type are inherited. | | | | | |
| HasSubtype | VariableType | TwoStateDiscreteType | Defined in [TwoStateDiscreteType] | | |
| HasSubtype | VariableType | MultiStateDiscreteType | Defined in [MultiStateDiscreteType] | | |
| HasSubtype | VariableType | MultiStateValueDiscreteType | Defined in [MultiStateValueDiscreteType] | | |

#### TwoStateDiscreteType

This VariableType defines the general characteristics of a DiscreteItem that can have two states. The TwoStateDiscreteType derives from the DiscreteItemType. It is formally defined in [Table 4].

Table 4 – TwoStateDiscreteType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | TwoStateDiscreteType | | | | |
| IsAbstract | False | | | | |
| ValueRank | −2 (−2 = ‘Any’) | | | | |
| DataType | Boolean | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the DiscreteItemType defined in [DiscreteItemType]; i.e the Properties of that type are inherited. | | | | | |
| HasProperty | Variable | TrueState | LocalizedText | PropertyType | Mandatory |
| HasProperty | Variable | FalseState | LocalizedText | PropertyType | Mandatory |

TrueState contains a string to be associated with this DataItem when it is TRUE. This is typically used for a contact when it is in the closed (non-zero) state.

for example: "RUN", "CLOSE", "ENABLE", "SAFE“, etc.

FalseState contains a string to be associated with this DataItem when it is FALSE. This is typically used for a contact when it is in the open (zero) state.

for example: "STOP", "OPEN", "DISABLE", "UNSAFE“, etc.

If the item contains an array, then the Properties will apply to all elements in the array.

The StatusCode SemanticsChanged bit shall be set if any of the FalseState or TrueState (changes can cause misinterpretation by users or (scripting) programs) Properties are changed (see section [SemanticsChanged] for additional information).

#### MultiStateDiscreteType

This VariableType defines the general characteristics of a DiscreteItem that can have more than two states. The MultiStateDiscreteType derives from the DiscreteItemType. It is formally defined in [Table 5].

Table 5 – MultiStateDiscreteType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | MultiStateDiscreteType | | | | |
| IsAbstract | False | | | | |
| ValueRank | −2 (−2 = ‘Any’) | | | | |
| DataType | UInteger | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the DiscreteItemType defined in [DiscreteItemType]; i.e the Properties of that type are inherited. | | | | | |
| HasProperty | Variable | EnumStrings | LocalizedText[] | PropertyType | Mandatory |

EnumStrings is a string lookup table corresponding to sequential numeric values (0, 1, 2, etc.)

Example:

”OPEN”

”CLOSE”

”IN TRANSIT” etc.

Here the string “OPEN” corresponds to 0, “CLOSE” to 1 and “IN TRANSIT” to 2.

Clients should be prepared to handle item values outside of the range of the list; and robust servers should be prepared to handle writes of illegal values.

If the item contains an array then this lookup table shall apply to all elements in the array.

NOTE The EnumStrings property is also used for Enumeration DataTypes (for the specification of this DataType, see [Part 3]).

The StatusCode SemanticsChanged bit shall be set if the EnumStrings (changes can cause misinterpretation by users or (scripting) programs) Property is changed (see section [SemanticsChanged] for additional information).

#### MultiStateValueDiscreteType

This VariableType defines the general characteristics of a DiscreteItem that can have more than two states and where the state values (the enumeration) does not consist of consecutive numeric values (may have gaps) or where the enumeration is not zero-based. The MultiStateValueDiscreteType derives from the DiscreteItemType. It is formally defined in [Table 6].

Table 6 – MultiStateValueDiscreteType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | MultiStateValueDiscreteType | | | | |
| IsAbstract | False | | | | |
| ValueRank | Scalar | | | | |
| DataType | Number | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the DiscreteItemType defined in [DiscreteItemType]; i.e the Properties of that type are inherited. | | | | | |
| HasProperty | Variable | EnumValues | See [Part 3] | Mandatory | |
| HasProperty | Variable | ValueAsText | See [Part 3] | Mandatory | |

EnumValues is an array of EnumValueType. Each entry of the array represents one enumeration value with its integer notation, a human-readable representation, and help information. This represents enumerations with integers that are not zero-based or have gaps (e.g. 1, 2, 4, 8, 16). See [Part 3] for the definition of this type. MultiStateValueDiscrete Variables expose the current integer notation in their Value Attribute. Clients will often read the EnumValues Property in advance and cache it to lookup a name or help whenever they receive the numeric representation.

MultiStateValueDiscrete Variables can have any numeric Data Type; this includes signed and unsigned integers from 8 to 64 Bit length.

The numeric representation of the current enumeration value is provided via the Value Attribute of the MultiStateValueDiscrete Variable. The ValueAsText 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.

### ArrayItemType

#### General

This abstract VariableType defines the general characteristics of an ArrayItem. Values are exposed in an array but the content of the array represents a single entity like an image. Other DataItems might contain arrays that represent for example several values of several temperature sensors of a boiler.

ArrayItemType or its subtype shall only be used when the Title and AxisScaleType Properties can be filled with reasonable values. If this is not the case DataItemType and subtypes like AnalogItemType, which also support arrays, shall be used. The ArrayItemType is formally defined in [Table 7].

Table 7 – ArrayItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | ArrayItemType | | | | |
| IsAbstract | True | | | | |
| ValueRank | 0 (0 = OneOrMoreDimensions) | | | | |
| DataType | BaseDataType | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the DataItemType defined in [DataItemType]; i.e the Properties of that type are inherited. | | | | | |
| HasSubtype | VariableType | YArrayItemType | Defined in [YArrayItemType] | | |
| HasSubtype | VariableType | XYArrayItemType | Defined in [XYArrayItemType] | | |
| HasSubtype | VariableType | ImageItemType | Defined in [ImageItemType] | | |
| HasSubtype | VariableType | CubeItemType | Defined in [CubeItemType] | | |
| HasSubtype | VariableType | NDimensionArrayItemType | Defined in [NDimensionArrayItemType] | | |
| HasProperty | Variable | InstrumentRange | Range | PropertyType | Optional |
| HasProperty | Variable | EURange | Range | PropertyType | Mandatory |
| HasProperty | Variable | EngineeringUnits | EUInformation | PropertyType | Mandatory |
| HasProperty | Variable | Title | LocalizedText | PropertyType | Mandatory |
| HasProperty | Variable | AxisScaleType | AxisScaleEnumeration | PropertyType | Mandatory |

InstrumentRange defines the range of the Value of the ArrayItem.

EURange defines the value range of the ArrayItem likely to be obtained in normal operation. It is intended for such use as automatically scaling a bar graph display.

EngineeringUnits holds the information about the engineering units of the Value of the ArrayItem.

For additional information about InstrumentRange, EURange, and EngineeringUnits see the description of AnalogItemType in [AnalogItemType].

Title holds the user readable title of the Value of the ArrayItem.

AxisScaleType defines the scale to be used for the axis where the Value of the ArrayItem shall be displayed.

The StatusCode SemanticsChanged bit shall be set if any of the InstrumentRange, EURange, EngineeringUnits or Title Properties are changed (see [SemanticsChanged] for additional information).

#### YArrayItemType

YArrayItemType represents a single-dimensional array of numerical values used to represent spectra or distributions where the x axis intervals are constant. YArrayItemType is formally defined in [Table 8].

Table 8 – YArrayItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | YArrayItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | 1 | | | | |
| DataType | BaseDataType | | | | |
| ArrayDimensions | {0} (0 = UnknownSize) | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the ArrayItemType defined in [General] | | | | | |
|  |  |  |  |  |  |
| HasProperty | Variable | XAxisDefinition | AxisInformation | PropertyType | Mandatory |

The Value of the YArrayItem contains the numerical values for the Y-Axis. Engineering Units and Range for the Value are defined by corresponding Properties inherited from the ArrayItemType.

