Client Development Introduction

Connection to the Server

Connect

This is happening on calling 'Connect':

1. Checking if an **address was set** (ServerAddress property).
2. The Client changes its status (**OpcClient.State** property) to the value ***Connecting***.
3. The Client **checks its configuration** for validity and conclusiveness.
4. Next the Client tries to **find an endpoint**.
   This happens via DiscoveryClient where endpoints with the desired endpoint configuration are compared and the endpoint fulfilling or at least sufficing the configuration is chosen. An endpoint is chosen depending on the used settings of the Client.
5. Next the Client creates the **configuration for a new session**.
6. **Instance certificates** are **checked**:
   1. Client certificate (depending on security configuration)
   2. Server certificate (the certificate provided by the endpoint)
7. A **channel** acting as a connection between Client and Server is **created**.
8. Attempt to **create a session** via the channel.
9. After further exchange and checking of session data the **session** gets **activated**.
10. Finally, **available Namespaces** are **retrieved**
11. And precautions for **connection surveillance** are taken:
    1. “KeepAlive-Tracking” for detecting connection abortions
    2. “Notification-Tracking” for receiving notifications
12. The Client changes its status (**OpcClient.State** property) to the value ***Connected***.

Disconnect

This is happening on calling 'Disconnect':

1. The Client changes its status (**OpcClient.State** property) to the value ***Disconnecting***.
2. The Client **releases** all **gathered resources** (e.g. File Handles for OPC UA File Nodes)
3. **Ends** the **connection surveillance**
4. The **active session is ended**.
5. The **channel** created during Connect **is closed and disposed of**.
6. The Client changes its status (**OpcClient.State** property) to the value ***Disconnected***.

BreakDetection

The “BreakDetection” is a mechanism responsible for the detection of connection abortions using “KeepAlive”-Tracking to **detect a timeout of the connection to the Server**. If there is a timeout, the Client **automatically tries to establish a connection to the Server**. In case of a newly created connection a **new session** often happens. While KeepAlive messages are sent between Client and Server in KeepAlive in order to “test” the connection and “hold it up”, it is assumed that the connection was interrupted when response times to a KeepAlive message are too long (= reached timeout?). In that case another KeepAlive message is sent in increasing time intervals. An aborted connection is assumed if these messages also are unanswered and the previously described mechanism to re-establish the connection is introduced. The abortion detection is active by default and can be activated via the **OpcClient.UseBreakDetection** property.

Connection Parameters

In order for the Client to connect to the Server the correct parameters have to be set. **Generally** the **address of the Server** (**OpcClient.ServerAddress** property) **is needed**. The Uri (= Uniform Resource Identifier) instance feeds the Client with every primarily necessary information about the Server. The Server-Address “opc.tcp://192.168.0.80:4840” e.g. contains the information of the scheme “opc.tcp” (possible are “http”, “https”, “opc.tcp”, “net.tcp” and “net.pipe”) which establishes over which protocol data is exchanged in which way. In general “opc.tcp” is recommended for OPC UA Servers in a local network. Servers outside a local network should use “http” or even better “https”. Furthermore the address defines that the Server is executed on a computer with the IP address “192.168.0.80” and listens to requests via the port numbered “4840” (which is the default port for the OPC UA, custom port numbers are also possible). Instead of a static IP address the DNS name of the computer can be used as well, so instead of “127.0.0.1” also “localhost” can be used.

If the Server does **not define an endpoint** whose policy uses the security mode **“None”** (also possible are “Sign” and “SignAndEncrypt”) for data exchange, **this Endpoint-Policy has to be configured** manually (**OpcClient.Security.EndpointPolicy** property). If, however, an **endpoint with the policy “None”** is provided by the Server, **the Client automatically chooses it**. This **behavior** is activated by default and **can be deactivated** (**OpcClient.Security.UseOnlySecureEndpoints** property). The automatic choice of the endpoint **can be done according to the OPC Foundation** by configuring the Client in a way that **the endpoint defining the highest Policy-Levels per definition** (a number) automatically is the “best” for data exchange. This behavior is deactivated by default but **can be activated** (**OpcClient.Security.UseHighLevelEndpoint** property).

If the Server uses an access control, for example via an ACL (= Access Control List), valid **user data for identifying the user has to be given** to the Server before a connection can be established. The user identity can either be varified through a username-password pair (**OpcClientIdentity** class) or through a certificate (**OpcCertificateIdentity** class). Then the identity has to be **mentioned to the Client** (**OpcClient.Security.UserIdentity** property) in order for it to deliver the identity to the Server while connecting.

Endpoints

Endpoints result from the cross product of the used base addresses of the Server and the security strategies supported by the Server. The results are the base addresses of every scheme-port pair supported, while several schemes (possible are “http”, “https”, “opc.tcp”, “net.tcp” and “net.pipe”) can be

determined for data exchange on different ports. The hereby linked policies determine the procedure during the data exchange. Consisting of the Policy Level, the Security-Mode and the Security-Algorithm, every policy determines the kind of secure data exchange.

For example, when two Security-Policies are followed, they can be defined as follows:

- Security-Policy A: Level=0, Security-Mode=None, Security-Algorithm=None
- Security-Policy B: Level=1, Security-Mode=Sign, Security-Algorithm=Basic256

When furthermore, for example, three Base-Addresses are combined for different schemes as follows:

- Base-Address A: "https://mydomain.com/"
- Base-Address B: "opc.tcp://192.168.0.123:4840/"
- Base-Address C: "opc.tcp://192.168.0.123:12345/"

The results will be the following endpoint descriptions through the cross product:

- Endpoint 1: Address="https://mydomain.com/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 2: Address="https://mydomain.com/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256
- Endpoint 3: Address="opc.tcp://192.168.0.123:4840/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 4: Address="opc.tcp://192.168.0.123:4840/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256
- Endpoint 5: Address="opc.tcp://192.168.0.123:12345/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 6: Address="opc.tcp://192.168.0.123:12345/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256

Here the address part of the endpoint is always needed by the Client (via constructor or via **ServerAddress** property). While the Client tries to find an endpoint with the Security-Mode “None” by default, the policy of the endpoint has to be configured manually (**OpcServer.Security.EndpointPolicies** property) when none exists.

Information about Certificates

Certificates in OPC UA

Certificates are used to **ensure** the **authenticity** and **integrity** of Client and Server applications. Therefore they act as a kind of identity card for Client as well as Server application. This “identification card” has to be stored somewhere as it exists as a form of file. The decision on where certificates are stored is individual. On Windows, every certificate can be passed to the **system** and Windows takes care of the **Store**. As an alternative **custom Stores** (= directories) can be set.

There are different types of Stores for certificates:

- **Store for application certificates**
  The Store also called **Application Certificate Store** exclusively contains certificates of those applications that use this Store as an Application Certificate Store. Here a Client / Server application saves its own certificate.

- **Store for certificates from trustworthy certificate issuers**
  The Store also called **Trusted Issuer Certificate Store** exclusively contains certificates from certificate issuers that issue further certificates. Here a Client / Server application saves all certificates from issuers whose certificates shall be treated as trusted by default.
- **Store for trustworthy certificates**
  The Store also called **Trusted Peer Store** exclusively contains certificates treated as trusted. Here a Client saves the **certificates from trusted Servers** and a Server saves the **certificates from trusted Clients**.
- **Store for rejected certificates**
  The Store also called **Rejected Certificate Store** exclusively contains certificates that are decreed as not trusted. Here a Client saves the **certificates from untrusted Servers** and a Server saves the **certificates from untrusted Clients**.

Regardless of the Store being located somewhere in the system or in the file system via a directory, generally certificates in the **Trusted Store** are **trusted** and certificates in the **Rejected Store** are **untrusted**. Certificates not belonging to either of the former are automatically saved in the Trusted Store, if the certificate of the certificate issuer mentioned in the certificate is deposited in the Trusted Issuer Store; otherwise it is automatically saved in the Rejected Store. Even if a trustworthy certificate has expired or if its deposited information cannot be successfully verified through the certification center the certificate is graded as not trustworthy and saved in the Rejected Store. During this process it also is removed from the Trusted Peer Store. A certificate can also expire when it is listed in a CRL (=Certificate Revocation List), which can be kept separately in the concerning store.

A certificate that the Client receives from the Server or the other way around is **for the moment always** classified as *unknown* and therefore also treated as **untrusted**. In order for a certificate to be treated as trusted it must be declared as such. This happens by saving the certificate of the Client in the Trusted Store of the Server and the certificate of the Server in the Trusted Store of the Client.

Dealing with a Server certificate at the Client:

1. The Client establishes the certificate of the Server on whose endpoint it shall connect with.
2. The Client verifies the certificate of the Server.
    1. Is the certificate valid?
        1. Has the effective date expired?
        2. Is the issuer's certificate valid?
    2. Does the certificate exist in the Trusted Peer Store?
        1. Is it listed in a CRL?
    3. Does the certificate exist in the Rejected Store?
3. When the certificate is trusted, the Client establishes a connection to the server.

Dealing with a Client certificate at the Server:

1. The Server receives the Client's certificate from the Client while connecting.
2. The Server verifies the certificate of the Client.
    1. Is the certificate valid?
        1. Has the effective date expired?
        2. Is the issuer's certificate valid?
    2. Does the certificate exist in the Trusted Peer Store?
        1. Is it listed in a CRL?
    3. Does the certificate exist in the Rejected Store?
3. When the certificate is trusted, the Server allows the connection of the Client and operates it.

In case the verification of the certificate from the respective counterpart fails, the verification can be

extended by custom mechanisms and still decided on user scale, if the certificate gets accepted or not.

Types of Certificates

General: Self-Signed Certificates vs. Signed Certificates

A certificate is comparable to a document. A document can be issued by everybody and can also be signed by everybody. However, the main difference here is, if the signee of a document really vouches for its correctness (like a notary) or if the signee is the owner of the document itself. Especially documents of the latter are not really inspiring confidence because no (legally) recognized instance as e.g. a notary vouches for the owner of the document.

As certificates are comparable to documents and also have to show a (digital) signature, the situation here is the same. The signature of a certificate has to tell the recipient of the certificate copy, who vouches for this certificate. Herefore it always applies that the issuer of a certificate also signs it. When the **issuer of a certificate equals the subject** of the certificate, you call this a **self-signed certificate** (subject equals issuer). When the **issuer of a certificate does not equal the subject** of the certificate, you call this a **(simple / normal / signed) certificate** (subject does not equal issuer).

As certificates are used especially in the context of the OPC UA authentication of an identity (of a certain Client or Server application), signed certificates should be used as application certificates for the own application. If, however, the issuer of the certificate also its owner, this self-signed certificate should only be trusted when the owner is rated as trusted. Such certificates were, as described, signed by the issuer of the certificate. Therefore, the issuer certificate has to be located in the **Trusted Issuer Store** of the application. When the issuer certificate cannot be found there , the certificate chain is declared incomplete and the certificate is not accepted by the counterpart. Yet, if the issuer certificate of the issuer of the application certificate is not a self-signed certificate, the certificate of its issuer has to be available in the **Trusted Issuer Store**.

User Identification

User Identification through Certificates

Next to the use of a certificate as an *identification card* for Client / Server applications, a certificate can also be used to identify a user. A Client application is always operated by a certain user by whom it operates with the Server. Depending on the Server configuration a Server can request additional information about the identity of the Client's user from the Client. The user has the possibility to prove his identity through a certificate. How thoroughly a Server is examining the certificate on validity, authenticity and confidentiality depends on the Server. The Server provided by the Framework exclusively checks, if the Thumbprint information of the user identity can be found in its ACL (=Access Control List) for certificate-based user identities.

Aspects of Security

Productive use

The primary goal of the Framework is to make getting the grips of the OPC UA as easy as possible. This basic thought sadly also leads to the fact that without secondary configuration of the Server a completely save connection / communication between Client and Server does not occur. Yet, if the final Spike has

been implemented and tested, second thought should be given to the *aspects of security*.

Even if one is dependant on the security mechanisms provided by the Server while developing a Client, one should always make the best choice possible. In general, the choice should always be the endpoint (**OpcClient.ServerAddress** property and **OpcClient.Security.EndpointPolicy** property) that provides the most secure connection (e.g. “https” instead of “http” as a scheme). This includes endpoints that follow the best Security-Policy possible. Keep an eye on the Security-Mode and the Security-Algorithm. According to the OPC Foundation, if you want to have the savest endpoint, refer to the endpoint with the highest Security-Level (**OpcClient.Security.UseHighLevelEndpoint** property).

For simplified handling of certificates the Client accepts every certificate by default (**OpcClient.Security.AutoAcceptUntrustedCertificates** property), also those it should deny under productive conditions because only certificates known to the Client (located in the Trusted Peer Store) apply as truly trusted. Apart from that the validity of a certificate should always be verified, including the “expiration date” of the certificate, for example. Furthermore it is advisable to check the domains referenced in the certificate (**OpcClient.Security.VerifyServersCertificateDomains** property). Other properties of the certificate or looser rules for the validity and trustworthiness of a Server certificate can be furthermore carried out manually (**OpcClient.CertificateValidationFailed** event).

If the Server uses a security process which controls the access via user identities, a concrete user identity should always be chosen (**OpcClient.Security.UserIdentity** property). Apart from the fact that anonymous identities almost always have only limited access, the Client can be granted access to more sensitive data when a concrete identity (e.g. a certificate or a username-password pair) is used. At the same time security is higher at e.g. a signed data transmission using a Certificate Identity.

OPC UA SDK
Client + Server Development

Client Development Guide

The Client Frame

A Client for OPC UA

1. Add reference to the **Opc.UaFx.Advanced** Client Namespace:
```
using Opc.UaFx.Client;
```
2. Create an instance of the OpcClient class with the address of the Server:
```
var client = new OpcClient("opc.tcp://localhost:4840/");
```
3. Build a connection to the Server and start a session:
```
client.Connect();
```
4. Your code to interact with the Server:
```
// Your code to interact with the server.
```
5. Close all sessions before closing the application:
```
client.Disconnect();
```
6. Using the using block this looks as follows:
```
using (var client = new OpcClient("opc.tcp://localhost:4840/")) {
    client.Connect();
    // Your code to interact with the server.
}
```
7. Are the Nodes/NodeIds of the Server ...
    - **unkown:** Find out which Nodes the Server have
    - **known:** Read Values of your Nodes or Write Values of your Nodes

A Client for OPC Classic

1. Add reference to the **Opc.UaFx.Advanced** Classic and Client Namespaces:
```
using Opc.UaFx.Client;
using Opc.UaFx.Client.Classic;
```
2. Create an instance of the OpcClient class with the address of the Server:
```
var client = new OpcClient("opc.com://localhost:48410/<progId>/<classId>");
```

3. Build a connection to the Server and start a session:

```
client.Connect();
```

4. Your code to interact with the Server:

```
// Your code to interact with the server.
```

5. Close all sessions before closing the application:

```
client.Disconnect();
```

6. Using the using block this looks as follows:

```
using (var client = new OpcClient("opc.com://localhost:48410/<progId>/<classId>")) {
    client.Connect();
    // Your code to interact with the server.
}
```

7. Are the Nodes/NodeIds of the Server ...
    - **unkown:** Find out which Nodes the Server have
    - **known:** Read Values of your Nodes or Write Values of your Nodes

What describes the address of the server opc.com://localhost:48410/<progId>/<classId> **?**

- **opc.com** indicates that a connection to an *OPC Classic Server* is to be used.
- **localhost** stands for the name or the IP address of the computer on which the *OPC Classic Server* is running.
- **48410** the optional port number of the *OPC UA Wrapper Server* [1]. If this is missing, a port number will be generated based on the <classId>.
- **<progId>** is a wildcard, replace it with the ProgID of the **DCOM Application Information** of the *OPC Classic Server*,
  e.g. 'OPCManager.DA.XML-DA.Server.DA'.
- **<classId>** is a wildcard, replace it with the ClassId (also known as CLSID or AppID) of the **DCOM Application Information** of the *OPC Classic Server*,
  e.g. ' {E4EBF7FA-CCAC-4125-A611-EAC4981C00EA} '.

How can I determine the <classId> or <progId> of the server?

1. **Method: OpcClassicDiscoveryClient**

   OpcClassicDiscoveryClient.cs

```
using (var discoveryClient = new OpcClassicDiscoveryClient("<host>")) {
    var servers = discoveryClient.DiscoverServers();

    foreach (var server in servers) {
        Console.WriteLine(
                "- {0}, ClassId={1}, ProgId={2}",
                server.Name,
                server.ClassId,
                server.ProgId);
    }
}
```

2. **Method: Systeminformation**
   Perform the following steps on the *OPC Classic Server* computer:

1. *AppID* using the Component Services
    - Control Panel
    - Administrative Tools
    - Component Services
    - expand 'Component Services'
    - expand 'Computers'
    - expand 'My Computer'
    - expand 'DCOM Config'
    - select '<OPC Classic Server>'
    - open 'Properties'
    - first tab 'General'
    - copy the 'Application ID:' (= *AppID*)
2. *ProgId* using the System Registry
    - 'Windows-Key' + 'R'
    - enter 'regedit'
    - click 'Run'
    - expand the key 'Computer'
    - then the key 'HKEY_LOCAL_MACHINE'
    - expand 'SOFTWARE'
    - expand 'SYSWOW6432Node' (only on 64 Bit Systems else continue)
    - expand 'Classes'
    - expand 'CLSID'
    - expand '<classId>'
    - select 'ProgID'
    - copy the '(Default)' value (= *ProgID*) in the 'Data' column

Values of Node(s)

Reading Values

The following types are used: OpcClient, OpcNodeId, OpcValue, OpcAttribute and OpcReadNode.

The **OpcNodeId** of a Node decides on which Node is to be read. When a Node value is read the current value of the *value attribute* is read by default. The hereby determined **OpcValue** consists, additionally to the actual value, of a time stamp at which the value was identified at the source of the value (**SourceTimestamp**) and of a second time stamp at which the value was registered by the Server (**ServerTimestamp**). If another attribute of the Node shall be read the according **OpcAttribute** has to be **mentioned** at the call of **ReadNode** and the concerning **OpcReadNode** instance.

- Read the value of the value attribute of a single Node:

```
OpcValue isRunning = client.ReadNode("ns=2;s=Machine/IsRunning");
```

- Read the values of the value attibute of several Nodes:

```
OpcReadNode[] commands = new OpcReadNode[] {
    new OpcReadNode("ns=2;s=Machine/Job/Number"),
    new OpcReadNode("ns=2;s=Machine/Job/Name"),
    new OpcReadNode("ns=2;s=Machine/Job/Speed")
};

IEnumerable<OpcValue> job = client.ReadNodes(commands);
```

- Read the value of the DisplayName attribute of a single Node:

```
OpcValue isRunningDisplayName = client.ReadNode("ns=2;s=Machine/IsRunning",
OpcAttribute.DisplayName);
```

- Read the values of the DisplayName attribute of several Nodes:

```
OpcReadNode[] commands = new OpcReadNode[] {
    new OpcReadNode("ns=2;s=Machine/Job/Number", OpcAttribute.DisplayName),
    new OpcReadNode("ns=2;s=Machine/Job/Name", OpcAttribute.DisplayName),
    new OpcReadNode("ns=2;s=Machine/Job/Speed", OpcAttribute.DisplayName)
};

IEnumerable<OpcValue> jobDisplayNames = client.ReadNodes(commands);
```

Writing Values

The following types are used: OpcClient, OpcNodeId, OpcValue, OpcAttribute, OpcStatus, OpcStatusCollection and OpcWriteNode.

The **OpcNodeId** of a Node decides which Node to write. When a Node value is written, the current value of the *value attribute* is written by default. The hereby set **OpcValue** automatically receives the latest time stamp as the time stamp of the source (**SourceTimestamp**). If another attribute of the Node shall be written the according **OpcAttribute** has to be mentioned at the call of the **WriteNode** or at the concerning **OpcWriteNode** instance.

- Write the value of a single Node:

```
OpcStatus result = client.WriteNode("ns=2;s=Machine/Job/Cancel", true);
```

- Write the values of several Nodes:

```
OpcWriteNode[] commands = new OpcWriteNode[] {
    new OpcWriteNode("ns=2;s=Machine/Job/Number", "0002"),
    new OpcWriteNode("ns=2;s=Machine/Job/Name", "MAN_F01_78910"),
    new OpcWriteNode("ns=2;s=Machine/Job/Speed", 1220.5)
};

OpcStatusCollection results = client.WriteNodes(commands);
```

- Write the value of the DisplayName attribute of a single Node:

```
client.WriteNode("ns=2;s=Machine/IsRunning", OpcAttribute.DisplayName, "IsActive");
```

- Write the values of the DisplayName attribute of several Nodes:

```
OpcWriteNode[] commands = new OpcWriteNode[] {
    new OpcWriteNode("ns=2;s=Machine/Job/Number", OpcAttribute.DisplayName, "Serial"),
    new OpcWriteNode("ns=2;s=Machine/Job/Name", OpcAttribute.DisplayName,
"Description"),
    new OpcWriteNode("ns=2;s=Machine/Job/Speed", OpcAttribute.DisplayName, "Rotations
per Second")
};

OpcStatusCollection results = client.WriteNodes(commands);
```

Processing Values

The following types are used here: OpcClient, OpcNodeId, OpcValue, OpcStatus and OpcStatusCollection.

The **ReadNode** methods always provide an **OpcValue** instance, while the **ReadNodes** methods provide a list of **OpcValue** instances (one **OpcValue** per read Node). The actual value read is in the *Value* property of the **OpcValue** instances. The result of the read request can be checked via the *Status* property. The timestamp at which the read value has been detected at the sourcecan be retrieved via the *SourceTimestamp* property. Correspondingly, the timestamp at which the read value was detected by the Server can be retrieved via the *ServerTimestamp* property.

- Read the value of a single Node:

```
OpcValue value = client.ReadNode("ns=2;s=Machine/Job/Speed");
```

- Chech the result of the read request:

```
if (value.Status.IsGood) {
    // Your code to operate on the value.
}
```

- Retrieve the scalar value of the **OpcValue** instance:

```
int intValue = (int)value.Value;
```

- Retrieve the array value of the **OpcValue** instance:

```
int[] intValues = (int[])value.Value;
```

The **WriteNode** methods always provide an **OpcStatus** instance, while the **WriteNodes** methods provide an **OpcStatusCollection** instance (that contains an **OpcStatus** for every written Node). The result of the write request can thereby be checkt via the properties of the **OpcStatus** instance(s).

- Write the scalar value of a single Node:

```
OpcStatus status = client.WriteNode("ns=2;s=Machine/Job/Speed", 1200);
```

- Write the array value of a single Node:

```
int[] values = new int[3] { 1200, 1350, 1780 };
OpcStatus status = client.WriteNode("ns=2;s=Machine/Job/Speeds", values);
```

- Check the result of a write request:

```
if (!status.IsGood) {
    // Your code to handle a failed write operation.
}
```

By using the individual steps to prepare the processing of scalar values and array values, the array value of a Variable Node can be modified as follows:

```
using (var client = new OpcClient("opc.tcp://localhost:4840")) {
    client.Connect();
    OpcValue arrayValue = client.ReadNode("ns=2;s=Machine/Job/Speeds");

    if (arrayValue.Status.IsGood) {
        int[] intArrayValue = (int[])arrayValue.Value;

        intArrayValue[2] = 100;
        intArrayValue[4] = 200;
        intArrayValue[9] = 300;

        OpcStatus status = client.WriteNode("ns=2;s=Machine/Job/Speeds", intArrayValue);

        if (!status.IsGood)
            Console.WriteLine("Failed to write array value!");
    }
}
```

Browsing Nodes

Which Nodes does the Server have?

The following types are used here: OpcClient, OpcNodeId, OpcNodeInfo, OpcAttribute, OpcAttributeInfo and OpcObjectTypes.

Starting from a Server whose Address-Space (all available nodes) are still (almost) unknown, it is advisable to inspect the provided Nodes of the Server. Either a graphical OPC UA client like the OPC Watch can be used or the Address-Space of the Server can be examined manually.

When using the class **OpcObjectTypes** already predefined Server-Nodes can also be examined by browsing. The “root” of all Nodes of the Server represents the Default-Node called “ObjectsFolder”. When browsing is started at the “ObjectsFolder”-Node, the entire Address-Space of the Server can be determined:

```
var node = client.BrowseNode(OpcObjectTypes.ObjectsFolder);
Browse(node);
...
private void Browse(OpcNodeInfo node, int level = )
{
    Console.WriteLine("{0}{1}({2})",
            new string('.', level * 4),
            node.Attribute(OpcAttribute.DisplayName).Value,
            node.NodeId);

    level++;

    foreach (var childNode in node.Children())
        Browse(childNode, level);
}
```

The output via the code snippet shown contains, among other things (in parentheses) the Node-IDs of the

Nodes of the Server. Based on these NodeId's the Nodes of the Server can be addressed directly. Simply pass the NodeId as a string (in double quotes) to the corresponding method of the **OpcClient** class. For example, what it looks like when reading a node value is shown in the section Reading Values.

Inspecting Node by Node

The following types are used here: OpcClient, OpcNodeId, OpcNodeInfo, OpcAttribute, OpcAttributeInfo, OpcMethodNodeInfo, OpcArgumentInfo and OpcObjectTypes.

Browsing in the OPC UA can be compared to .NET Reflections. Through browsing it is therefore possible to dynamically determine and examine the entire “Address Space” of a Server. This includes all Nodes, their references towards each other and their Node Types. Browsing is introduced through the **OpcNodeId** of the Node on which the browsing procedure shall be started. Coming from the hereby retrieved **OpcNodeInfo**, browsing can be continued on Child, Parent or Attribute Level.

If a Node is a method-depicting Node, then browsing provides an **OpcMethodNodeInfo** instance by the help of which Input / Output arguments of the method can be examined.

1. Determine the OpcNodeInfo of the desired Node:
```
OpcNodeInfo machineNode = client.BrowseNode("ns=2;s=Machine");
```
2. Use the **Child** or **Children** method to browse the Child-Node:
```
OpcNodeInfo jobNode = machineNode.Child("Job");

foreach (var childNode in machineNode.Children()) {
    // Your code to operate on each child node.
}
```
3. Use the **Attribute** or **Attributes** method to browse the attributes:
```
OpcAttributeInfo displayName = machineNode.Attribute(OpcAttribute.DisplayName);

foreach (var attribute in machineNode.Attributes()) {
    // Your code to operate on each attribute.
}
```
4. In case a Node depicts a method, the Node can be visualized and examined like this:
```
if (childNode.Category == OpcNodeCategory.Method) {
    var methodNode = (OpcMethodNodeInfo)childNode;

    foreach (var argument in methodNode.GetInputArguments()) {
        // Your code to operate on each argument.
    }
}
```

High-Speed Browsing

The following types are used here: OpcNodeInfo OpcNodeId, OpcBrowseNode, OpcReferenceTypeOpcBrowseNodeDegree and OpcBrowseOptions.

If a Server provides a very extensive “Address Space”, browsing through all nodes is often a bit slow, especially if the large amount of node information also has to be transported via a quite weak hardware or network configuration. The additional load on the Server also leads to a loss of performance if Clients go

through the entire node tree node by node.

To optimize this situation, the SDK offers the option of defining how many nodes and node levels should be examined at the same time. The `OpcBrowseNodeDegree` enumeration is used for this. Depending on the number of nodes required at the same time, the corresponding value of the enumeration is to be specified via the Degree property or in the constructor of the OpcBrowseNode class. There exists also the option of reducing the user data to a minimum or only to the really relevant data when browsing. The `OpcBrowseOptions` enumeration offers various options for this. It should be noted that at least the `ReferenceTypeId` must be part of the node information. If you want to receive additional node information, such as the DisplayName, then the DisplayName must also be included (when using the Options property).

Browsing can be parameterized and thus further optimized using the following properties:

```
// Create a browse command to browse all hierarchical references.
var browse = new OpcBrowseNode(
        nodeId: OpcNodeId.Parse("ns=2;s=Machine"),
        degree: OpcBrowseNodeDegree.Generation);

// Create a browse command to browse specific types of references.
var browse = new OpcBrowseNode(
        nodeId: OpcNodeId.Parse("ns=2;s=Machine"),
        degree: OpcBrowseNodeDegree.Generation,
        referenceTypes: new[] {
            OpcReferenceType.Organizes,
            OpcReferenceType.HasComponent,
            OpcReferenceType.HasProperty
        });

// Reduce browsing to the smallest possible amount of data.
browse.Options = OpcBrowseOptions.IncludeReferenceTypeId
        | OpcBrowseOptions.IncludeBrowseName;

var node = client.BrowseNode(browse);

foreach (var childNode in node.Children()) {
    // Continue recursively...
}
```

It should also be noted that if nodes that only have a certain relationship to one another (which is expressed using ReferenceTypes) are to be examined, browsing can also be further optimized here. The node references relevant for browsing can also be used as parameters for the browse operation (see the code snippet above) so that only the nodes that use one of the specified ReferenceTypes are visited.