The DataType of this VariableType is restricted to SByte, Int16, Int32, Int64, Float, Double, ComplexNumberType and DoubleComplexNumberType.

The XAxisDefinition Property holds the information about the Engineering Units and Range for the X-Axis.

The StatusCode SemanticsChanged bit shall be set if any of the following five Properties are changed: InstrumentRange, EURange, EngineeringUnits, Title or XAxisDefinition (see [SemanticsChanged] for additional information).

[Figure 3] shows an example of how Attributes and Properties may be used in a graphical interface.

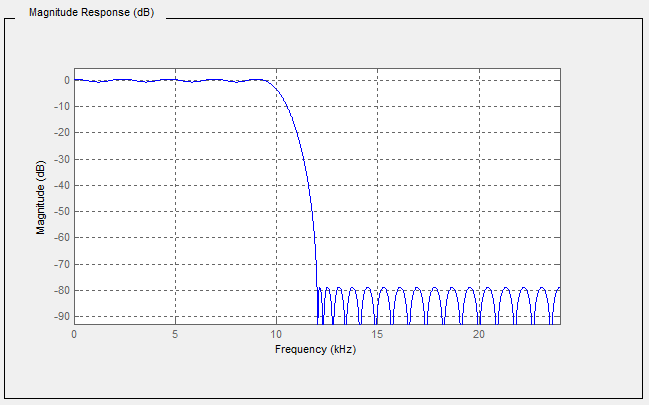


Figure 3 – Graphical view of a YArrayItem

[Table 9] describes the values of each element presented in [Figure 3].

Table 9 – YArrayItem item description

|  |  |
| --- | --- |
| Attribute / Property | Item value |
| Description | Magnitude Response (dB) |
| axisScaleType | AxisScaleEnumeration.LINEAR\_0 |
| InstrumentRange.low | -90 |
| InstrumentRange.high | 5 |
| EURange.low | -90 |
| EURange.high | 2 |
| EngineeringUnits.namespaceUrl | http://www.opcfoundation.org/UA/units/un/cefact |
| EngineeringUnits.unitId | 2N |
| EngineeringUnits.displayName | “en-us”, “dB” |
| EngineeringUnits.description | “en-us”, “decibel” |
| Title | Magnitude |
| XAxisDefinition.EngineeringUnits.namespaceUrl | http://www.opcfoundation.org/UA/units/un/cefact |
| XAxisDefinition.EngineeringUnits.unitId | kHz |
| XAxisDefinition.EngineeringUnits.displayName | “en-us”, “kHz” |
| XAxisDefinition.EngineeringUnits.description | “en-us”, “kilohertz” |
| XAxisDefinition.Range.low | 0 |
| XAxisDefinition.Range.high | 25 |
| XAxisDefinition.title | “en-us”, “Frequency” |
| XAxisDefinition.axisScaleType | AxisScaleEnumeration.LINEAR\_0 |
| XAxisDefinition.axisSteps | null |

Interpretation notes:

* Not all elements of this table are used in the graphic.
* The X axis is displayed in reverse order, however, the XAxisDefinition.Range.low shall be lower than XAxisDefinition.Range.high. It is only a graphical representation that reverses the display order.
* There is a constant X axis

#### XYArrayItemType

XYArrayItemType represents a vector of XVType values like a list of peaks, where XVType.x is the position of the peak and XVType.value is its intensity. XYArrayItemType is formally defined in [Table 10].

Table 10 – XYArrayItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | XYArrayItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | 1 | | | | |
| DataType | XVType (defined in [XVType]) | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the ArrayItemType defined in [General] | | | | | |
|  |  |  |  |  |  |
| HasProperty | Variable | XAxisDefinition | AxisInformation | PropertyType | Mandatory |

The Value of the XYArrayItem contains an array of structures (XVType) where each structure specifies the position for the X-Axis (XVType.x) and the value itself (XVType.value), used for the Y-Axis. Engineering units and range for the Value are defined by corresponding Properties inherited from the ArrayItemType.

XAxisDefinition Property holds the information about the Engineering Units and Range for the X-Axis.

The axisSteps of XAxisDefinition shall be set to NULL because it is not used.

The StatusCode SemanticsChanged bit shall be set if any of the InstrumentRange, EURange, EngineeringUnits, Title or XAxisDefinition Properties are changed (see [SemanticsChanged] for additional information).

#### ImageItemType

ImageItemType defines the general characteristics of an ImageItem which represents a matrix of values like an image, where the pixel position is given by X which is the column and Y the row. The value is the pixel intensity.

ImageItemType is formally defined in [Table 11].

Table 11 – ImageItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | ImageItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | 2 (2 = two dimensional array) | | | | |
| DataType | BaseDataType | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the ArrayItemType defined in [General] | | | | | |
|  |  |  |  |  |  |
| HasProperty | Variable | XAxisDefinition | AxisInformation | PropertyType | Mandatory |
| HasProperty | Variable | YAxisDefinition | AxisInformation | PropertyType | Mandatory |

Engineering units and range for the Value are defined by corresponding Properties inherited from the ArrayItemType.

The DataType of this VariableType is restricted to SByte, Int16, Int32, Int64, Float, Double, ComplexNumberType and DoubleComplexNumberType.

The ArrayDimensions Attribute for Variables of this type or subtypes shall use the first entry in the array ([0]) to define the number of columns and the second entry ([1]) to define the number of rows, assuming the size of the matrix is not dynamic.

XAxisDefinition Property holds the information about the engineering units and range for the X-Axis.

YAxisDefinition Property holds the information about the engineering units and range for the Y-Axis.

The StatusCode.SemanticsChanged bit shall be set if any of the InstrumentRange, EURange, EngineeringUnits, Title, XAxisDefinition or YAxisDefinition Properties are changed.

#### CubeItemType

CubeItemType represents a cube of values like a spatial particle distribution, where the particle position is given by X which is the column, Y the row and Z the depth. In the example of a spatial partical distribution, the value is the particle size. CubeItemType is formally defined in [Table 12].

Table 12 – CubeItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | CubeItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | 3 (3 = three dimensional array) | | | | |
| DataType | BaseDataType | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the ArrayItemType defined in [General] | | | | | |
|  |  |  |  |  |  |
| HasProperty | Variable | XAxisDefinition | AxisInformation | PropertyType | Mandatory |
| HasProperty | Variable | YAxisDefinition | AxisInformation | PropertyType | Mandatory |
| HasProperty | Variable | ZAxisDefinition | AxisInformation | PropertyType | Mandatory |

Engineering units and range for the Value are defined by corresponding Properties inherited from the ArrayItemType.

The DataType of this VariableType is restricted to SByte, Int16, Int32, Int64, Float, Double, ComplexNumberType and DoubleComplexNumberType.

The ArrayDimensions Attribute for Variables of this type or subtypes should use the first entry in the array ([0]) to define the number of columns, the second entry ([1]) to define the number of rows, and the third entry ([2]) define the number of steps in the Z axis, assuming the size of the matrix is not dynamic.

XAxisDefinition Property holds the information about the engineering units and range for the X-Axis.

YAxisDefinition Property holds the information about the engineering units and range for the Y-Axis.

ZAxisDefinition Property holds the information about the engineering units and range for the Z-Axis.

The StatusCode SemanticsChanged bit shall be set if any of the InstrumentRange, EURange, EngineeringUnits, Title, XAxisDefinition, YAxisDefinition or ZAxisDefinition Properties are changed (see [SemanticsChanged] for additional information).

#### NDimensionArrayItemType

This VariableType defines a generic multi-dimensional ArrayItem.

This approach minimizes the number of types however it may be proved more difficult to utilize for control system interactions.

NDimensionArrayItemType is formally defined in [Table 13].

Table 13 – NDimensionArrayItemType definition

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Attribute | Value | | | | |
| BrowseName | NdimensionArrayItemType | | | | |
| IsAbstract | False | | | | |
| ValueRank | 0 (0 = OneOrMoreDimensions) | | | | |
| DataType | BaseDataType | | | | |
| References | NodeClass | BrowseName | DataType | TypeDefinition | ModellingRule |
| Subtype of the ArrayItemType defined in [General] | | | | | |
|  |  |  |  |  |  |
| HasProperty | Variable | AxisDefinition | AxisInformation [] | PropertyType | Mandatory |

The DataType of this VariableType is restricted to SByte, Int16, Int32, Int64, Float, Double, ComplexNumberType and DoubleComplexNumberType.

AxisDefinition Property holds the information about the Engineering Units and Range for all axis.

The StatusCode SemanticsChanged bit shall be set if any of the InstrumentRange, EURange, EngineeringUnits, Title or AxisDefinition Properties are changed (see [SemanticsChanged] for additional information).

## Address Space model

DataItems are always defined as data components of other Nodes in the AddressSpace. They are never defined by themselves. A simple example of a container for DataItems would be a “Folder Object” but it can be an Object of any other type.

[Figure 4] illustrates the basic AddressSpace model of a DataItem, in this case an AnalogItem.



Figure 4 – Representation of DataItems in the AddressSpace

Each DataItem is represented by a DataVariable with a specific set of Attributes. The TypeDefinition reference indicates the type of the DataItem (in this case the AnalogItemType). Additional characteristics of DataItems are defined using Properties. The VariableTypes in [SemanticsChanged] specify which properties may exist. These Properties have been found to be useful for a wide range of Data Access clients. Servers that want to disclose similar information should use the OPC-defined Property rather than one that is vendor-specific.

The above figure shows only a subset of Attributes and Properties. Other Attributes that are defined for Variables in [Part 3] (e.g., Description) may also be available.

## Attributes of DataItems

This subclause lists the Attributes of Variables that have particular importance for Data Access. They are specified in detail in [Part 3]. The following Attributes are particularly important for Data Access:

* Value
* DataType
* AccessLevel
* MinimumSamplingInterval

Value is the most recent value of the Variable that the Server has. Its data type is defined by the DataType Attribute. The AccessLevel Attribute defines the Server’s basic ability to access current data and MinimumSamplingInterval defines how current the data is.

When a client requests the Value Attribute for reading or monitoring, the Server will always return a StatusCode (the quality and the Server’s ability to access/provide the value) and, optionally, a ServerTimestamp and/or a SourceTimestamp – based on the Client’s request. See [Part 4] for details on StatusCode and the meaning of the two timestamps. Specific status codes for Data Access are defined in [Data Access status codes].

## DataTypes

### Overview

Following is a description of the DataTypes defined in this specification.

DataTypes like String, Boolean, Double or LocalizedText are defined in [Part 3]. Their representation is specified in [Part 5].

### Range

This structure defines the Range for a value. Its elements are defined in [Table 14].

Table 14 – Range DataType structure

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| Range | structure |  |
| low | Double | Lowest value in the range. |
| high | Double | Highest value in the range. |

If a limit is not known a NaN shall be used.

Its representation in the AddressSpace is defined in [Table 15]

Table 15 – Range definition

|  |  |
| --- | --- |
| Attributes | Value |
| BrowseName | Range |

### EUInformation

This structure contains information about the EngineeringUnits. Its elements are defined in [Table 16].

Table 16 – EUInformation DataType structure

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| EUInformation | structure |  |
| namespaceUri | String | Identifies the organization (company, standards organization) that defines the EUInformation. |
| unitId | Int32 | Identifier for programmatic evaluation.  −1 is used if a unitId is not available. |
| displayName | LocalizedText | The displayName of the engineering unit is typically the abbreviation of the engineering unit, for example ”h” for hour or ”m/s” for meter per second. |
| description | LocalizedText | Contains the full name of the engineering unit such as ”hour” or ”meter per second”. |

Its representation in the AddressSpace is defined in [Table 17]

Table 17 – EUInformation definition

|  |  |
| --- | --- |
| Attributes | Value |
| BrowseName | EUInformation |

To facilitate interoperability, OPC UA specifies how to apply the widely accepted “Codes for Units of Measurement” published by the “United Nations Centre for Trade Facilitation and Electronic Business” (see [UN/CEFACT: UNECE Recommendation N° 20]). It uses and is based on the International System of Units (SI Units) but in addition provides a fixed code that can be used for automated evaluation. This recommendation has been accepted by many industries on a global basis.

The UNECE recommendation can be found here:

http://www.unece.org/tradewelcome/un-centre-for-trade-facilitation-and-e-business-uncefact/outputs/cefactrecommendationsrec-index/list-of-trade-facilitation-recommendations-n-16-to-20.html

The latest UNECE version (Rev 12. Filename = rec20\_Rev12e\_2016.xls, published in 2016) is available here:

http://www.unece.org/fileadmin/DAM/cefact/recommendations/rec20/rec20\_Rev12e\_2016.xls

The mapping of the UNECE codes to OPC UA (EUInformation.unitId) is available here:

[http://www.opcfoundation.org/UA/EngineeringUnits/UNECE/UNECE\_to\_OPCUA.csv]

[Table 18] contains a small excerpt of the published Annex with Code Lists:

Table 18 – Examples from the UNECE Recommendation

|  |  |  |  |
| --- | --- | --- | --- |
| Excerpt from Recommendation N°. 20, Annex 1 | | | |
| Common Code | Name | Conversion Factor | Symbol |
| C81 | radian |  | rad |
| C25 | milliradian | 10–3 rad | mrad |
| MMT | millimetre | 10–3 m | mm |
| HMT | hectometre | 102 m | hm |
| KTM | kilometre | 103 m | km |
| KMQ | kilogram per cubic metre | kg/m3 | kg/m3 |
| FAH | degree Fahrenheit | 5/9 ( K | °F |
| J23 | degree Fahrenheit per hour | 1,543 210 ( 10–4 K/s | °F/h |

* The Common Code is represented as an alphanumeric variable length of 3 characters. It shall be used for the EUInformation.unitId. The following pseudo code specifies the algorithm to convert the Common Code into an Int32 as needed for EUInformation.unitId:

Int32 unitId = 0;   
 Int32 c;   
 for (i=0; i<=3;i++)   
 {

c = CommonCode[i];   
 if (c == 0) break; // end of Common Code   
 unitId = unitId << 8;   
 unitId = unitId | c;   
}

* The Symbol field shall be copied to the EUInformation.displayName. The localeId field of EUInformation.displayName shall be empty.
* The Name field shall be used for EUInformation.description. If the name is copied, then the localeId field of EUInformation.description shall be empty. If the name is localized then the localeId field shall specify the correct locale.

The EUInformation.namespaceUri shall be http://[www.opcfoundation.org/UA/units/un/cefact].

NOTE  It will be advantegous to use Recommendation N°. 20 as specified, because it can be programmatically interpreted by generic OPC UA Clients. However, the EUInformation structure has been defined such that other standards bodies can incorporate their engineering unit definitions into OPC UA. If Servers use such an approach then they shall identify this standards body by using a proper namespaceUri in EUInformation.namespaceUri.

### ComplexNumberType

This structure defines float IEEE 32 bits complex value. Its elements are defined in [Table 19].

Table 19 – ComplexNumberType DataType structure

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| ComplexNumberType | structure |  |
| real | Float | Value real part |
| imaginary | Float | Value imaginary part |

Table 20 – ComplexNumberType definition

|  |  |
| --- | --- |
| Attributes | Value |
| BrowseName | ComplexNumberType |

### DoubleComplexNumberType

This structure defines double IEEE 64 bits complex value. Its elements are defined in [Table 21].

Table 21 – DoubleComplexNumberType DataType structure

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| DoubleComplexNumberType | structure |  |
| real | Double | Value real part |
| imaginary | Double | Value imaginary part |

Table 22 – DoubleComplexNumberType definition

|  |  |
| --- | --- |
| Attributes | Value |
| BrowseName | DoubleComplexNumberType |

### AxisInformation

This structure defines the information for auxiliary axis for ArrayItemType Variables.