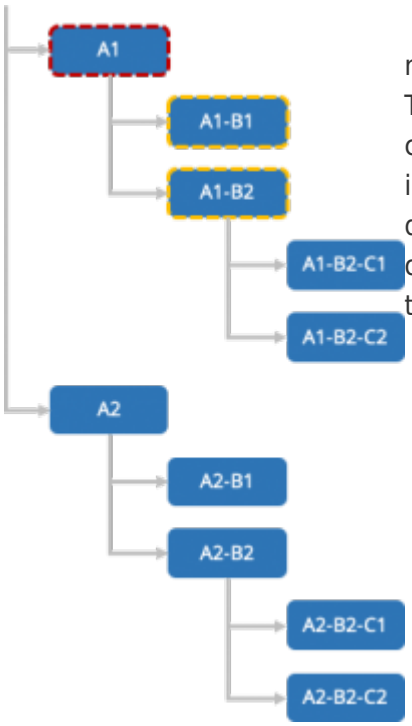
High-Speed Browsing - Details

If a Server provides a very extensive “Address Space”, browsing through all nodes is often a bit slow, especially if the large amount of node information also has to be transported via a quite weak hardware or network configuration. The additional load on the Server also leads to a loss of performance if Clients go through the entire node tree node by node.

In such cases it is important to keep the **workload** for the Server and the entire **communication** between Client and Server as **lean** and **as short as possible**. For this purpose, OPC UA offers various mechanisms with which a Client can signal to the Server that many more nodes than just one level are being examined. The Server then has the option to prepare the information and communicate it to the Client in packets. This therefore reduces further internal reprocessing of the node tree on the Server side, always on request

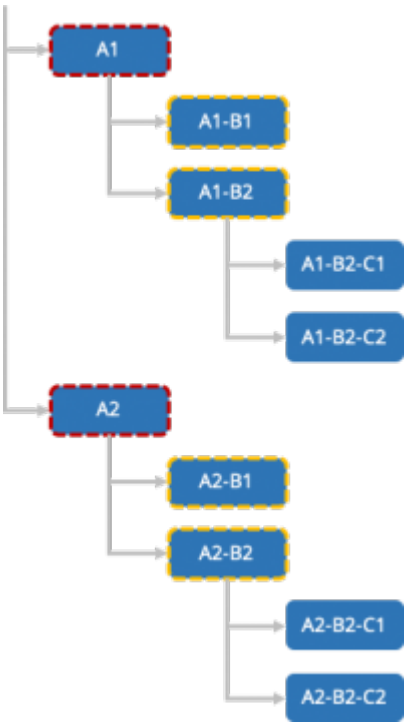
from the Client. In addition, a Client can, with the appropriate logic, query further nodes in advance from the Server, of which it is known that their node information and that of their children and their children-children (and so on) would also be processed.

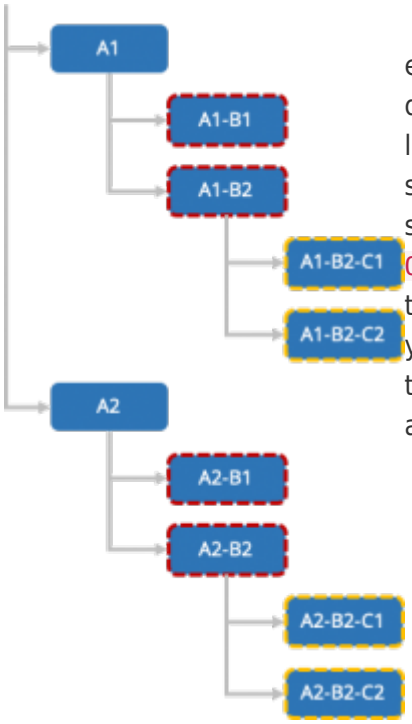
The **SDK offers various parameters** for optimizing the browse operations, which can be used to determine the behavior when browsing. Depending on the browsing process, the SDK uses the parameters to decide which nodes with which information should be prepared in advance on the Server side for the current browse process. The SDK then automatically retrieves these nodes during further browsing, stores them in the memory in advance for the further browsing process and then delivers them from the internal cache instead from the Server.



A value of the `OpcBrowseNodeDegree` enumeration is used to control which nodes are to be automatically requested by the Server at the same time. The value `Self` corresponds to the standard behavior in which only the children of the current node are examined. In the tree on the left, browsing is started at node `A1`. As a result, the Server only delivers the nodes directly below node `A1`, i.e. the nodes `A1-B1` and `A1-B2`. The nodes of all other subtrees, including those of the nodes next to the node `A1`, at which the browse operation was started, are not part of the browse operation.

With the value `Sibling`, all children of the sibling nodes are retrieved from the Server at the same time when the child nodes of the current node are examined. In this case, when the browse operation starts at node `A1`, the SDK not only determines the direct child nodes of node `A1`, but also those of all nodes that are siblings of `A1`. This means that the subtrees from `A2` to `An` are also determined during the browse operation. The SDK temporarily stores the node information obtained in this way and (again) retrieves it from the memory instead from the Server as soon as the developer requires the subtree of e.g. Node `A2`. In the picture on the right you can see that a browse operation - starting from node `A1` - behaves as if you were browsing nodes `A1` to `An` at the same time.





If the value `Generation` is used, all nodes of the same generation are examined at the same time, which means that all nodes of the same level depth are examined. Specifically, this means, as shown in the tree on the left, that if a browse operation is started at the node `A1-B1`, not only its subtree (as when browsing with `OpcBrowseNodeDegree.Self`), but also the subtrees of his siblings (as when browsing with `OpcBrowseNodeDegree.Sibling`) as well as the subtrees of his cousins of the nth degree can also be called up. In this way, browsing behaves as if you were browsing the nodes `A1-B1`, `A1-B2`, `A2-B1` and `A2-B2` at the same time. Here, too, the node information of the subtrees is cached and made available to the developer if required.

It should be noted that the use of the individual `OpcBrowseNodeDegree` values is always associated with a little caution. If, for example, a Server provides a relatively “flat address space” that contains a large number of nodes per subtree, the “Generation” option can lead to relatively long browse operations, which in turn can be very memory-intensive. The same applies to the `Self` option, especially if one has a large number of small subtrees on the same level, which in turn also contain many other child nodes.

The general **recommendation** is therefore that the developer either knows the complexity of the Server in advance and selects the level of browse operations based on this, or in the case of unknown/changing Servers by choosing the level `Sibling` or `Generation` the node information shall be reduced via the Options property. Any further necessary node information can then be called up by the developer using a separate browse operation.

Subscriptions

Subscription Creation

The following types are used here: OpcClient, OpcNodeId, OpcSubscribeDataChange, OpcSubscribeEvent, OpcSubscription, OpcMonitoredItem, OpcMonitoredItemCollection, OpcDataChangeReceivedEventHandler, OpcDataChangeReceivedEventArgs, OpcEventReceivedEventHandler, OpcEventReceivedEventArgs and OpcNotification.

Subscriptions in the OPC UA can be compared to subscriptions to one or more journals in the bundle. Instead of magazines, however, Node Events (= in the OPC UA: Monitored Item) or changes to the Node Values (= in the OPC UA: Monitored Item) are subscribed. For each subscription, it is possible to specify in which interval the notifications (**OpcNotification** instances) of the monitored items should be published (**OpcSubscription.PublishingInterval**). Which Node to subscribe to is determined by the **OpcNodeId** of the Node. By default, the *Value-Attribute* is monitored. If another attribute of the Node is to be monitored, the corresponding **OpcAttribute** have to be specified when calling **SubscribeDataChange** or when using a respective **OpcSubscribeDataChange** instance.

- Subscribe to notifications about changes to the Node Value:

```
OpcSubscription subscription = client.SubscribeDataChange(
        "ns=2;s=Machine/IsRunning",
        HandleDataChanged);
```

- Subscribe to notifications about changes to multiple Node Values:

```
OpcSubscribeDataChange[] commands = new OpcSubscribeDataChange[] {
    new OpcSubscribeDataChange("ns=2;s=Machine/IsRunning", HandleDataChanged),
    new OpcSubscribeDataChange("ns=2;s=Machine/Job/Speed", HandleDataChanged)
};

OpcSubscription subscription = client.SubscribeNodes(commands);
```

- Handle notifications of changes to Node Values:

```
private static void HandleDataChanged(
        object sender,
        OpcDataChangeReceivedEventArgs e)
{
    // Your code to execute on each data change.
    // The 'sender' variable contains the OpcMonitoredItem with the NodeId.
    OpcMonitoredItem item = (OpcMonitoredItem)sender;

    Console.WriteLine(
            "Data Change from NodeId '{0}': {1}",
            item.NodeId,
            e.Item.Value);
}
```

- Subscribe to notifications about Node Events:

```
OpcSubscription subscription = client.SubscribeEvent(
        "ns=2;s=Machine",
        HandleEvent);
```

- Subscribe to notifications about Node Events of multiple Nodes:

```
OpcSubscribeEvent[] commands = new OpcSubscribeEvent[] {
    new OpcSubscribeEvent("ns=2;s=Machine", HandleEvent),
    new OpcSubscribeEvent("ns=2;s=Machine/Job", HandleEvent)
};

OpcSubscription subscription = client.SubscribeNodes(commands);
```

- Handle notifications about Node Events:

```
private void HandleEvent(object sender, OpcEventReceivedEventArgs e)
{
    // Your code to execute on each event raise.
}
```

- Configuration of the **OpcSubscription**:

```
subscription.PublishingInterval = 2000;

// Always call apply changes after modifying the subscription; otherwise
// the server will not know the new subscription configuration.
subscription.ApplyChanges();
```

- Subscribe to notifications of changes to multiple Node Values through a single subscription and set custom values of the *Tag* property of the **OpcMonitoredItem**:

```
string[] nodeIds = {
    "ns=2;s=Machine/IsRunning",
    "ns=2;s=Machine/Job/Speed",
    "ns=2;s=Machine/Diagnostics"
};

// Create an (empty) subscription to which we will addd OpcMonitoredItems.
OpcSubscription subscription = client.SubscribeNodes();

for (int index = ; index < nodeIds.Length; index++) {
    // Create an OpcMonitoredItem for the NodeId.
    var item = new OpcMonitoredItem(nodeIds[index], OpcAttribute.Value);
    item.DataChangeReceived += HandleDataChanged;

    // You can set your own values on the "Tag" property
    // that allows you to identify the source later.
    item.Tag = index;

    // Set a custom sampling interval on the
    // monitored item.
    item.SamplingInterval = 200;

    // Add the item to the subscription.
    subscription.AddMonitoredItem(item);
}

// After adding the items (or configuring the subscription), apply the changes.
subscription.ApplyChanges();
```

Handler:

```
private static void HandleDataChanged(
        object sender,
        OpcDataChangeReceivedEventArgs e)
{
    // The tag property contains the previously set value.
    OpcMonitoredItem item = (OpcMonitoredItem)sender;

    Console.WriteLine(
            "Data Change from Index {0}: {1}",
            item.Tag,
            e.Item.Value);
}
```

Subscription Filtering

The following types are used here: OpcClient, OpcNodeId, OpcSubscribeDataChange, OpcDataChangeFilter, OpcDataChangeTrigger, OpcSubscription, OpcMonitoredItem, OpcMonitoredItemCollection, OpcDataChangeReceivedEventHandler, OpcDataChangeReceivedEventArgs and OpcNotification.

A Client application is notified through a once created subscription only about changes of the Status or of the Value of a Node, by default. However, for a Server to notify the Client about changes to the Node according to certain policies, it is possible to setup a trigger of a notification to evaluate. For this, the desired Trigger is determined via a value of the **OpcDataChangeTrigger** enumeration. The following

examples subscribe to notifications about changes in the Status or the Value or the Timestamp of a Node.

- Subscribe to notifications about changes to the Node Value and Node Timestamps:

```
OpcSubscription subscription = client.SubscribeDataChange(
        "ns=2;s=Machine/IsRunning",
        OpcDataChangeTrigger.StatusValueTimestamp,
        HandleDataChanged);
```

- Subscribe to notifications about changes to multiple Node Values and Node Timestamps:

```
OpcSubscribeDataChange[] commands = new OpcSubscribeDataChange[] {
    new OpcSubscribeDataChange(
            "ns=2;s=Machine/IsRunning",
            OpcDataChangeTrigger.StatusValueTimestamp,
            HandleDataChanged),
    new OpcSubscribeDataChange(
            "ns=2;s=Machine/Job/Speed",
            OpcDataChangeTrigger.StatusValueTimestamp,
            HandleDataChanged)
};

OpcSubscription subscription = client.SubscribeNodes(commands);
```

- Handle notifications of changes to Node Values and Node Timestamps:

```
private static void HandleDataChanged(
        object sender,
        OpcDataChangeReceivedEventArgs e)
{
    // Your code to execute on each data change.
    // The 'sender' variable contains the OpcMonitoredItem with the NodeId.
    OpcMonitoredItem item = (OpcMonitoredItem)sender;

    Console.WriteLine(
            "Data Change from NodeId '{0}': {1} at {2}",
            item.NodeId,
            e.Item.Value,
            e.Item.Value.SourceTimestamp);
}
```

The used **OpcDataChangeTrigger**-Value of the preceding samples can be defined using an instance of the **OpcDataChangeFilter** class as well. Doing so enables the reuse of the once defined filter within multiple subscriptions and monitored items:

```
OpcDataChangeFilter filter = new OpcDataChangeFilter();
filter.Trigger = OpcDataChangeTrigger.StatusValueTimestamp;

OpcSubscription subscriptionA = client.SubscribeDataChange(
        "ns=2;s=Machine/IsRunning",
        filter,
        HandleDataChanged);

// or

OpcSubscribeDataChange[] commands = new OpcSubscribeDataChange[] {
    new OpcSubscribeDataChange(
            "ns=2;s=Machine/IsRunning",
            filter,
            HandleDataChanged),
    new OpcSubscribeDataChange(
            "ns=2;s=Machine/Job/Speed",
            filter,
            HandleDataChanged)
};

OpcSubscription subscriptionB = client.SubscribeNodes(commands);
```

Structured Data

In the following sections **it is assumed** that the server provides a node (via the NodeId “ns=2;s=Machine/Operator”), which makes use of the **(fictitious) data type “StaffType”** ,
Die Struktur des Datentypen wird dabei wie folgt definiert:

```
StaffType
  .Name : string
  .ID : long
  .Shift : ShiftInfoType
    .Name : string
    .Elapsed : DateTime
    .Remaining : int
```

Simplest Access

The following types are used here: OpcClient, OpcNodeId, OpcValue and OpcDataObject.