There are three typical uses of this structure:

The step between points is constant and can be predicted using the range information and the number of points. In this case, axisSteps can be set to NULL.

The step between points is not constant, but remains the same for a long period of time (from acquisition to acquisition for example). In this case, axisSteps contains the value of each step on the axis.

The step between points is not constant and changes at every update. In this case, a type like XYArrayType shall be used and axisSteps is set to NULL.

Its elements are defined in [Table 23].

Table 23 – AxisInformation DataType structure

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| AxisInformation | structure |  |
| engineeringUnits | EUInformation | Holds the information about the engineering units for a given axis. |
| eURange | Range | Limits of the range of the axis |
| title | Localizedtext | User readable axis title, useful when the units are %, the Title may be “Particle size distribution” |
| axisScaleType | AxisScaleEnumeration | LINEAR, LOG, LN, defined by AxisSteps |
| axisSteps | Double[] | Specific value of each axis steps, may be set to “Null” if not used |

When the steps in the axis are constant, axisSteps may be set to “Null” and in this case, the Range limits are used to compute the steps. The number of steps in the axis comes from the parent ArrayItem.ArrayDimensions.

### AxisScaleEnumeration

This enumeration identifies on which type of axis the data shall be displayed. Its values are defined in [Table 24].

Table 24 – AxisScaleEnumeration values

|  |  |
| --- | --- |
| Value | Description |
| LINEAR\_0 | Linear scale |
| LOG\_1 | Log base 10 scale |
| LN\_2 | Log base e scale |

Its representation in the AddressSpace is defined in [Table 25].

Table 25 – AxisScaleEnumeration definition

|  |  |
| --- | --- |
| Attributes | Value |
| BrowseName | AxisScaleEnumeration |

### XVType

This structure defines a physical value relative to a X axis and it is used as the DataType of the Value of XYArrayItemType. For details see [XYArrayItemType].

Many devices can produce values that can perfectly be represented with a float IEEE 32 bits but, they can position them on the X axis with an accuracy that requires double IEEE 64 bits. For example, the peak value in an absorbance spectrum where the amplitude of the peak can be represented by a float IEEE 32 bits, but its frequency position required 10 digits which implies the use of a double IEEE 64 bits.

Its elements are defined in [Table 26].

Table 26 – XVType DataType structure

|  |  |  |
| --- | --- | --- |
| Name | Type | Description |
| XVType | structure |  |
| x | Double | Position on the X axis of this value |
| value | Float | The value itself |

Table 27 – XVType definition

|  |  |
| --- | --- |
| Attributes | Value |
| BrowseName | XVType |

# Data Access specific usage of Services

## General

[Part 4] specifies the complete set of services. The services needed for the purpose of DataAccess are:

* The View service set and Query service set to detect DataItems, and their Properties.
* The Attribute service set to read or write Attributes and in particular the value Attribute.
* The MonitoredItem and Subscription service set to set up monitoring of DataItems and to receive data change notifications.

## PercentDeadband

The DataChangeFilter in [Part 4] defines the conditions under which a data change notification shall be reported. This filter contains a deadbandValue which can be of type AbsoluteDeadband or PercentDeadband. [Part 4] already specifies the behaviour of the AbsoluteDeadband. This sub-clause specifies the behaviour of the PercentDeadband type.

DeadbandType = PercentDeadband

For this type of deadband the deadbandValue is defined as the percentage of the EURange. That is, it applies only to AnalogItems with an EURange Property that defines the typical value range for the item. This range shall be multiplied with the deadbandValue and then compared to the actual value change to determine the need for a data change notification. The following pseudo code shows how the deadband is calculated:

DataChange if (absolute value of (last cached value - current value) >  
 (deadbandValue/100.0) \* ((high–low) of EURange)))

The range of the deadbandValue is from 0.0 to 100.0 Percent. Specifying a deadbandValue outside of this range will be rejected and reported with the StatusCode Bad\_DeadbandFilterInvalid (see [Table 28]).

If the Value of the MonitoredItem is an array, then the deadband calculation logic shall be applied to each element of the array. If an element that requires a DataChange is found, then no further deadband checking is necessary and the entire array shall be returned.

## Data Access status codes

### Overview

This subclause defines additional codes and rules that apply to the StatusCode when used for Data Access values.

The general structure of the StatusCode is specified in [Part 4] and includes a set of common operational result codes that also apply to Data Access.

### Operation level result codes

Certain conditions under which a Variable value was generated are only valid for automation data and in particular for device data; they are similar, but are slightly more generic than the description of data quality in the various fieldbus specifications.

In the following, [Table 28] contains codes with BAD severity which indicates a failure.

[Table 29] contains codes with UNCERTAIN severity which indicates that the value has been generated under sub-normal conditions.

[Table 30] contains GOOD (success) codes.

Note again, that these are the codes that are specific for Data Access and supplement the codes that apply to all types of data which are defined in [Part 4].

Table 28 – Operation level result codes for BAD data quality

|  |  |
| --- | --- |
| Symbolic Id | Description |
| Note - Bad is defined in [Part 4]. It shall be used when there is no special reason why the Value is bad. | |
| Bad\_ConfigurationError | There is a problem with the configuration that affects the usefulness of the value. |
| Bad\_NotConnected | The variable should receive its value from some data source, but has never been configured to do so. |
| Bad\_DeviceFailure | There has been a failure in the device/data source that generates the value that has affected the value. |
| Bad\_SensorFailure | There has been a failure in the sensor from which the value is derived by the device/data source. The limits bits are used to define if the limits of the value have been reached. |
| Note - Bad\_NoCommunication is defined in [Part 4]. It shall be used when communications to the data source is defined, but not established, and there is no last known value available. | |
| Bad\_OutOfService | The source of the data is not operational. |
| Bad\_LastKnown | OPC UA requires that the Server shall return a Null value when the Severity is Bad. Therefore, the Fieldbus code “Bad\_LastKnown” shall be mapped to Uncertain\_NoCommunicationLastUsable. |
| Bad\_DeadbandFilterInvalid | The specified PercentDeadband is not between 0.0 and 100.0 or a PercentDeadband is not supported, since an EURange is not configured. |
| Note - Bad\_WaitingForInitialData is defined in [Part 4]. | |

Table 29 – Operation level result codes for UNCERTAIN data quality

|  |  |
| --- | --- |
| Symbolic Id | Description |
| Note - Uncertain is defined in [Part 4]. It shall be used when there is no special reason why the Value is uncertain. | |
| Uncertain\_ NoCommunicationLastUsable | Communication to the data source has failed. The variable value is the last value that had a good quality and it is uncertain whether this value is still current.  The server timestamp in this case is the last time that the communication status was checked. The time at which the value was last verified to be true is no longer available. |
| Uncertain\_ LastUsableValue | Whatever was updating this value has stopped doing so. This happens when an input variable is configured to receive its value from another variable and this configuration is cleared after one or more values have been received.  This status/substatus is not used to indicate that a value is stale. Stale data can be detected by the client looking at the timestamps. |
| Uncertain\_SubstituteValue | The value is an operational value that was manually overwritten. |
| Uncertain\_InitialValue | The value is an initial value for a variable that normally receives its value from another variable. This status/substatus is set only during configuration while the variable is not operational (while it is out-of-service). |
| Uncertain\_ SensorNotAccurate | The value is at one of the sensor limits. The Limits bits define which limit has been reached. Also set if the device can determine that the sensor has reduced accuracy (e.g. degraded analyzer), in which case the Limits bits indicate that the value is not limited. |
| Uncertain\_ EngineeringUnitsExceeded | The value is outside of the range of values defined for this parameter. The Limits bits indicate which limit has been reached or exceeded. |
| Uncertain\_SubNormal | The value is derived from multiple sources and has less than the required number of Good sources. |

Table 30 – Operation level result codes for GOOD data quality

|  |  |
| --- | --- |
| Symbolic Id | Description |
| Note - Good is defined in [Part 4]. It shall be used when there are no special conditions. | |
| Good\_LocalOverride | The value has been Overridden. Typically this is means the input has been disconnected and a manually-entered value has been ”forced”. |

### LimitBits

The bottom 16 bits of the StatusCode are bit flags that contain additional information, but do not affect the meaning of the StatusCode. Of particular interest for DataItems is the LimitBits field. In some cases, such as sensor failure it can provide useful diagnostic information.

Servers that do not support Limit have to set this field to 0.

1. (informative): OPC COM DA to UA Mapping
   1. Introduction

This Annex provides details on mapping OPC COM Data Access (DA) information to OPC UA to help vendors migrate to OPC UA based systems while still being able to access information from existing OPC COM DA systems.

The OPC Foundation provides COM UA Wrapper and Proxy samples that act as a bridge between the OPC DA and the OPC UA systems.

The COM UA Wrapper is an OPC UA Server that wraps an OPC DA Server and with that enables an OPC UA Client to access information from the DA Server. The COM UA Proxy enables an OPC DA Client to access information from an OPC UA Server.

The mappings describe generic DA interoperability components. It is recommended that vendors use this mapping if they develop their own components, however, some applications may benefit from vendor specific mappings.

* 1. Security Considerations

COM DA relies on the Microsoft COM security infrastructure and does not specify any security parameters such as user identity. The developer of UA Wrapper and Proxy therefore has to consider the mapping of security aspects.

The COM UA Wrapper for instance may accept any Username/password and then try to impersonate this user by calling proper Windows services before connecting to the COM DA Server.

* 1. COM UA wrapper for OPC DA Server
     1. Information Model mapping
        1. General

OPC DA defines 3 elements in the address space: Branch, Item and Property. The COM UA Wrapper maps these types to the OPC UA types as described below.



Figure A.5 – Sample OPC UA Information Model for OPC DA

* + - 1. Branch

DA Branches are represented in the COM UA Wrapper as Objects of FolderType.

The top-level branch (the root) should be represented by an Object where the BrowseName is the Server ProgId.

The OPC DA Address space hierarchy is discovered using the ChangeBrowsePosition from the Root and BrowseOPCItemIds to get the Branches, Items and Properties.

The name returned from the BrowseOPCItemIds enumString is used as the BrowseName and the DisplayName for each Branch. See also clause [A.3.1.5].

The ItemId obtained using the GetItemID is used as a part of the NodeId for each Branch. See also clause [A.3.1.5].

An OPC UA Folder representing a DA Branch uses the Organizes References to reference child DA Branches and uses HasComponent References for DA Leafs (Items). It is acceptable for customized wrappers to use a sub-type of these ReferenceTypes.

* + - 1. Item

DA items (leafs) are represented in the COM UA Wrapper as Variables. The VariableType depends on the existance of special DA properties as follows:

* AnalogItemType: An item in the DA server that has High EU and Low EU properties or its EU Type property is Analog is represented as Variable of AnalogItemType in the COM UA Wrapper. The AnalogItemType has the following Properties:
* EURange: The values of the High EU and Low EU properties of the DA Item are assigned to the EURange Property
* EngineeringUnits: The value of the Engineering Unit property of the DA Item are assigned to the EngineeringUnits Property.
* InstrumentRange: The values of the High IR and Low IR properties of the DA Item are assigned to the InstrumentRange Property
* TwoStateDiscreteType: An item in DA server that has Open Label and Close Label properties is represented as Variable of TwoStateDiscreteType in the COM UA Wrapper. The TwoStateDiscreteType has the following Properties
* TrueState: The value of the Close Label property of the DA item is assigned to the TrueState Property.
* FalseState: The value of the Open Label property of the DA item is assigned to the FalseState Property.
* MultiStateDiscreteType: An item in the DA server that has its EU Type property as enumerated is represented as Variable of MultiStateDiscreteType in the COM UA Wrapper. The MultiStateDiscreteType has the following Property:
* EnumStrings: The enumerated values of the EUInfo Property of the DA item are assigned to the EnumStrings Property.
* DataItemType: An item in the DA Server that is not any of the above types is represented as Variable of DataItemType in the COM UA Wrapper.

Below are mappings that are common for all item types

* The name of the item in the DA Server is used as the BrowseName and the DisplayName for the Node in the COM UA Wrapper. See also clause [A.3.1.5].
* The ItemId in the DA server is used as a part of the NodeId for the Node. See also clause [A.3.1.5].
* TimeZone property in the DA server is represented by a TimeZone Property.
* The Description property value in the DA server is assigned to the Description Attribute.
* The DataType property value in the DA server is assigned to the DataType Attribute.
* If the item in the DA server is an array, the ValueRank Attribute is set as OneOrMoreDimensions. If not, it is set to Scalar.
* The AccessLevel Attribute is set with the AccessRights value in the DA server:
* OPC\_READABLE -> Readable
* OPC\_WRITABLE -> Writable

Note that the same values are also set for the UserAccessLevel in the COM UA Wrapper.

* The ScanRate property value in the DA server is assigned to the MinimumSamplingInterval Attribute.

Any Properties added to a Node in the COM UA Wrapper are referenced using the HasProperty ReferenceType.

* + - 1. Property

A property in the DA server is represented in the COM UA Wrapper as a Variable with TypeDefinition as PropertyType.

The properties for an item are retrieved using the QueryAvailableProperties call in the DA server.

Below are mappings of the property details to the OPC UA Property:

* The description of a property in the DA server is used as the BrowseName and the DisplayName of the Node in the COM UA Wrapper.
* The PropertyID and ItemID (if they exist for the property) in the DA server are used as a part of the NodeID for the node in the COM UA Wrapper.
* The DataType value in the DA server is used as value for the DataType Attribute of the Property in the COM UA Wrapper.
* If the property value in the DA server is an array, the ValueRank Attribute of the Property is set to OneOrMoreDimensions. Otherwise it is set to Scalar.
* If the property has an ItemID in the DA server, then the AccessLevel attribute for the Node is set to ReadableOrWriteable. If not, it is set to Readable.

[Table A.1] shows the mapping between the common OPC COM DA properties to the OPC UA Node attributes/properties.

Table A.31 – OPC COM DA to OPC UA Properties mapping

|  |  |  |
| --- | --- | --- |
| Property Name (PropertyID) of OPC COM DA | OPC UA Information Model | OPC UA DataType |
| Access Rights (5) | AccessLevel Attribute | Int32 |
| EU Units (100) | EngineeringUnits Property | String |
| Item Description (101) | Description Attribute | String |
| High EU (102) | EURange Property | Double |
| Low EU (103) | EURange Property | Double |
| High Instrument Range (104) | InstrumentRange Property | Double |
| Low Instrument Range (105) | InstrumentRange Property | Double |
| Close Label (106) | TrueState Property | String |
| Open Label (107) | FalseState Property | String |
| Other Properties (include Vendor specific Properties) | PropertyType | Based on the DataType of the Property |

* + - 1. BrowseName and DisplayName Mapping

As described above, both the OPC UA Browsename and Displayname for Nodes representing COM DA Branches and Leafs are derived from the name of the corresponding item in the COM DA Server.

This name can only be acquired by using the COM DA Browse Services. In OPC UA, however, the BrowseName and DisplayName are Attributes that Clients can ask for at any time. There are several options to support this in a Wrapper but all of them have pros and cons. Here are some popular implementation options:

Allow browsing the complete COM DA Address Space and then build and persist an offline copy of it. Resolve the BrowseName by scanning this offline copy.

* Pro: The ItemID can be used as is for the OPC UA NodeId.
* Con: The initial browse can take a while and may have to be repeated for COM DA Servers with a dynamic Address Space.

Create OPC UA NodeId values that include both the COM DA ItemID and the Item name. When the OPC UA Client passes such a NodeId to read the BrowseName or DisplayName Attribute, the wrapper can easily extract the name from the NodeId value.