For easy access to values of variable nodes with structured data, the framework supports the use of the keyword `dynamic`. Accesses to variables that are declared using `dynamic` are evaluated by .NET at runtime. This means that the data of a structured data type can be accessed without prior explicit implementation of a .NET type. Such an access could look like this:

```
client.UseDynamic = true;
client.Connect();

dynamic staff = client.ReadNode("ns=2;s=Machine/Operator").Value;

// Access the 'Name' and 'ID' field of the data without to declare the data type itself.
// Just use the field names known as they would be defined in a .NET Type.
Console.WriteLine("Name: {0}", staff.Name);
Console.WriteLine("Staff ID: {0}", staff.ID);

// Continue accessing subsequently used data types.
Console.WriteLine("Shift: {0}", staff.Shift.Name);
Console.WriteLine("- Time Elapsed: {0}", staff.Shift.Elapsed);
Console.WriteLine("- Jobs Remaining: {0}", staff.Shift.Remaining);

// Change Shift
staff.Name = "John";
staff.ID = 4242;
staff.Shift.Name = "Swing Shift";

client.WriteNode("ns=2;s=Machine/Operator", staff);
```

Name-based Access

The following types are used here: OpcClient, OpcNodeId, OpcValue, OpcDataObject and OpcDataField.

For name-based access to values of variable nodes with structured data, the **OpcDataObject** class can be used directly. If the names of the fields of the data type are known, these can be accessed in the following way:

```
client.UseDynamic = true;
client.Connect();

OpcDataObject staff = client.ReadNode("ns=2;s=Machine/Operator").As<OpcDataObject>();

// Access the 'Name' and 'ID' field of the data without to declare the data type itself.
// Just use the field names known as the 'key' to access the according field value.
Console.WriteLine("Name: {0}", staff["Name"].Value);
Console.WriteLine("Staff ID: {0}", staff["ID"].Value);

// Continue accessing subsequently used data types using the OpcDataObject as before.
OpcDataObject shift = (OpcDataObject)staff["Shift"].Value;

Console.WriteLine("Shift: {0}", shift["Name"].Value);
Console.WriteLine("- Time Elapsed: {0}", shift["Elapsed"].Value);
Console.WriteLine("- Jobs Remaining: {0}", shift["Remaining"].Value);

// Change Shift
staff["Name"].Value = "John";
staff["ID"].Value = 4242;
shift["Name"].Value = "Swing Shift";

client.WriteNode("ns=2;s=Machine/Operator", staff);
```

Dynamic Access

The following types are used here: OpcClient, OpcNodeSet, OpcAutomatism and OpcDataTypeSystem.

For the “simples access” (see Simplest Access) via `dynamic` (in Visual Basic not typed using `Dim`) as well as the name-based access (see Name-based Access) the **OpcClient** needs information about the data types provided by the server. This information determines the **OpcClient** class automatically during *Connect()* from the server if the property *UseDynamic* either on the **OpcClient** or the static class **OpcAutomatism** is set to the value `true` before connecting.

By enabling the feature, the **OpcClient** will load the necessary type information from the server so that it can be accessed following the call to *Connect()* without explicit coding or shown in the previous sections.

If a **UANodeSet.xml** or a XML file with the description of the server is available (an XML file whose content starts with *UANodeSet*), this file can also be loaded into the client application. The **OpcClient** can then retrieve the information from the NodeSet and does not need to retrieve the type information when connecting. This could then look like this:

```
using (OpcClient client = new OpcClient("opc.tcp://localhost:4840")) {
    client.NodeSet = OpcNodeSet.Load(@"..\Resources\MyServersNodeSet.xml");
    client.UseDynamic = true;

    client.Connect();
    dynamic staff = client.ReadNode("ns=2;s=Machine/Operator").Value;

    Console.WriteLine("Name: {0}", staff.Name);
    Console.WriteLine("Staff ID: {0}", staff.ID);
}
```

Note that the **OpcClient** class when calling *GetDataTypeSystem()* after setting a NodeSet provides an instance of the **OpcDataTypeSystem** class that describes the type system described in the NodeSet. If, on the other hand, no NodeSet is set using the *NodeSet* property of the **OpcClient** class, calling *GetDataTypeSystem()* returns a **OpcDataTypeSystem** instance representing the server's type system which was determined when calling *Connect ()*.

Typed Access

The following types are used here: OpcClient, OpcNodeId, OpcDataTypeAttribute and OpcDataTypeEncodingAttribute.

For typed access, .NET types are defined in the client application as they are defined in the server. All required metadata is provided via attributes. Definition of .NET types for structured data types:

```
[OpcDataType("ns=2;s=StaffType")]
[OpcDataTypeEncoding("ns=2;s=StaffType-Binary")]
public class Staff
{
    public string Name { get; set; }
    public int ID { get; set; }
    public ShiftInfo Shift { get; set; }
}

[OpcDataType("ns=2;s=ShiftInfoType")]
[OpcDataTypeEncoding("ns=2;s=ShiftInfoType-Binary")]
public class ShiftInfo
{
    public string Name { get; set; }
    public DateTime Elapsed { get; set; }
    public byte Remaining { get; set; }
}
```

After the definition of the .NET type for a structured data type (on the client-side) defined by the server, this can be used as follows:

```
client.Connect();
Staff staff = client.ReadNode("ns=2;s=Machine/Operator").As<Staff>();

// Access the 'Name' and 'ID' field of the data with the declared the data type.
Console.WriteLine("Name: {0}", staff.Name);
Console.WriteLine("Staff ID: {0}", staff.ID);

// Continue accessing subsequently used data types.
Console.WriteLine("Shift: {0}", staff.Shift.Name);
Console.WriteLine("- Time Elapsed: {0}", staff.Shift.Elapsed);
Console.WriteLine("- Jobs Remaining: {0}", staff.Shift.Remaining);

// Change Shift
staff.Name = "John";
staff.ID = 4242;
staff.Shift.Name = "Swing Shift";

client.WriteNode("ns=2;s=Machine/Operator", staff);
```

Generate Data Types

If the typed access (see Typed Access) is to be used, there is the option to generate either only certain or all data types of an OPC UA server via the OPC Watch.

Generation using a Server

To generate a single data type implemented in .NET, perform the following steps:

1. Open OPC Watch
2. Create a new connection (+) and configure it (if necessary)
3. Connect to the server (plug icon)
4. Select a node...
    1. either a variable-node with a structured data type as its value
    2. or a DataType-node under /Types/DataTypes/BaseDataType/Structure or /Enumeration
5. Right click on this node

6. Click “Generate DataType”
7. Paste the code into the application, done!

All data types can be generated either in a code file (*.cs) or assembly file (*.dll). To do this, follow these steps:

1. Open OPC Watch
2. Create a new connection (+) and configure it (if necessary)
3. Connect to the server (plug icon)
4. Select the Server-node “opc.tcp://...”
5. Right click on this node
6. Click “Generate Models”
7. Select the desired file type in the dialog
8. Click “Save”
9. Add the file to the project, done!

Generation using a NodeSet

1. Open OPC Watch
2. Click the first icon in the upper right corner of the application
3. Open the NodeSet file (usually a XML file of a Companion Specification)
4. NodeSet is loaded and then a “Save as ...” dialog is displayed
5. Select the desired file type in the dialog
6. Click “Save”
7. Add the file to the project, done!

Define Data Types

The following types are used here: OpcClient, OpcNodeId, OpcData, OpcDataTypeAttribute, OpcDataTypeEncodingAttribute, OpcDataTypeSystem and OpcDataTypeInfo.

As an alternative to generating the data type as a .NET code or .NET assembly (see Generate Data Types), these can also be defined manually. To do this, implement the type as defined by the server. This means that the .NET Type (regardless of structure or class) must provide the fields of the structured data type - in terms of their type - in exactly the same order. All other metadata is provided via corresponding attributes:

```
[OpcDataType("<NodeId of DataType Node>")]
[OpcDataTypeEncoding(
        "<NodeId of Binary Encoding Node>",
        NamespaceUri = "<NamespaceUri.Value of binary Dictionary-Node>")]
internal struct MyDataType
{
    public short FieldA;
    public int FieldB;
    public string FieldC;
    ...
}
```

The information required for the definition can be obtained either via the OPC UA Server manual, the responsible PLC developer or via the **OpcClient** class. To get the necessary information via the **OpcClient** class, you can examine the variable node - which uses the structured data types - as follows:

```
OpcNodeInfo node = client.BrowseNode("ns=2;s=Machine/Operator");

if (node is OpcVariableNodeInfo variableNode) {
    OpcNodeId dataTypeId = variableNode.DataTypeId;
    OpcDataTypeInfo dataType = client.GetDataTypeSystem().GetType(dataTypeId);

    Console.WriteLine(dataType.TypeId);
    Console.WriteLine(dataType.Encoding);

    Console.WriteLine(dataType.Name);

    foreach (OpcDataFieldInfo field in dataType.GetFields())
        Console.WriteLine(".{0} : {1}", field.Name, field.FieldType);

    Console.WriteLine();
    Console.WriteLine("Data Type Attributes:");
    Console.WriteLine(
            "\t[OpcDataType(\"{0}\")]",
            dataType.TypeId.ToString(OpcNodeIdFormat.Foundation));
    Console.WriteLine(
            "\t[OpcDataTypeEncoding(\"{0}\", NamespaceUri = \"{1}\")]",
            dataType.Encoding.Id.ToString(OpcNodeIdFormat.Foundation),
            dataType.Encoding.Namespace.Value);
}
```

Data Types with optional Fields

The following types are used here: OpcClient, OpcNodeId, OpcData, OpcDataTypeAttribute, OpcDataTypeEncodingAttribute, OpcDataTypeEncodingMaskAttribute and OpcDataTypeMemberSwitchAttribute.

In order to reduce the amount of data transported, it is possible to “mark” certain fields of a structured data type as existent or missing in the data stream depending on certain conditions or on the value of another field within the data structure. Thus, to “mark” that a field is available, either the value of another field or a single bit within the EncodingMask (a field coded as a preamble before the data in the stream) is used. The size of the EncodingMask is specified in number of bytes in the 'OpcDataTypeEncodingMaskAttribute'; if the 'Size' property is not explicitly set, its value (if 'OpcEncodingMaskKind.Auto' is used) will be the smallest number of bytes needed (based on the number of optional fields).

The following options are available for defining the optional fields:

```
[OpcDataType("<NodeId of DataType Node>")]
[OpcDataTypeEncoding(
        "<NodeId of Binary Encoding Node>",
        NamespaceUri = "<NamespaceUri.Value of binary Dictionary-Node>")]
[OpcDataTypeEncodingMask(OpcEncodingMaskKind.Auto)]
internal struct MyDataTypeWithOptionalFields
{
    public short FieldA;
    public int FieldB;
    public string FieldC;

    // Nullables are treat as optional fields by default.
    // Existence-Indicator-Bit is Bit0 in the encoding mask.
    public uint? OptionalField1;

    // Existence-Indicator-Bit is Bit1 (the next unused bit) in the encoding mask.
    [OpcDataTypeMemberSwitch]
    public int OptionalField2;

    // Existence-Indicator-Bit is Bit3 (bit 2 is unused) in the encoding mask.
    [OpcDataTypeMemberSwitch(bit: 3)]
    public byte OptionalField3;

    public bool FieldD;

    // 'OptionalField4' exists only if the value of 'FieldD' is equals 'true'.
    [OpcDataTypeMemberSwitch("FieldD")]
    public string OptionalField4;

    public int FieldE;

    // 'OptionalField5' exists only if the value of 'FieldE' is greater than '42'.
    [OpcDataTypeMemberSwitch("FieldE", value: 42, @operator:
OpcMemberSwitchOperator.GreaterThan)]
    public string OptionalField5;
}
```

Historical Data

The following types are used here: OpcClient, OpcNodeId, IOpcNodeHistoryNavigator, OpcHistoryValue and OpcAggregateType.

According to OPC UA specification every Node of the category **Variable** supports the historical recording of the values from its *Value Attribute*. Hereby the new value is saved together with the time stamp of the *Value Attribute* at every change of value of the *Value Attribute*. These **pairs consisting of value and timestamp** are called **historical data**. The Server itself decides on where to save the data. However, the Client can detect via the *IsHistorizing Attribute* of the Node, if the Server provides historical data for a Node and / or historically saves value changes. The **OpcNodeId** of the Node determines from which Node the historical data shall be accessed. Hereby the Client can read, update, replace, delete and create historical data. Mostly, historical data is read by the Client. Processing all historical values, independent from reading with or without navigator, is not necessary.