* Pro: Efficient and reliable.
* Con: The NodeId will not represent the ItemId. It becomes difficult for human users to match the two IDs.

A number of COM DA Servers use ItemIDs that consist of a path where the path elements are separated with a delimiter and the last element is the item name. Wrappers may provide ways to configure the delimiter so that they can easily extract the item name.

* Pro: Efficient and reliable. The ItemID can be used as is for the OPC UA NodeId.
* Con: Not a generic solution. Only works for specific COM-DA Servers.

For wrappers that are custom to a specific Server, knowledge of the COM DA server address space can result in other optimizations or short cuts (i.e. the server will always have a certain schema / naming sequence etc.).

* + 1. Data and error mapping
       1. General

In DA server, Automation Data is represented by Value, Quality and Time Stamp for a Tag.

The COM UA Wrapper maps the VQT data to the Data Value and Diagnostic Info structures.

The Error codes returned by the DA server are based on the HRESULT type. The COM UA Wrapper maps this error code to an OPC UA Status Code. [Figure A.2] illustrates this mapping.



Figure A.6 – OPC COM DA to OPC UA data & error mapping

* + - 1. Value

The data values in the DA server are represented as Variant Data type. The COM UA Wrapper converts them to the corresponding OPC UA data type. The mapping is shown in [Table A.2]:

Table A.32 – DataTypes and mapping

|  |  |
| --- | --- |
| Variant Data  Type (In DA server) | OPC UA  Data type Mapping in COM UA Server (DataValue structure) |
| VT\_I2 | Int16 |
| VT\_I4 | Int32 |
| VT\_R4 | Float |
| VT\_R8 | Double |
| VT\_BSTR | String |
| VT\_BOOL | Boolean |
| VT\_UI1 | Byte |
| VT\_I1 | SByte |
| VT\_UI2 | UInt16 |
| VT\_UI4 | UInt32 |
| VT\_I8 | Int64 |
| VT\_UI8 | UInt64 |
| VT\_DATE | Double |
| VT\_DECIMAL | Decimal |
| VT\_ARRAY | Array of OPC UA types |

* + - 1. Quality

The Quality of a Data Value in the DA server is represented as a 16 bit value where the lower 8 bits is of the form QQSSSSLL (Q: Main Quality, S: Sub Status, L: Limit) and higher 8 bits is vendor specific.

The COM UA Wrapper maps the DA server to the OPC UA Status code as shown [Figure A.3]:



Figure A.7 - Status Code mapping

The primary quality is mapped to the Severity field of the Status code. The Sub Status is mapped to the SubCode and the Limit is mapped to the Limit Bits of the Status Code.

Please note that the Vendor quality is currently discarded.

[Table A.3] shows a mapping of the OPC COM DA primary quality mapping to OPC UA status code

Table A.33 – Quality mapping

|  |  |
| --- | --- |
| OPC DA Primary Quality (Quality & Sub status QQSSSS) | OPC UA Status Code |
| GOOD | Good |
| LOCAL\_OVERRIDE | Good\_LocalOverride |
| UNCERTAIN | Uncertain |
| SUB\_NORMAL | Uncertain\_SubNormal |
| SENSOR\_CAL | Uncertain\_SensorNotAccurate |
| EGU\_EXCEEDED | Uncertain\_EngineeringUnitsExceeded |
| LAST\_USABLE | Uncertain\_LastUsableValue |
| BAD | Bad |
| CONFIG\_ERROR | Bad\_ConfigurationError |
| NOT\_CONNECTED | Bad\_NotConnected |
| COMM\_FAILURE | Bad\_NoCommunication |
| DEVICE\_FAILURE | Bad\_DeviceFailure |
| SENSOR\_FAILURE | Bad\_SensorFailure |
| LAST\_KNOWN | Bad\_OutOfService |
| OUT\_OF\_SERVICE | Bad\_OutOfService |
| WAITING\_FOR\_INITIAL\_DATA | Bad\_WaitingForInitialData |

* + - 1. Timestamp

The Timestamp provided for a value in the DA server is assigned to the SourceTimeStamp of the DataValue in the COM UA Wrapper.

The ServerTimeStamp in the DataValue is set to the current time by the COM UA Wrapper at the start of the Read Operation.

* + 1. Read data

The COM UA Wrapper supports performing Read operations to DA servers of versions 2.05a and 3.

For version 2.05a, the COM UA wrapper creates a Group using the IOPCServer::AddGroup method and adds the items whose data is to be read to the Group using IOPCItemMgmt::AddItems method. The Data is retrieved for the items using the IOPCSyncIO::Read method. The VQT for each item is mapped to the DataValue structure as shown in [Figure A.2]. Please note that only Read from Device is supported for this version. The “maxAge” parameter is ignored.

For version 3, the COM UA Wrapper uses the IOPCItemIO::Read to retrieve the data. The VQT for each item is mapped to the DataValue structure as shown in [Figure A.2]. The Read supports both the Read from Device and Cache and uses the “maxAge” parameter.

If there are errors for the items in the Read from the DA server, then these are mapped to the StatusCode of the DataValue in the COM UA Wrapper.

The mapping of the OPC COM DA Read Errors code to OPC UA Status code (in the COM UA Wrapper) is shown in [Table A.4]:

Table A.34 – OPC DA Read error mapping

|  |  |
| --- | --- |
| OPC DA Error ID | OPC UA Status Code |
| OPC\_E\_BADRIGHTS | Bad\_NotReadable |
| E\_OUTOFMEMORY | Bad\_OutOfMemory |
| OPC\_E\_INVALIDHANDLE | Bad\_NodeIdUnknown |
| OPC\_E\_UNKNOWNITEMID | Bad\_NodeIdUnknown |
| E\_INVALIDITEMID | Bad\_NodeIdInvalid |
| E\_INVALID\_PID | Bad\_AttributeIdInvalid |
| E\_ACCESSDENIED | Bad\_OutOfService |
| Others | Bad\_UnexpectedError |

* + 1. Write Data

The COM UA Wrapper supports performing Write operations to DA servers of versions 2.05a and 3.

For version 2.05a, the COM UA wrapper creates a Group using the IOPCServer::AddGroup method and adds the items whose data is to be written using IOPCItemMgmt::AddItems method. The value is written for the items using the IOPCSyncIO::Write method. Note that if the StatusCode or TimeStamps (Source or Server) is specified to be written for the item then the COM UA Wrapper returns a BadWriteNotSupported Status code for the item.

For version 3, the COM UA Wrapper uses the IOPCItemIO::WriteVQT data including StatusCode and TimeStamp.If a SourceTimeStamp is provided, this timestamp is used for the Write else the ServerTimeStamp is used.

If there are errors for the items in the Write from the DA server, then these are mapped to the StatusCode for the corresponding item.

The mapping of the OPC COM DA Write Errors code to OPC UA Status code (in the COM UA Wrapper) is shown in [Table A.5]:

Table A.35 – OPC DA Write error code mapping

|  |  |
| --- | --- |
| OPC DA Error ID | OPC UA Status Code |
| E\_BADRIGHTS | Bad\_NotWritable |
| DISP\_E\_TYPEMISMATCH | Bad\_TypeMismatch |
| E\_BADTYPE | Bad\_TypeMismatch |
| E\_RANGE | Bad\_OutOfRange |
| DISP\_E\_OVERFLOW | Bad\_OutOfRange |
| E\_OUTOFMEMORY | Bad\_OutOfMemory |
| E\_INVALIDHANDLE | Bad\_NodeIdUnknown |
| E\_UNKNOWNITEMID | Bad\_NodeIdUnknown |
| E\_INVALIDITEMID | Bad\_NodeIdInvalid |
| E\_INVALID\_PID | Bad\_NodeIdInvalid |
| E\_NOTSUPPORTED | Bad\_WriteNotSupported |
| S\_CLAMP | Good\_Clamped |
| Others | Bad\_UnexpectedError |

* + 1. Subscriptions

A subscription is created in the DA server when a MonitoredItem is created in the COM UA Wrapper.