In order to read historical data the Client can:

- read all values within an **open time frame** (= non-defined StartTime or EndTime)

  - read all values **from a particular timestamp forward** (= StartTime):

```
var startTime = new DateTime(2017, 2, 16, 10, , );
var history = client.ReadNodeHistory(
        startTime, null, "ns=2;s=Machine/Job/Speed");
```

  - read all values **up until a particular timestamp** (= EndTime):

```
var endTime = new DateTime(2017, 2, 16, 15, , );
var history = client.ReadNodeHistory(
        null, endTime, "ns=2;s=Machine/Job/Speed");
```

- read all values within a **closed time window** (= defined StartTime and EndTime):

```
var startTime = new DateTime(2017, 2, 16, 10, , );
var endTime = new DateTime(2017, 2, 16, 15, , );

var history = client.ReadNodeHistory(
        startTime, endTime, "ns=2;s=Machine/Job/Speed");
```

- The values are being processed via an instance that implements the **IEnumerable** interface:

```
foreach (var value in history) {
    Console.WriteLine(
            "{0}: {1}",
            value.Timestamp,
            value);
}
```

In order to read historical data pagewise (= only a particular number of values is retrieved from the Server) the Client can:

- read a **particular number of values** per page:

```
var historyNavigator = client.ReadNodeHistory(
        10, "ns=2;s=Machine/Job/Speed");
```

- read a **particular number of values** per page within an **open time frame** (= undefined StartTime or EndTime)
  - read a **particular number of values** per page **from a particular timestamp forward** (= StartTime):

```
var startTime = new DateTime(2017, 2, 16, 15, , );
var historyNavigator = client.ReadNodeHistory(
        startTime, 10, "ns=2;s=Machine/Job/Speed");
```

  - read a **particular number of values** per page **up until a particular timestamp** (= EndTime):

```
var endTime = new DateTime(2017, 2, 16, 15, , );
var historyNavigator = client.ReadNodeHistory(
        null, endTime, 10, "ns=2;s=Machine/Job/Speed");
```

- read a **particular number of values** per page **within a closed time frame** (= defined StartTime and EndTime):

```
var startTime = new DateTime(2017, 2, 16, 10, , );
var endTime = new DateTime(2017, 2, 16, 15, , );

var historyNavigator = client.ReadNodeHistory(
        startTime, endTime, 10, "ns=2;s=Machine/Job/Speed");
```

- The values are then processed via an instance that implements the **IOpcNodeHistoryNavigator** interface:

```
do {
    foreach (var value in historyNavigator) {
        Console.WriteLine(
                "{0}: {1}",
                value.Timestamp,
                value);
    }
} while (historyNavigator.MoveNextPage());

historyNavigator.Close();
```

- Always ensure that the *Close* method of the **IOpcNodeHistoryNavigator** instance is called. This is necessary in order for the Server to be able to dispose of the historical data buffered for the request afterwards. As an alternative to the explicit call of the *Close* method the navigator can also be used in a *using* block:

```
using (historyNavigator) {
    do {
        foreach (var value in historyNavigator) {
            Console.WriteLine(
                    "{0}: {1}",
                    value.Timestamp,
                    value);
        }
    } while (historyNavigator.MoveNextPage());
}
```

Different types of aggregation can be chosen for processed reading of the historical data via the **OpcAggregateType**:

- For reading the **lowest value** within a time frame:

```
var minSpeed = client.ReadNodeHistoryProcessed(
        startTime,
        endTime,
        OpcAggregateType.Minimum,
        "ns=2;s=Machine/Job/Speed");
```

- For reading the **average value** within a time frame:

```
var avgSpeed = client.ReadNodeHistoryProcessed(
        startTime,
        endTime,
        OpcAggregateType.Average,
        "ns=2;s=Machine/Job/Speed");
```

- For reading the **highest value** within a time frame:

```
var maxSpeed = client.ReadNodeHistoryProcessed(
        startTime,
        endTime,
        OpcAggregateType.Maximum,
        "ns=2;s=Machine/Job/Speed");
```

Nodes

Method Nodes

The following types are used here: OpcClient, OpcNodeId and OpcCallMethod.

The **OpcNodeId** of the Node determines which method Node is to be called. The hereby expected parameters of a method can be provided via the *parameters* when calling **CallMethod** or by the according **OpcCallMethod** instance. Note that first the **OpcNodeId** of the *owner* of the method has to be given and then the **OpcNodeId** of the method itself. The **OpcNodeId** of the *owner* determines the identifier of the object Node or the object type Node, that references the method as a *HasComponent reference*.

- Call a single method Node without parameters (the method does not define any IN arguments):

```
// The result array contains the values of the OUT arguments offered by the method.
object[] result = client.CallMethod(
        "ns=2;s=Machine",                  /* NodeId of Owner Node */
        "ns=2;s=Machine/StartMachine"      /* NodeId of Method Node*/);
```

- Call a single method Node with parameters (the method defines some IN arguments):

```
// The result array contains the values of the OUT arguments offered by the method.
object[] result = client.CallMethod(
        "ns=2;s=Machine",                  /* NodeId of Owner Node */
        "ns=2;s=Machine/StopMachine",      /* NodeId of Method Node */
        "Job Change",                      /* Parameter 1: 'reason' */
        10023,                             /* Parameter 2: 'reasonCode' */
        DateTime.Now                       /* Parameter 3: 'scheduleDate' */);
```

- Call several method Nodes without parameters (the methods do not define any IN arguments):

```
OpcCallMethod[] commands = new OpcCallMethod[] {
    new OpcCallMethod("ns=2;s=Machine", "ns=2;s=Machine/StopMachine"),
    new OpcCallMethod("ns=2;s=Machine", "ns=2;s=Machine/ScheduleJob"),
    new OpcCallMethod("ns=2;s=Machine", "ns=2;s=Machine/StartMachine")
};

// The result array contains the values of the OUT arguments offered by the methods.
object[][] results = client.CallMethods(commands);
```

- Call several method Nodes with parameters (the methods do define some IN arguments):

```
OpcCallMethod[] commands = new OpcCallMethod[] {
    new OpcCallMethod(
            "ns=2;s=Machine",              /* NodeId of Owner Node */
            "ns=2;s=Machine/StopMachine",  /* NodeId of Method Node */
            "Job Change",                  /* Parameter 1: 'reason' */
            10023,                         /* Parameter 2: 'reasonCode' */
            DateTime.Now                   /* Parameter 3: 'scheduleDate' */),
    new OpcCallMethod(
            "ns=2;s=Machine",              /* NodeId of Owner Node */
            "ns=2;s=Machine/ScheduleJob",  /* NodeId of Method Node */
            "MAN_F01_78910"                /* Parameter 1: 'jobSerial' */),
    new OpcCallMethod(
            "ns=2;s=Machine",              /* NodeId of Owner Node */
            "ns=2;s=Machine/StartMachine", /* NodeId of Method Node */
            10021                          /* Parameter 1: 'reasonCode' */)
};

// The result array contains the values of the OUT arguments offered by the methods.
object[][] results = client.CallMethods(commands);
```

File Nodes

The following types are used here: OpcClient, OpcNodeId, OpcFile, OpcFileMode, OpcFileStream, OpcFileInfo, OpcFileMethods and SafeOpcFileHandle.

Nodes of the type **FileType** define per definition of the OPC UA specification certain properties (= Property Nodes) and methods (= Method Nodes) that allow access to a data stream as if your were accessing a file in the file system. Hereby information about the content of the logical and physical file is provide exclusively. According to the specification, a possibly existing path to the file is not provided. The access to the file itself is realized via Open, Close, Read, Write, GetPosition and SetPosition. The data is always processed in a binary way. Like on every other platform in the OPC UA you can choose a mode while opening Open which sets the kind of data access planned. You can also request exclusive access to a file in the OPC UA. After calling the Open method you recieve a numeric key for further file handle. This key always has to be handed over at the methods Read, Write, GetPosition and SetPosition. An open file has to be closed again when no longer needed.

Access to Nodes of the type FileType can be executed manually via the OpcClient by using the ReadNode and CallMethod functions. As an alternative the Framework provides numerous other classes that - modelled after the .NET Framework - allow access to Nodes of the type FileType. The **OpcNodeId** of the Node determines which “File Node” shall be accessed.

Data access with the **OpcFile** class:

- Reading the entire content of a text file:

```
string reportText = OpcFile.ReadAllText(client, "ns=2;s=Machine/Report");
```

- Appending further text data to a text file:

```
OpcFile.AppendAllText(client, "ns=2;s=Machine/Report", "Lorem ipsum");
```

- Opening and reading the file via **OpcFileStream**:

```
using (var stream = OpcFile.OpenRead(client, "ns=2;s=Machine/Report")) {
    var reader = new StreamReader(stream);

    while (!reader.EndOfStream)
        Console.WriteLine(reader.ReadLine());
}
```

- Opening and writing the file via **OpcFileStream**:

```
using (var stream = OpcFile.OpenWrite(client, "ns=2;s=Machine/Report")) {
    var writer = new StreamWriter(stream);

    writer.WriteLine("Lorem ipsum");
    writer.WriteLine("dolor sit");
    // ...
}
```

Data access with the **OpcFileInfo** class:

- Creating an **OpcFileInfo** instance:

```
var file = new OpcFileInfo(client, "ns=2;s=Machine/Report");
```

- Working with the **OpcFileInfo** instance:

```
if (file.Exists) {
    Console.WriteLine($"File Length: {file.Lengh}");

    if (file.CanUserWrite) {
        using (var stream = file.OpenWrite()) {
            // Your code to write via stream.
        }
    }
    else {
        using (var stream = file.OpenRead()) {
            // Your code to read via stream.
        }
    }
}
```

Data access with the **OpcFileMethods** class:

- via .NET SafeHandle concept (realized via the **SafeOpcFileHandle** class):

```
using (var handle = OpcFileMethods.SecureOpen(client, "ns=2;s=Machine/Report",
OpcFileMode.ReadWrite)) {
    byte[] data = OpcFileMethods.SecureRead(handle, 100);

    long position = OpcFileMethods.SecureGetPosition(handle);
    OpcFileMethods.SecureSetPosition(handle, position + data[data.Length - 1]);

    OpcFileMethods.SecureWrite(handle, new byte[] { 1, 2, 3 });
}
```

- via numeric File Handle:

```
uint handle = OpcFileMethods.Open(client, "ns=2;s=Machine/Report",
OpcFileMode.ReadWrite);

try {
    byte[] data = OpcFileMethods.Read(client, "ns=2;s=Machine/Report", handle, 100);

    ulong position = OpcFileMethods.GetPosition(client, "ns=2;s=Machine/Report",
handle);
    OpcFileMethods.SetPosition(client, "ns=2;s=Machine/Report", handle, position +
data[data.Length - 1]);

    OpcFileMethods.Write(client, "ns=2;s=Machine/Report", handle, new byte[] { 1, 2, 3
});
}
finally {
    OpcFileMethods.Close(client, "ns=2;s=Machine/Report", handle);
}
```

Only file accesses via **OpcFile**, **OpcFileInfo**, **OpcFileStream** and **SafeOpcFileHandle** guarantee an also implicit release of an open file, even if the call of the *Close* method has been “forgotten”. When closing the connection to the Server, at the latest, all open files are closed by the **OpcClient** automatically. However, this is not the case, if the methods of the class **OpcFileMethods** are used without the “Secure” prefix.

The OPC UA specification does not define a way to determine a Node as a Node of the type FileType and therefore as a File-Node. For this the Framework offers the option to identify a File-Node via its Node structure:

```
if (OpcFileMethods.IsFileNode(client, "ns=2;s=Machine/Report")) {
    // Your code to operate on the file node.
}
```

Datatype Nodes

The following types are used here: OpcClient, OpcNodeId, OpcNodeInfo and OpcTypeNodeInfo.

In case there a Server provides a Node, through that the Server publishes information about a Server defined Datatype, it can be necessary that a Client wants to query such type information. The simplest way to do so is Browsing. The framework provides especially for Datatype Nodes a specialisation of the **OpcNodeInfo** - the **OpcTypeNodeInfo**. Using the properties of this class additional information can be queried about the user defined Datatype. For example whether the Datatype is an enumeration. In this case it is possible to query the different enum-entries as well. This works as follows:

```
var machineStatusNode = client.BrowseNode("ns=2;s=MachineStatus") as OpcTypeNodeInfo;

if (machineStatusNode != null && machineStatusNode.IsEnum) {
    var members = machineStatusNode.GetEnumMembers();

    foreach (var member in members)
        Console.WriteLine(member.Name);
}
```

Data Nodes

The following types are used here: OpcClient, OpcNodeId, OpcNodeInfo and OpcVariableNodeInfo.

Working with Data Nodes is primarily restricted to Reads and Writes regarding the *Value*-Attribut of the Node. This works like on every other Node as already explained in “Reading Values of Node(s)” and “Writing Values of Node(s)”. In case there additional information is required except of the value of the Node (without the need to manually retrieve them using *ReadNode* requests), then they can be directly and simple requested from the Server using Browsing. The following sample represents how this does work:

```
var machineStatusNode = client.BrowseNode("ns=2;s=Machine/Status") as OpcVariableNodeInfo;

if (machineStatusNode != null) {
    Console.WriteLine($"AccessLevel: {machineStatusNode.AccessLevel}");
    Console.WriteLine($"UserAccessLevel: {machineStatusNode.UserAccessLevel}");
    ...
}
```

Furthermore it is possible to continue the Browsing on the Datatype Node used by the Data Node:

```
var dataTypeNode = machineStatusNode.DataType;

if (dataTypeNode.IsSystemType) {
    ...
}
```

Data-Item Nodes

The following types are used here: OpcClient und OpcNodeId.

Data-Item Nodes, provided by the **OpcDataItemNode** through a Server, are an extension of the simple **OpcDataVariableNode**. They are also primarily used for value provision. Beyond from that they provide additional useful Metadata. One of that additional information is published through the *Definition* property which is defined as Property-Node which is in turn a child of the Data-Item Node. This property is used to ensure the correct processing and interpreation of the data provided by the Node. The value of the property is vendor specific and shall inform the user how the value is achieved. Apart from that it is also possible to work with the Node as represented in “Reading Values of Node(s)” and “Writing Values of Node(s)”.

Data-Item Nodes for analog Values

The following types are used here: OpcClient, OpcNodeId, OpcNodeInfo and OpcAnalogItemNodeInfo.

This kind of Node represents a specialisation of the Data-Item Node **OpcDataItemNode**. The values provided are especially used in analog environments and can be described througth the additional properties *InstrumentRange*, *EngineeringUnit* and *EngineeringUnitRange*. While the *InstrumentRange* describes the value range of the analog data of its source, the *EngineeringUnit* defines the measure of the provided values. Is the value determined under normal conditions, then it is within the customizable value range defined by the *EngineeringUnitRange* property. The *EngineeringUnit* property described measure is defined by the UNECE Recommendation N° 20. These recommendations are based on the International System of Units (short SI Units). The **OpcAnalogItemNodeInfo** provides an appropriate interface for

simplified processing of the provided information of such a Node through Browsing:

```
var temperatureNode = client.BrowseNode("ns=2;s=Machine/Temperature") as
OpcAnalogItemNodeInfo;

if (temperatureNode != null) {
    Console.WriteLine($"InstrumentRange: {temperatureNode.InstrumentRange}");

    Console.WriteLine($"EngineeringUnit: {temperatureNode.EngineeringUnit}");
    Console.WriteLine($"EngineeringUnitRange: {temperatureNode.EngineeringUnitRange}");
}
```

Events

Event Subscription

The following types are used: OpcClient, OpcObjectTypes, OpcEventReceivedEventArgs, OpcEvent, OpcAlarmCondition, OpcSimpleAttributeOperand, OpcFilter, OpcEventFilter und OpcEventSeverity.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

Events inform a subscriber (such as Clients) about operations, conditions, and system-specific events. Such information can be delivered to interested parties directly via **global events**. A global event is always published through the Server's “Server” Node. For this reason, global events are also subscribed via the Server Node as follows:

```
client.SubscribeEvent(OpcObjectTypes.Server, HandleGlobalEvents);
```

An event is generally handled with a method of the following signature:

```
private static void HandleGlobalEvents(
        object sender,
        OpcEventReceivedEventArgs e)
{
    Console.WriteLine(e.Event.Message);
}
```

The event data received via the **OpcEventReceivedEventArgs** instance can be retrieved via the *Event* property. The property always returns an instance of the type **OpcEvent**. If the received event data is a specialization of the **OpcEvent** class, it can be simply cast as follows:

```
private static void HandleGlobalEvents( _
        object sender, _
        OpcEventReceivedEventArgs e)
{
    var alarm = e.Event as OpcAlarmCondition;

    if (alarm != null)
        Console.WriteLine("Alarm: " + alarm.Message);
}
```

The call shown above subscribes to all events published globally by the Server. In order to restrict the information received as well as the events which are ever sent from the Server to the Client, an event filter can be defined and transmitted to the Server when a subscription is concluded:

```
// Define an attribute operand using the identifier of the type which defines the
// attribute / property including the name of the attribute / property to evaluate
// by the operand.
var severity = new OpcSimpleAttributeOperand(OpcEventTypes.Event, "Severity");
var conditionName = new OpcSimpleAttributeOperand(OpcEventTypes.Condition, "ConditionName");

var filter = OpcFilter.Using(client)
        .FromEvents(OpcEventTypes.AlarmCondition)
        .Where(severity > OpcEventSeverity.Medium & conditionName.Like("Temperature"))
        .Select();

client.SubscribeEvent(
        OpcObjectTypes.Server,
        filter,
        HandleGlobalEvents);
```

Creating an event filter always requires a **OpcClient** instance, which must already have a connection to the destination Server. This is required because the Client collects the type information from the Server relevant for the assembling of the filter when assembling. In the above example, all properties of the Node type **OpcAlarmConditionNode** are recursively collected up to the **OpcNode** via the Client, and according to the *Where* and *Select* clauses rules for the selection of the Event data are created. The Node types to be analyzed can be passed with comma separated to the *FromEvents(...)*- method:

```
var severity = new OpcSimpleAttributeOperand(OpcEventTypes.Event, "Severity");
var conditionName = new OpcSimpleAttributeOperand(OpcEventTypes.Condition, "ConditionName");

var filter = OpcFilter.Using(client)
        .FromEvents(
            OpcEventTypes.AlarmCondition,
            OpcEventTypes.ExclusiveLimitAlarm,
            OpcEventTypes.DialogCondition)
        .Where(severity > OpcEventSeverity.Medium & conditionName.Like("Temperature"))
        .Select();

client.SubscribeEvent(
        OpcObjectTypes.Server,
        filter,
        HandleGlobalEvents);
```

The *Where(...)* method can then be used to restrict the information collected by *FromEvents(...)* about the properties provided by the Node types. For this, the framework offers various operator overloads (<=, <, >, >= and ==). For logical combinations of the operands it also offers the logical operators OR (|) and AND (&). In addition, various methods are available for further restrictions, such as: *Like*, *Between*, *InList*, *IsNull*, *Not* and *OfType*.

After the restriction has been made, you can use the *Select(...)* method to select the properties that will be additionally selected by the Server when the event occurs (which corresponds to the conditions specified under *Where(...)*) and are transferred to the Client.

Event Nodes

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcEvent und OpcSubscription.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

It is not always appropriate for a Server to send events globally through the Server Node to all subscribers. Often the context therefore plays a crucial role in whether an event is of interest to a subscriber. Event Nodes are used to define local events. If the Server uses an Event Node to provide event data for a Node, then the Event Node is a so-called “Notifier” of the Node. For this reason, it is also possible to recognize by a *HasNotifier* reference which event Node reports event data to a Node. It should be noted that an Event Node may be a “Notifier” for multiple Nodes. As a result, local events are always subscribed via the notified Nodes:

```
client.SubscribeEvent(machineNodeId, HandleLocalEvents);
```

An event is generally handled with a method of the following signature. The further processing of the event data is identical to the processing of global events (see section 'Working with Events').

```
private static void HandleLocalEvents(
        object sender,
        OpcEventReceivedEventArgs e)
{
    Console.WriteLine(e.Event.Message);
}
```

Of course, local events, as shown in the section 'Working with Events', can also be filtered.

Generally, after a subscriber (a Client) is only informed of events as long as he is in contact with the Server and has initiated a subscription, a subscriber will not know what events have already occurred prior to establishing a connection to the Server. If the Server is to inform subscribers of past events, subscribers can request them from the Server as follows. **In general, however, a Server is not obliged to provide past events.**

```
var subscription = client.SubscribeEvent(
        machineNodeId,
        HandleLocalEvents);

// Query most recent event information.
subscription.RefreshConditions();
```

Event Nodes with Conditions

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcEvent, OpcCondition und OpcEventSeverity.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A specialization of the **OpcEvent** (featured in the 'Working with Events' section) is the **OpcCondition** class. It serves to provide event data to which specific conditions are attached. Only in the case that a condition awarded to an Event Node is true will such an event be triggered. The information of the event includes information about the state of the condition as well as information related to the evaluation of the condition. Since this information can vary in complexity depending on the scenario, the **OpcCondition** represents the base class of all event data to which a condition is attached.

In addition to the general properties of an event (provided by the **OpcEvent** base class), one instance of the **OpcCondition** provides information that may be of interest to the Client for further processing of the event. This allows the Client to verify that, in general, the Server evaluates the event as relevant to a Client (see *IsRetained* property). Similarly, the Client can evaluate the state of the condition, that is, whether it is active or inactive (see *IsEnabled* property).

```
private static void HandleLocalEvents(
        object sender,
        OpcEventReceivedEventArgs e)
{
    var condition = e.Event as OpcCondition;

    if (condition.IsRetained) {
        Console.Write((condition.ClientUserId ?? "Comment") + ":");
        Console.WriteLine(condition.Comment);
    }
}
```

If the client does not want to further evaluate the condition, the client can deactivate it:

```
private static void HandleLocalEvents(object sender, OpcEventReceivedEventArgs e)
{
    var condition = e.Event as OpcCondition;

    if (condition.IsEnabled && condition.Severity < OpcEventSeverity.Medium)
        condition.Disable(client);
}
```

In addition, the client can also add a comment to the current state of the condition:

```
private static void HandleLocalEvents(object sender, OpcEventReceivedEventArgs e)
{
    var condition = e.Event as OpcCondition;

    if (condition != null)
        condition.AddComment(client, "Evaluated by me!");
}
```

Event Nodes with Dialog Conditions

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcCondition, OpcDialogCondition, OpcEventSeverity und OpcDialogRequestedEventArgs.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A specialization of the **OpcCondition** is the **OpcDialogCondition**. The condition associated with this event is a dialog with the subscribers. In this case, such a condition consists of a prompt, response options and information as to which option should be selected by default (*DefaultResponse* property), which option to confirm the dialog (*OkResponse* property) and which is used to cancel the dialog (*CancelResponse* property). When such a dialog-driven event is triggered, the Server waits for one of the subscribers to provide it with an answer in the form of the choice made based on the given answer options. The condition for further processing, the operations linked to the dialog, is thus the answer to a task, a question, an information or a warning. The information provided for this by the event can be processed as follows and reported back to the Server:

```
private static void HandleLocalEvents(object sender, OpcEventReceivedEventArgs e)
{
    var condition = e.Event as OpcDialogCondition;

    if (condition != null && condition.IsActive) {
        Console.WriteLine(condition.Prompt);
        Console.WriteLine("    Options:");

        var responseOptions = condition.ResponseOptions;

        for (int index = ; index < responseOptions.Length; index++) {
            Console.Write($"      [{index}] = {responseOptions[index].Value}");

            if (index == condition.DefaultResponse)
                Console.Write(" (default)");

            Console.WriteLine();
        }

        var respond = string.Empty;
        var respondOption = condition.DefaultResponse;

        do {
            Console.Write("Enter the number of the option and press Enter to respond: ");
            respond = Console.ReadLine();

            if (string.IsNullOrEmpty(respond))
                break;
        } while (!int.TryParse(respond, out respondOption));

        condition.Respond(client, respondOption);
    }
}
```

Apart from the standard event handling method, the **OpcClient** class also provides the *DialogRequested* event. If **OpcDialogCondition** event data is received by the Client and not answered by any handler, the Client executes the *DialogRequested* event to perform a dialog processing on it. This also simplifies the handling of the event data somewhat, since these can be passed on typed to the event handler:

```
client.DialogRequested += HandleDialogRequested;
...

private static void HandleDialogRequested(
        object sender,
        OpcDialogRequestedEventArgs e)
{
    // Just use the default response, here.
    e.SelectedResponse = e.Dialog.DefaultResponse;
}
```

You just need to set the *SelectedResponse* property of the event arguments. Calling the *Respond(...)* method of the **OpcDialogCondition** is done by the **OpcClient** after the execution of the event handler.

Event Nodes with Feedback Conditions

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcEvent, OpcCondition,

OpcAcknowledgeableCondition und OpcEventSeverity.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

Based on **OpcCondition** events, the **OpcAcknowledgeableCondition** is a specialization used as the base class for conditions with feedback requirements. Events of this type define that, when their condition is met, a “report with acknowledgment of receipt” is issued. The “return receipt” - that is the feedback - can be used to control further processes as well as to easily acknowledge hints and warnings. The feedback mechanism provided for this purpose is divided into two stages. While the first stage is a kind of “read receipt”, the second level is a kind of “read receipt with a nod”. OPC UA defines the read receipt as a simple confirmation and the read receipt as a nod with acknowledgment. For both types of recognition, the events provide corresponding *Confirm* and *Acknowledge* methods. By definition, the execution of the “acknowledge” process should make an explicit execution of the “confirm” process unnecessary. On the other hand, it is possible to first send a confirmation and then, separately, an acknowledgment. Regardless of the order and the type of feedback, a comment from the operator can optionally be specified for the confirm or acknowledge. An acknowledgment as feedback could be implemented as follows:

```
private static void HandleLocalEvents(object sender, OpcEventReceivedEventArgs e)
{
    var condition = e.Event as OpcAcknowledgeableCondition;

    if (condition != null && !condition.IsAcked) {
        Console.WriteLine($"Acknowledgment is required for condtion:
{condition.ConditionName}");
        Console.WriteLine($"  -> {condition.Message}");
        Console.Write("Enter your acknowlegment comment and press Enter to acknowledge: ");

        var comment = Console.ReadLine();
        condition.Acknowledge(client, comment);
    }
}
```

In addition, when processing this type of event, you can check whether the event has already been confirmed by Confirm (see *IsConfirmed* property) or by Acknowledge (see *IsAcked* property). **It should be noted that a Server must always define the interpretation itsefl as well as the logic following the respective feedback.** So whether a Server makes use of both feedback options or only one is left to the respective developer. In the best case, a Server uses at least the *Acknowledge* method, as it is defined by the specification as “stronger”.

Event Nodes with Alarm Conditions

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcAlarmCondition, OpcAcknowledgeableCondition und OpcEventSeverity.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

The most important implementation of the **OpcAcknowledgeableCondition** in OPC UA is the **OpcAlarmCondition**. With the help of **OpcAlarmCondition** events it is possible to define events whose behavior is comparable to a bedside timer. Accordingly, such an event becomes active (see *IsActive* property) if the condition associated with it is met. In the case of an alarm clock, for example, “reaching the alarm time”. For example, an alarm that is set with a wake-up time but should not be activated when it is reached is called a suppressed alarm (see *IsSuppressed* and *IsSuppressedOrShelved* property). But if an alarm becomes active, it can be shelved (see *IsSuppressedOrShelved* property). An alarm can be reset once (“One Shot Shelving”) or in time (“Timed Shelving”) (see *Shelving* Child Node). Alternatively, a reset

alarm can also be “unshelved” again (see *Shelving* Child Node).

```
private static void HandleLocalEvents(
        object sender,
        OpcEventReceivedEventArgs e)
{
    var alarm = e.Event as OpcAlarmCondition;

    if (alarm != null) {
        Console.Write($"Alarm {alarm.ConditionName} is");
        Console.WriteLine($"{(alarm.IsActive ? "active" : "inactive")}!");
    }
}
```

Event Nodes with discrete Alarm Conditions

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcDiscreteAlarm, OpcOffNormalAlarm und OpcTripAlarm.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

Based on the **OpcAlarmCondition** event data, there are several specializations that have been explicitly defined for specific types of alarms to further specify the form, reason or content of an alarm by the nature of the alarm. A subclass of such self-describing alarms are the discrete alarms. The basis for a discrete alarm is the **OpcDiscreteAlarm** class. It defines an alarm state that is used to classify types into alarm states, where the input for the alarm can only accept a certain number of possible values (e.g. true / false, running / paused / terminated). If an alarm represents a discrete condition that is considered abnormal, the **OpcOffNormalAlarm** or a subclass of it will be used. Starting from this alarm class, the framework offers a further concretization with the **OpcTripAlarm**. The **OpcTripAlarm** becomes active when, for example, an abnormal fault occurs on a monitored device, e.g. when the motor is shut down due to overload.

```
private static void HandleLocalEvents(object sender, OpcEventReceivedEventArgs e)
{
    var alarm = e.Event as OpcDiscreteAlarm;

    if (alarm != null) {
        if (alarm is OpcTripAlarm)
            Console.WriteLine("Trip Alarm!");
        else if (alarm is OpcOffNormalAlarm)
            Console.WriteLine("Off Normal Alarm!");
    }
}
```

Event Nodes with Alarm Conditions for Limits

The following types are used: OpcClient, OpcEventReceivedEventArgs und OpcLimitAlarm.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

If the Server checks process-specific limit values and then publishes the output of the check for limit value overruns / underruns, then the **OpcLimitAlarm** class represents the central starting point for entering the classes of limit alarms. Using this class limits are divided into up to four levels. To differentiate them, they are called LowLow, Low, High and HighHigh (called in order of their metric order). By definition, the Server does not need to define all limits.

```
private static void HandleLocalEvents(
        object sender,
        OpcEventReceivedEventArgs e)
{
    var alarm = e.Event as OpcLimitAlarm;

    if (alarm != null) {
        Console.Write(alarm.LowLowLimit);
        Console.Write(" ≤ ");
        Console.Write(alarm.LowLimit);
        Console.Write(" ≤ ");
        Console.Write(alarm.HighLimit);
        Console.Write(" ≤ ");
        Console.Write(alarm.HighHighLimit);
    }
}
```

Event Nodes with Alarm Conditions for exclusive Limits

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcLimitAlarm, OpcExclusiveLimitAlarm, OpcExclusiveDeviationAlarm, OpcExclusiveLevelAlarm und OpcExclusiveRateOfChangeAlarm.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A subclass of the **OpcLimitAlarm** events is the class **OpcExclusiveLimitAlarm**. As its name suggests, it serves to define limit alerts for exclusive boundaries. Such a limit alarm uses values for the boundaries that are mutually exclusive. This means that if a limit value has been exceeded / undershot, it is not possible for another limit value to be exceeded or undershot at the same time.