The SamplingInterval and the Deadband value are used for the subscription to setup a periodic data change call back on the COM UA Wrapper. Note that only the PercentDeadbandType is supported by the COM UA Wrapper.

The VQT for each item is mapped to the DataValue structure as shown in [Figure A.2] and published to the client by the COM UA Wrapper periodically.

The mapping of the OPC COM DA Read Errors code to OPC UA Status code (in the COM UA Wrapper) is the same as the Read mapping in [Figure A.2].

* 1. COM UA proxy for DA Client
     1. Guidelines

The Data Access COM UA Proxy is a COM Server combined with a UA Client. It maps the Data Access address space of UA Data Access Server into the appropriate COM Data Access objects.

Clauses [A.4.1]through [A.4.6] identify the design guidelines and constraints used to develop the Data Access COM UA Proxy provided by the OPC Foundation. In order to maintain a high degree of consistency and interoperability, it is strongly recommended that vendors, who choose to implement their own version of the Data Access COM UA Proxy, follow these same guidelines and constraints.

The Data Access COM Client simply needs to address how to connect to the UA Data Access Server. Connectivity approaches include the one where Data Access COM Clients connect to a UA Data Access Server with a CLSID just as if the target Server were a Data Access COM Server. However, the CLSID can be considered virtual since it is defined to connect to intermediary components that ultimately connect to the UA Data Access Server. Using this approach, the Data Access COM Client calls co-create instance with a virtual CLSID as described above. This connects to the Data Access COM UA Proxy components. The Data Access COM UA Proxy then establishes a secure channel and session with the UA Data Access Server. As a result, the Data Access COM Client gets a COM Data Access Server interface pointer.

* + 1. Information Model and Address Space mapping
       1. General

OPC UA defines 8 Node Class types in the address space Object, Variable, Method, ObjectType, VariableType, ReferenceType, DataType, View. The COM UA Proxy maps only the nodes of Node Class types Object, Variable to the OPC DA types as shown in the figure below. Only the nodes under the Objects node are considered for the COM UA Proxy address space and others such as Types, Views are not mapped.



Figure A.8 – Sample OPC DA mapping of OPC UA Information Model and Address Space

* + - 1. Object Nodes

A node of Object Node class in the OPC UA server is represented in the Data Access COM UA Proxy as a Branch.

The root of the Data Access COM UA Proxy is the Objects folder of the OPC UA Server.

The OPC UA Address space hierarchy is discovered using the Browse Service for the Objects Node using the following filters:

* BrowseDirection as Forward
* ReferenceTypeId as Organizes and HasChild.
* IncludeSubtypes as True
* NodeClassMask as Object and Variable

The DisplayName of the OPC UA node is used as the Name for each Branch in the Data Access COM UA Proxy

Each Branch in the Data Access COM UA Proxy is assigned 3 properties:

* UA Browse Name (Property ID: 613): The value of the BrowseName attribute of the node in the OPC UA Server is assigned to this property.
* UA Description (Property ID: 614): The value of the Description attribute of the node in the OPC UA Server is assigned to this property, if a Description attribute is provided.
* Item Description (Property ID: 101): The value of the DisplayName attribute of the node in the OPC UA Server is assigned to this property.

Note COM DA Clients typically display the ItemID and the Item Description. Since the ItemID generated by the UA Proxy may be particularly difficult to read and understand, the DisplayName as value for the Item Description Property is recommended as it will be easier to understand by a human user.

* + - 1. Variable Nodes

A node of Variable Node class in the OPC UA server is represented in the Data Access COM UA Proxy as an Item.

The DisplayName of the OPC UA node is used as the Name for each Item in the Data Access COM UA Proxy.

The NodeId of the OPC UA node is used as the ItemId for each Item in the Data Access COM UA Proxy. But the ‘=” character is replaced with ‘-’ in the string. E.g. NodeId: ns=4,i=10, ItemID = “ns-4;i-10” or NodeId: ns=4,s=FL102, ItemID = “ns-4,s-FL102”

Each Item in the Data Access COM UA Proxy is assigned the following properties based on the node attributes or its references:

Standard Properties:

* Item Canonical Data Type (Property ID: 1): The combined value of the DataType attribute and the ValueRank attribute of the node in the OPC UA Server is assigned to this property (see [A.4.3.2]).
* Item Value (Property ID: 2): The value of the Value attribute of the node in the OPC UA Server is assigned to this property. Details on Value mapping are in [A.4.3.2]
* Item Quality (Property ID: 3): The StatusCode of the Value obtained for the node in the OPC UA Server is assigned to this property. Details on Quality mapping are in [A.4.3.3]
* Item Timestamp (Property ID: 4): The SourceTimestamp or ServerTimestamp of the Value obtained for the node in the OPC UA Server is assigned to this property. Details on Timestamp mapping are in [A.4.3.4]
* Item Access Rights (Property ID: 5): The value of the AccessLevel attribute of the node in the OPC UA Server is assigned to this property based on the following mapping:
* CurrentRead -> OPC\_READABLE
* CurrentWrite -> OPC\_WRITABLE

The other AccessLevel provided by OPC are ignored

* Server Scan Rate (Property ID: 6): The value of the MinimumSamplingInterval attribute of the node in the OPC UA Server is assigned to this property.
* Item EU Type (Property ID: 7): The EU Type value is assigned based on the references of the node in the OPC UA Server:
* Analog(1) : if the node in the OPC UA Server references a EURange property node, then it is assigned the Analog EU Type.
* Enumerated(2): if the node in the OPC UA Server references a EnumStrings property node, then it is assigned the Enumerated EU Type.
* Empty(0): For a node in the OPC UA Server that does not meet above criteria, the type is set as 0 (Empty)
* EU Info (Property ID: 8): if the node in the OPC UA Server references an EnumStrings property node, then the enumerated values of the property node is assigned to this property.
* EU Units ((Property ID: 100): if the node in the OPC UA Server references a EngineeringUnits property node, then the value of the EngineeringUnits property node is assigned the EU Units property.
* Item Description (Property ID: 101): The value of the DisplayName attribute of the node in the OPC UA Server is assigned to this property.
* High EU ((Property ID: 102): if the node in the OPC UA Server references a EURange property node, then the ‘High’ value of the property node is assigned to this property.
* Low EU((Property ID: 103): if the node in the OPC UA Server references a EURange property node, then the ‘Low’ value of the property node is assigned to this property.
* High Instrument Range (Property ID: 104): if the node in the OPC UA Server references an InstrumentRange property node, then the ‘High’ value of the property node is assigned to this property.
* Low Instrument Range (Property ID: 105): if the node in the OPC UA Server references an InstrumentRange property node, then the ‘Low’ value of the property node is assigned to this property.
* Contact Close Label (Property ID: 106): if the node in the OPC UA Server references a FalseState property node, then the value of the property node is assigned to this property.
* Contact Open Label (Property ID: 107): if the node in the OPC UA Server references a TrueState property node, then the value of the property node is assigned to this property.
* Item Time Zone (Property ID: 108): if the node in the OPC UA Server references a TimeZone property node, then the ‘Offset’ value of the property node is assigned to this property.

New Properties:

* UA BuiltIn Type (Property ID: 610): The identifier value of the DataType node associated with the DataType attribute of the node in the OPC UA Server is assigned to this property.
* UA Data Type Id (Property ID: 611): The complete NodeId value (namespace and identifier) of the DataType node associated with the DataType attribute of the node in the OPC UA Server is assigned to this property.
* UA Value Rank (Property ID: 612): The value of the ValueRank attribute of the node in the OPC UA Server is assigned to this property.
* UA Browse Name (Property ID: 613): The value of the BrowseName attribute of the node in the OPC UA Server is assigned to this property.
* UA Description (Property ID: 614): The value of the Description attribute of the node in the OPC UA Server is assigned to this property.
  + - 1. Namespace Indices

For generating ItemIDs, the Proxy uses Namespace Indices. To assure that Clients can persist these ItemIDs, the Namespace Indices must never change. To accomplish this the Proxy has to persist its Namespace Table and only append entries but never change existing ones.