There are three further specializations of the **OpcExclusiveLimitAlarm** within the OPC UA.

OpcExclusiveDeviationAlarm
This type of alarm is used when a slight deviation from defined limits is detected.

OpcExclusiveLevelAlarm
This type of alarm is used when a limit is exceeded. This typically affects an instrument - such as a temperature sensor. This type of alarm becomes active when the observed value is above an upper limit or below a lower limit.

OpcExclusiveRateOfChangeAlarm
This type of alarm is used to report an unusual change or missing change in a measured value with respect to the rate at which the value has changed. The alarm becomes active if the rate at which the value changes exceeds or falls below a defined limit.

Event Nodes with Alarm Conditions for non-exclusive Limits

The following types are used: OpcClient, OpcEventReceivedEventArgs, OpcLimitAlarm, OpcNonExclusiveLimitAlarm, OpcNonExclusiveDeviationAlarm, OpcNonExclusiveLevelAlarm und OpcNonExclusiveRateOfChangeAlarm.

This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A subclass of the **OpcLimitAlarm** events is the class **OpcNonExclusiveLimitAlarm**. As its name suggests, it serves to define limit alerts for non-exclusive boundaries. Such a limit alarm uses values for the limits that are not mutually exclusive. This means that when a limit has been exceeded / undershot, that at the same time another limit may be exceeded / undershot. The limits that are thereby violated can be checked with the properties *IsLowLow*, *IsLow*, *IsHigh* and *IsHighHigh* of the event data.

There are three further specializations of the **OpcNonExclusiveLimitAlarm** within the OPC UA.

OpcNonExclusiveDeviationAlarm
This type of alarm is used when a slight deviation from defined limits is detected.

OpcNonExclusiveLevelAlarm
This type of alarm is used when a limit is exceeded. This typically affects an instrument - such as a temperature sensor. This type of alarm becomes active when the observed value is above an upper limit or below a lower limit.

OpcNonExclusiveRateOfChangeAlarm
This type of alarm is used to report an unusual change or missing change in a measured value with respect to the rate at which the value has changed. The alarm becomes active if the rate at which the value changes exceeds or falls below a defined limit.

Editing the Address Space

Adding Nodes

The following types are used: OpcClient, OpcAddNode, OpcAddNodeResult, OpcAddNodeResultCollection, OpcAddDataItemNode, OpcAddAnalogItemNode, OpcAddObjectNode, OpcAddFolderNode, OpcAddDataVariableNode and OpcAddPropertyNode.

While a Server provides a predefined set of “default nodes” to its Clients, the Clients can cause the Server to provide additional nodes. This is done by using the “AddNodes” interface of the server. Starting from the OpcAddNode class, the framework provides many further subclasses that can be used to create type-specific nodes. A new folder node can thus be created in the following way:

```
OpcAddNodeResult result = client.AddNode(new OpcAddFolderNode(
    name: "Jobs",
    nodeId: OpcNodeId.Null,
    parentNodeId: "ns=2;s=Machine"));
```

The parameters used provide the necessary minimum of information required. The first parameter “name” is used for the Name property, the DisplayName property, the SymbolicName property, and the Description property of the Node. The second parameter “nodeId” tells the Server which identifier is to be used for the node. In case there the identifier is already used in the address space of the Nodes of the Server for another Node, the Node is not created and the Client receives the result code “BadNodeIdRejected”. If OpcNodeId.Null is used instead, as shown in the example, the server will automatically create and assign a new identifier for the Node. The parameter “parentNodeId” finally defines the identifier of the parent Node under which the new Node is to be created in the tree.

Calling the AddNode method returns an instance of the OpcAddNodeResult class. In addition to the information about the result of the operation, it also provides the identifier that was finally used for the new Node:

```
if (result.IsGood)
    Console.WriteLine($"NodeId of 'Jobs': {result.NodeId}");
else
    Console.WriteLine($"Failed to add node: {result.Description}");
```

Besides the possibility to add a single Node, several Nodes can be added simultaneously:

```
OpcNodeId jobsNodeId = result.NodeId;

OpcAddNodeResultCollection results = client.AddNodes(
        new OpcAddDataVariableNode<string>("CurrentJob", jobsNodeId),
        new OpcAddDataVariableNode<string>("NextJob", jobsNodeId),
        new OpcAddDataVariableNode<int>("NumberOfJobs", jobsNodeId));
```

Calling the AddNodes method returns an instance of the OpcAddNodeResultCollection class. Which contains OpcAddNodeResult instances that can be evaluated and processed in the same way as described above.

In addition to the possibility of adding one or more Nodes at the same time, it is possible to pass entire trees of Nodes to the methods AddNode and AddNodes:

```
OpcAddNodeResultCollection results = client.AddNodes(
        new OpcAddObjectNode(
                "JOB001",
                nodeId: OpcNodeId.Null,
                parentNodeId: jobsNodeId,
                new OpcAddDataVariableNode<sbyte>("Status", -1),
                new OpcAddDataVariableNode<string>("Serial", "J01-DX-11.001"),
                new OpcAddAnalogItemNode<float>("Speed", 1200f) {
                    EngineeringUnit = new OpcEngineeringUnitInfo(5067859, "m/s", "metre per
second"),
                    EngineeringUnitRange = new OpcValueRange(5400, ),
                    Definition = "DB100.DBW 0"
                },
                new OpcAddObjectNode(
                        "Setup",
                        new OpcAddPropertyNode<bool>("UseCutter"),
                        new OpcAddPropertyNode<bool>("UseDrill")),
                new OpcAddObjectNode(
                        "Schedule",
                        new OpcAddPropertyNode<DateTime>("EarliestStartTime"),
                        new OpcAddPropertyNode<DateTime>("LatestStartTime"),
                        new OpcAddPropertyNode<TimeSpan>("EstimatedRunTime"))),
        new OpcAddObjectNode(
                "JOB002",
                nodeId: OpcNodeId.Null,
                parentNodeId: jobsNodeId,
                new OpcAddDataVariableNode<sbyte>("Status", -1),
                new OpcAddDataVariableNode<string>("Serial", "J01-DX-53.002"),
                new OpcAddAnalogItemNode<float>("Speed", 3210f) {
                    EngineeringUnit = new OpcEngineeringUnitInfo(5067859, "m/s", "metre per
second"),
                    EngineeringUnitRange = new OpcValueRange(5400, ),
                    Definition = "DB200.DBW 0"
                },
                new OpcAddObjectNode(
                        "Setup",
                        new OpcAddPropertyNode<bool>("UseCutter"),
                        new OpcAddPropertyNode<bool>("UseDrill")),
                new OpcAddObjectNode(
                        "Schedule",
                        new OpcAddPropertyNode<DateTime>("EarliestStartTime"),
                        new OpcAddPropertyNode<DateTime>("LatestStartTime"),
                        new OpcAddPropertyNode<TimeSpan>("EstimatedRunTime"))));
```

Such a tree can also be constructed using the corresponding properties:

```
var jobsNodeId = result.NodeId;

var job = new OpcAddObjectNode(
        name: "JOB003",
        nodeId: OpcNodeId.Null,
        parentNodeId: jobsNodeId);

job.Children.Add(new OpcAddDataVariableNode<sbyte>("Status", -1));
job.Children.Add(new OpcAddDataVariableNode<string>("Serial", "J01-DX-78.003"));
job.Children.Add(new OpcAddAnalogItemNode<float>("Speed", 1200f) {
    EngineeringUnit = new OpcEngineeringUnitInfo(5067859, "m/s", "metre per second"),
    EngineeringUnitRange = new OpcValueRange(5400, ),
    Definition = "DB100.DBW 0"
});

var setup = new OpcAddObjectNode("Setup");
setup.Children.Add(new OpcAddPropertyNode<bool>("UseCutter"));
setup.Children.Add(new OpcAddPropertyNode<bool>("UseDrill"));

job.Children.Add(setup);

var schedule = new OpcAddObjectNode("Schedule");
schedule.Children.Add(new OpcAddPropertyNode<DateTime>("EarliestStartTime"));
schedule.Children.Add(new OpcAddPropertyNode<DateTime>("LatestStartTime"));
schedule.Children.Add(new OpcAddPropertyNode<TimeSpan>("EstimatedRunTime"));

job.Children.Add(schedule);

OpcAddNodeResult result = client.AddNode(job);
```

In case there other type definitions shall be used for the Nodes than those provided by the corresponding subclasses of OpcAddNode, then it is possible to create object and variable Nodes based on their type definition:

```
client.AddObjectNode(OpcObjectType.DeviceFailureEventType, "FailureInfo");
client.AddVariableNode(OpcVariableType.XYArrayItem, "Coordinates");
```

Unlike adding nodes based on Foundation-defined type definitions, it is also possible to add nodes based on the identifier of their type definition. For this, the type to be used must be declared in advance via an object or variable-specific type definition. This can then be used again and again to add corresponding nodes:

```
// Declare Job Type
var jobType = OpcAddObjectNode.OfType(OpcNodeId.Of("ns=2;s=Types/JobType"));

client.AddNodes(
        jobType.Create("JOB001", nodeId: OpcNodeId.Null, parentNodeId: jobsNodeId),
        jobType.Create("JOB002", nodeId: OpcNodeId.Null, parentNodeId: jobsNodeId),
        jobType.Create("JOB003", nodeId: OpcNodeId.Null, parentNodeId: jobsNodeId),
        jobType.Create("JOB004", nodeId: OpcNodeId.Null, parentNodeId: jobsNodeId));

var scheduleNodeId = OpcNodeId.Parse("ns=2;s=Machine/JOB002/Schedule");

// Declare Shift Time Type
var shiftTimeType = OpcAddVariableNode.OfType(OpcNodeId.Of("ns=2;s=Types/ShiftTimeType"));

OpcAddNodeResult result = client.AddNode(new OpcAddObjectNode(
        "ShiftPlanning",
        nodeId: OpcNodeId.Null,
        parentNodeId: scheduleNodeId,
        shiftTimeType.Create("Early"),
        shiftTimeType.Create("Noon"),
        shiftTimeType.Create("Late")));
```

Deleting Nodes

The following types are used: OpcClient, OpcDeleteNode, OpcStatus and OpcStatusCollection.

Server-provided and client-added nodes can be deleted using the Server's “DeleteNodes” interface. This requires primarily the identifier of the node to be deleted:

```
OpcStatus result = client.DeleteNode("ns=2;s=Machine/Jobs");
```

The possibility shown in the above example uses an instance of the OpcDeleteNode class for deletion, which by default also includes the deletion of all references pointing to the Node. However, if the references to the Node are to be retained, the parameter “includeTargetReferences” have to be set to the value “false”:

```
OpcStatus result = client.DeleteNode(
        "ns=2;s=Machine/Jobs",
        includeTargetReferences: false);
```

Besides the possibility to delete a single Node, several Nodes can be deleted at the same time:

```
OpcStatusCollection results = client.DeleteNodes(
        new OpcDeleteNode("ns=2;s=Machine/Jobs/JOB001"),
        new OpcDeleteNode("ns=2;s=Machine/Jobs/JOB002"),
        new OpcDeleteNode("ns=2;s=Machine/Jobs/JOB003"));
```

Adding References

The following types are used: OpcClient, OpcAddReference, OpcStatus and OpcStatusCollection.

Nodes that already exist in the address space of a Server can have different relationships to one another. These relationships are described by so-called references in the address space of the Server. While nodes are physically placed in the role of the parent or child Node, there may be more logical relationships

between them. These relationships thus serve to define more precisely the function and dependencies of the Nodes with each other. In addition, such trees can be used to define additional trees in the address space of the Server without having to reorganize existing nodes.

To add a reference, the Client uses the Server's “AddReferences” interface as follows:

```
client.AddReference(
        "ns=2;s=Machines/MAC01",
        targetNodeId: "ns=2;s=Plant",
        targetNodeCategory: OpcNodeCategory.Object);
```

The example shown adds a relationship starting from the Node with the identifier “ns=2;s=Plant” to the Node “ns=2;s=Machines/MAC01” of the type “Organizes”.

The statement shown corresponds 1:1 to the result of the following example:

```
client.AddReference(
        "ns=2;s=Machines/MAC01",
        targetNodeId: "ns=2;s=Plant",
        targetNodeCategory: OpcNodeCategory.Object,
        direction: OpcReferenceDirection.ParentToChild,
        referenceType: OpcReferenceType.Organizes);
```

While the first identifier always indicates the source Node, the parameter “targetNodeId” specifies the identifier of the destination Node. The additional parameter “targetNodeCategory” must correspond to the Category property (= NodeClass according to Foundation) of the destination Node, because this ensures that the Server knows that the desired destination Node is sufficiently known.

In addition to the possibility to add a single reference, several references can be added simultaneously:

```
client.AddReferences(
        new OpcAddReference("ns=2;s=Machines/MAC01", "ns=2;s=Plant01",
OpcNodeCategory.Object),
        new OpcAddReference("ns=2;s=Machines/MAC02", "ns=2;s=Plant01",
OpcNodeCategory.Object),
        new OpcAddReference("ns=2;s=Machines/MAC03", "ns=2;s=Plant02",
OpcNodeCategory.Object));
```

The example above organizes three nodes each representing one machine for itself below the “Machines” Node below the “Plant01” and the “Plant02” Nodes. The “Organizes” relationship used here by default means that the nodes are still available below the “Machines” Node, but also below the “Plant01” Node, the Nodes “MAC01” and “MAC02”, as well as the Node “MAC03” below the Node “Plant02”.