The Proxy also has to provide a translation from the current Namespace Table in the Server to the persisted Namespace Table.

If you move or copy the Proxy to another machine, the Namespace Table has to be copied to this machine as well.

* + 1. Data and error mapping
       1. General

In an OPC UA Server, Automation Data is represented as a Data Value and and status, in addition additional error data can be provided via Diagnostic Info for a tag

The COM UA Proxy maps the Data Value structure into VQT data and error code.

For successful operations(StatusCode of Good and Uncertain), the COM UA Proxy maps the Status Code of the DataValue to the OPC DA Quality But in case of error(StatusCode of Bad), the Status Code is mapped to the OPC DA Error code.

The StatusCode in the Diagnostic Info returned by the OPC UA Server are mapped to OPC DA Error codes. [Figure A.5] illustrates this mapping.



Figure A.9 – OPC UA to OPC DA data & error mapping

* + - 1. Value

The COM UA Proxy converts the OPC UA Data Value to the corresponding OPC DA Variant type. The mapping is shown in [Table A.6]. For DataTypes that are subtypes of an existing base DataType the conversion for the Base DataType is used.

Table A.36 – DataTypes and Mapping

|  |  |
| --- | --- |
| OPC UA  Data type (Bin UA Server) | Variant Data  Type (In DA server) |
| Int16 | VT\_I2 |
| Int32 | VT\_I4 |
| Float | VT\_R4 |
| Double | VT\_R8 |
| Decimal | VT\_DECIMAL |
| String | VT\_BSTR |
| Boolean | VT\_BOOL |
| Byte | VT\_UI1 |
| SByte | VT\_I1 |
| UInt16 | VT\_UI2 |
| UInt32 | VT\_UI4 |
| Int64 | VT\_I8 |
| UInt64 | VT\_UI8 |
| Guid | VT\_BSTR |
| DateTime | VT\_DATE |
| NodeId | VT\_BSTR |
| XmlElement | VT\_BSTR |
| ExpandedNodeId | VT\_BSTR |
| QualifiedName | VT\_BSTR |
| LocalizedText | VT\_BSTR |
| StatusCode | VT\_UI4 |
| ExtensionObject | Array of VT\_UI1 |
| Array of above OPC UA types | Array of corresponding Variant type |

* + - 1. Quality

The Quality of a Data Value in the OPC UA Server is represented as a StatusCode.

The COM UA Proxy maps the Severity, Subcode and the limit bits of the OPC UA Status code to the lower 8 bits of the OPC DA Quality structure (of the form QQSSSSLL).



Figure A.10 – OPC UA Status Code to OPC DA quality mapping

The Severity field of the Status code is mapped to the primary quality. The SubCode is mapped to the Sub Status and the Limit Bits are mapped to the Limit field.

[Table A.7] shows a mapping of the OPC UA status code to OPC DA primary quality

Table A.37 – Quality mapping

|  |  |
| --- | --- |
| OPC UA Status Code | OPC DA Primary Quality (Quality & Sub status QQSSSS) |
| Good | GOOD |
| Good\_LocalOverride | LOCAL\_OVERRIDE |
| Uncertain | UNCERTAIN |
| Uncertain\_SubNormal | SUB\_NORMAL |
| Uncertain\_SensorNotAccurate | SENSOR\_CAL |
| Uncertain\_EngineeringUnitsExceeded | EGU\_EXCEEDED |
| Uncertain\_LastUsableValue | LAST\_USABLE |
| Bad | BAD |
| Bad\_ConfigurationError | CONFIG\_ERROR |
| Bad\_NotConnected | NOT\_CONNECTED |
| Bad\_NoCommunication | COMM\_FAILURE |
| Bad\_OutOfService | OUT\_OF\_SERVICE |
| Bad\_DeviceFailure | DEVICE\_FAILURE |
| Bad\_SensorFailure | SENSOR\_FAILURE |
| Bad\_WaitingForInitialData | WAITING\_FOR\_INITIAL\_DATA |

* + - 1. Timestamp

If available, the SourceTimestamp of the DataValue in the OPC UA Server is assigned to the Timestamp for the value in the COM UA Proxy. If SourceTimestamp is not available, then the ServerTimestamp is used.

* + 1. Read data

The COM UA Proxy converts all the ItemIds in the Read into valid NodeIds by replacing the ‘-’ with ‘=’ and calls the OPC UA Read Service for the Value Attribute.

If the Read Service call is successful then DataValue for each node is mapped to the VQT for each item as shown in [Figure A.5].

If the Read Service call fails or If there are errors for some of the Nodes, then the StatusCodes of these Nodes are mapped to the error code by the COM UA Proxy.

The mapping of the OPC UA Status code to OPC DA Read Error code (in the COM UA Proxy) is shown in [Table A.8]:

Table A.38 – OPC UA Read error mapping

|  |  |
| --- | --- |
| OPC UA Status Code | OPC DA Error ID |
| Bad\_OutOfMemory | E\_OUTOFMEMORY |
| Bad\_NodeIdInvalid | E\_INVALIDITEMID |
| Bad\_NodeIdUnknown | E\_UNKNOWNITEMID |
| Bad\_NotReadable | E\_BADRIGHTS |
| Bad\_UserAccessDenied | E\_ACCESSDENIED |
| Bad\_AttributeIdInvalid | E\_INVALIDITEMID |
| Bad\_UnexpectedError | E\_FAIL |
| Bad\_InternalError | E\_FAIL |
| Bad\_SessionClosed | E\_FAIL |
| Bad\_TypeMismatch | E\_BADTYPE |

* + 1. Write data

The COM UA Proxy converts all the ItemIds in the Write into valid NodeIds by replacing the ‘-’ with ‘=’. It converts the Value, Quality and Timestamp (VQT) to a DataValue structure as per the mapping in [Figure A.5]. and calls the OPC UA Write Service for the Value Attribute.

If the Write Service call fails or if there are errors for some of the Nodes, then the StatusCodes of these Nodes are mapped to the error code by the COM UA Proxy.

The mapping of the OPC UA Status code to OPC DA Write Error code (in the COM UA Proxy) is shown in [Table A.9]:

Table A.39 – OPC UA Write error code mapping

|  |  |
| --- | --- |
| OPC UA Status Code | OPC DA Error ID |
| Bad\_TypeMismatch | E\_BADTYPE |
| Bad\_OutOfMemory | E\_OUTOFMEMORY |
| Bad\_NodeIdInvalid | E\_INVALIDITEMID |
| Bad\_NodeIdUnknown | E\_UNKNOWNITEMID |
| Bad\_NotWritable | E\_BADRIGHTS |
| Bad\_UserAccessDenied | E\_ACCESSDENIED |
| Bad\_AttributeIdInvalid | E\_UNKNOWNITEMID |
| Bad\_WriteNotSupported | E\_NOTSUPPORTED |
| Bad\_OutOfRange | E\_RANGE |

* + 1. Subscriptions

The COM UA Proxy creates a Subscription in the OPC UA Server when a Group is created. The Name, Active flag, UpdateRate parameters of the Group are used while creating the subscription.

The COM UA Proxy Creates Monitored Items in the OPC UA Server when items are added to the Group.

Following parameters and filters are used for creating the monitored items:

* The ItemIds are converted to valid NodeIds by replacing the ‘-’ with ‘=’.
* Data Change Filter is used for Items with EU type as Analog:
* Trigger = STATUS\_VALUE\_1
* If DeadBand value is specified for the Group, the;
* DeadbandType = Percent\_2
* DeadbandValue = deadband specified for the group.

The COM UA Proxy calls the Publish Service of the OPC UA Server periodically and sends any data changes to the client.

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