Deleting References

The following types are used: OpcClient, OpcDeleteReference, OpcStatus and OpcStatusCollection.

Already existing references between the Nodes in the address space of the Server can be deleted via the “DeleteReferences” interface of the Server:

```
client.DeleteReference(
        nodeId: "ns=2;s=Machines/MAC03",
        targetNodeId: "ns=2;s=Plant");
```

In this case, the example shown deletes all “Organizes” references in the direction of the Node with the identifier “ns=2;s=Machines/MAC03” as well as in the direction of the Node with the identifier

“ns=2;s=Plant” between the both Nodes exist.

If, on the other hand, you want to delete only “Organizes” references from the source to the destination Node in one specific direction, you can do this as follows:

```
client.DeleteReference(
        nodeId: "ns=2;s=Machines/MAC03",
        targetNodeId: "ns=2;s=Plant",
        direction: OpcReferenceDirection.ChildToParent);
```

If, on the other hand, you want to delete references that are not of the “Organizes” type, they can be specified using the additional “referenceType” or “referenceTypeId” parameter as follows:

```
client.DeleteReference(
        nodeId: "ns=2;s=Machines/MAC03",
        targetNodeId: "ns=2;s=Plant",
        direction: OpcReferenceDirection.ChildToParent,
        referenceType: OpcReferenceType.HierarchicalReferences);
```

In addition to the possibility to delete individual references, several references can be deleted at the same time:

```
client.DeleteReferences(
        new OpcDeleteReference("ns=2;s=Machines/MAC01", "ns=2;s=Plant01"),
        new OpcDeleteReference("ns=2;s=Machines/MAC02", "ns=2;s=Plant01"),
        new OpcDeleteReference("ns=2;s=Machines/MAC03", "ns=2;s=Plant02"));
```

Client Configuration

General Configuration

The following types are used here: OpcClient, OpcCertificateStores und OpcCertificateStoreInfo.

In all code snippets depicted here the Client is always configured via the Code (if the default configuration of the Client is not applied). The **OpcClient** instance is the certral port for configuring the Client application, the session parameter and the connection parameter. All settings concerning security can be found as an instance of the **OpcClientSecurity** class via the *Security* property of the Client. All settings concerning the Certificate Store can be found as an instance of the **OpcCertificateStores** class via the *CertificateStores* property of the Client.

If the Client shall also be configurable via XML, the configuration of the Client can be loaded either from a specific or a random XML file. The necessary steps are described in the section “Preparing the Client Configuration via XML”.

As soon as the according preparations for configuring the Client configuration via XML have been made, the settings can be loaded as follows:

- Loading the configuration file via the App.config

  ```
  client.Configuration =
  OpcApplicationConfiguration.LoadClientConfig("Opc.UaFx.Client");
  ```

- Loading the configuration file via the path to the XML file

```
client.Configuration =
OpcApplicationConfiguration.LoadClientConfigFile("MyClientAppNameConfig.xml");
```

Amongst others, the following options are provided for configuring the Client application:

- Configuring the application
  - via Code:

```
// Default: Value of AssemblyTitleAttribute of entry assembly.
client.ApplicationName = "MyClientAppName";

// Default: A null reference to auto complete on connect to "urn::" +
ApplicationName
client.ApplicationUri = "http://my.clientapp.uri/";
```

  - via XML (underneath the *OpcApplicationConfiguration* element):

```
  <ApplicationName>MyClient Configured via XML</ApplicationName>
  <ApplicationUri>http://myclient/application</ApplicationUri>
```

- Configuring the session parameters
  - via Code:

```
client.SessionTimeout = 30000;          // Default: 60000
client.SessionName = "My Session Name"; // Default: null
```

  - via XML (underneath the *OpcApplicationConfiguration* element):

```
    <DefaultSessionTimeout>600000</DefaultSessionTimeout>
```

- Configuring the connection parameters
  - via Code:

```
client.OperationTimeout = 10000;        // Default: 60000
client.DisconnectTimeout = 5000;        // Default: 10000
client.ReconnectTimeout = 5000;         // Default: 10000
```

  - via XML (underneath the *OpcApplicationConfiguration* element):

```
    <OperationTimeout>120000</OperationTimeout>
```

- Configuring the Certificate Store
  - via Code:

```
// Default: ".\CertificateStores\Trusted"
client.CertificateStores.ApplicationStore.Path
        = @"%LocalApplicationData%\MyClientAppName\App Certificates";

// Default: ".\CertificateStores\Rejected"
client.CertificateStores.RejectedStore.Path
        = @"%LocalApplicationData%\MyClientAppName\Rejected Certificates";

// Default: ".\CertificateStores\Trusted"
client.CertificateStores.TrustedIssuerStore.Path
        = @"%LocalApplicationData%\MyClientAppName\Trusted Issuer Certificates";

// Default: ".\CertificateStores\Trusted"
client.CertificateStores.TrustedPeerStore.Path
        = @"%LocalApplicationData%\MyClientAppName\Trusted Peer Certificates";
```

  - via XML (underneath the *OpcApplicationConfiguration* element):

```
  <SecurityConfiguration>
    <ApplicationCertificate>
      <StoreType>Directory</StoreType>
      <StorePath>.\CertificateStores\App</StorePath>
      <SubjectName>CN=MyClient, C=US, S=Arizona, O=YourCompany,
DC=localhost</SubjectName>
      <!-- <Thumbprint>3a35fb798fc6dee8a7e7e4652b0e28fc14c6ee0f</Thumbprint> -->
    </ApplicationCertificate>

    <TrustedIssuerCertificates>
      <StoreType>Directory</StoreType>
      <StorePath>.\CertificateStores\Trusted</StorePath>
    </TrustedIssuerCertificates>

    <TrustedPeerCertificates>
      <StoreType>Directory</StoreType>
      <StorePath>.\CertificateStores\Trusted</StorePath>
    </TrustedPeerCertificates>

    <NonceLength>32</NonceLength>

    <RejectedCertificateStore>
      <StoreType>Directory</StoreType>
      <StorePath>.\CertificateStores\Rejected</StorePath>
    </RejectedCertificateStore>
  </SecurityConfiguration>
```

Certificate Configuration

The following types are used here: OpcClient, OpcCertificateManager, OpcClientSecurity, OpcCertificateStores and OpcCertificateStoreInfo.

Certificates of the type .der, .pem, **.pfx** and **.p12** are recommended. If the Client shall use a secure Server endpoint (where the **OpcSecurityMode** equals *Sign* or *SignAndEncrypt*), the certificate has to have a private key.

1. An **existing certificate** is loaded from any path:
   ```
   var certificate = OpcCertificateManager.LoadCertificate("MyClientCertificate.pfx");
   ```
2. A **new certificate** is generated (in memory):
   ```
   var certificate = OpcCertificateManager.CreateCertificate(client);
   ```
3. Save a certificate in any path:
   ```
   OpcCertificateManager.SaveCertificate("MyClientCertificate.pfx", certificate);
   ```
4. Set the Client certificate:
   ```
   client.Certificate = certificate;
   ```
5. The certificate has to be stored in the **Application Store**:
   ```
   if (!client.CertificateStores.ApplicationStore.Contains(certificate))
       client.CertificateStores.ApplicationStore.Add(certificate);
   ```
6. If **no or an invalid certificate** is used, a new certificate is generated / used by default. If the Client

shall only use the mentioned certificate this function has to be deactivated. For **deactivating the function** set the property **AutoCreateCertificate** to the value *false*:

```
client.CertificateStores.AutoCreateCertificate = false;
```

User Identity Configuration

The following types are used here: OpcClient, OpcUserIdentity, OpcClientIdentity, OpcCertificateIdentity, OpcClientSecurity, OpcCertificateStores and OpcCertificateStoreInfo.

If a Server is expecting additional information about the user identity other than the Client certificate, the user has to be set via the *UserIdentity* property. You can choose between identities based on username-password and a certificate. If the Server supports an anonymized user identity, no special identity has to be set.

- Setting a user identity consisting of **username-password**:

```
client.Security.UserIdentity = new OpcClientIdentity("userName", "password");
```

- Setting a user identity via **certificate (with private key)**:

```
client.Security.UserIdentity = new OpcCertificateIdentity(new
X509Certificate2("Doe.pfx"));
```

- Setting an **anonymous** user identity (pre-configured by default):

```
client.Security.UserIdentity = null;
```

Server Endpoint Configuration

The following types are used here: OpcClient, OpcClientSecurity, OpcSecurityPolicy, OpcSecurityMode, OpcSecurityAlgorithm and OpcDiscoveryClient.

By default the Client chooses the Server endpoint with the **simplest security configuraton**. Hereby it chooses an endpoint with the **OpcSecurityMode** of *None*, *Sign* or *SignAndEncrypt*. According to the OPC Foundation the level of a policy of an endpoint serves as a relative measure for security mechanisms used by the endpoint. Per definition an endpoint with a higher level is more secure than an endpoint with a lower level. By default the Client ignores the Policy-Level of the endpoints.

1. If the Client shall exclusively consider secure endpoints, the **UseOnlySecureEndpoints** property has to be set to the value *true*:

```
client.Security.UseOnlySecureEndpoints = true;
```

2. If the Client shall choose an endpoint defining the highest Policy-Level, the **UseHighLevelEndpoint** property has to be set to the value *true*:

```
client.Security.UseHighLevelEndpoint = true;
```

3. If the Client shall choose an endpoint with the best security configuration, the **EndpointPolicy** property has to be set as follows:

```
client.Security.EndpointPolicy = new OpcSecurityPolicy(
        OpcSecurityMode.None, OpcSecurityAlgorithm.Basic256);
```

4. To examine the endpoints provided by the Server use the **OpcDiscoveryClient**:

```
using (var client = new OpcDiscoveryClient("opc.tcp://localhost:4840/")) {
    var endpoints = client.DiscoverEndpoints();

    foreach (var endpoint in endpoints) {
        // Your code to operate on each endpoint.
    }
}
```

Further Security Settings

The following types are used here: OpcClient, OpcClientSecurity, OpcCertificateValidationFailedEventArgs, OpcCertificateStores and OpcCertificateStoreInfo.

A Server sends its certificate to the Client for authentication whilst connecting. Using the Server certificate, the Client can decide if to establish a connection to this Server and therefore trust it.

- For additional checking of the domains deposited in the Server certificate the property **VerifyServersCertificateDomains** can be used (deactivated by default):

```
client.Security.VerifyServersCertificateDomains = true;
```

- If the Client shall accept **only trustworthy** certificates, the default acceptance of all certificates has to be deactivated as follows:

```
client.Security.AutoAcceptUntrustedCertificates = false;
```

- As soon as the default acceptance of all certificates has been deactivated, a custom checking of certificates should be considered:

```
client.CertificateValidationFailed += HandleCertificateValidationFailed;
...
private void HandleCertificateValidationFailed(
        object sender,
        OpcCertificateValidationFailedEventArgs e)
{
    if (e.Certificate.SerialNumber == "...")
        e.Accept = true;
}
```

- If the Server certificate is categorized as **untrusted** it can be manually declared **trusted**. Therefore it has to be saved in the TrustedPeerStore:

```
// In context of the event handler the sender is an OpcClient.
var client = (OpcClient)sender;

if (!client.CertificateStores.TrustedPeerStore.Contains(e.Certificate))
    client.CertificateStores.TrustedPeerStore.Add(e.Certificate);
```

Configuration via XML

If the Client shall also be configurable via XML, the configuration of the Client can be directly loaded either from a specific or from a random XML file.

Using a certain XML file it has to show the following default XML tree:

```
<?xml version="1.0" encoding="utf-8" ?>
<OpcApplicationConfiguration
    xmlns="http://opcfoundation.org/UA/SDK/Configuration.xsd"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:ua="http://opcfoundation.org/UA/2008/02/Types.xsd"
    schemaLocation="AppConfig.xsd">
```

In case that a random XML file shall be used for the configuration, a .config file has to be created that refers to the XML file the configuration of the Client shall be loaded from. The following section shows which entries the .config file therefore has to contain and which structure the XML file has to show.

Creating and preparing the App.config of the application:

1. Add an App.config (if not already existing) to the project
2. Insert the following *configSections* element underneath the *configuration* element:

```
<?xml version="1.0" encoding="utf-8"?>
<configuration>
  <configSections>
    <section name="Opc.UaFx.Client"
             type="Opc.Ua.ApplicationConfigurationSection,
                   Opc.UaFx.Advanced,
                   Version=2.0.0.0,
                   Culture=neutral,
                   PublicKeyToken=0220af0d33d50236" />
  </configSections>
```

3. Also insert the following *Opc.UaFx.Client* element underneath the *configuration* element:

```
  <Opc.UaFx.Client>
    <ConfigurationLocation xmlns="http://opcfoundation.org/UA/SDK/Configuration.xsd">
      <FilePath>ClientConfig.xml</FilePath>
    </ConfigurationLocation>
  </Opc.UaFx.Client>
```

4. The value of the *FilePath* element can show towards a random file path where the XML configuration file to be used can be found. The value depicted here would refer to a configuration file lying next to the application.
5. Save the changes to the App.config

Creating and preparing the XML configuration file:

1. Create an XML file with the file name used in the App.config and save the used path.
2. Insert the following default XML tree for XML configuration files:

```
<?xml version="1.0" encoding="utf-8" ?>
<OpcApplicationConfiguration
    xmlns="http://opcfoundation.org/UA/SDK/Configuration.xsd"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:ua="http://opcfoundation.org/UA/2008/02/Types.xsd"
    schemaLocation="AppConfig.xsd">
```

3. Save the changes to the XML file.

Client Application Delivery

This is how you prepare your OPC UA Client application for the use in productive environments.

Application certificates - *Using a concrete certificate*
For productive use don't use a certificate automatically generated by the Framework.

If you already have an appropriate certificate for your application you can load your PFX-based certificate from any random Store and assign it to the Client instance via the **OpcCertificateManager**:

```
var certificate = OpcCertificateManager.LoadCertificate("MyClientCertificate.pfx");
client.Certificate = certificate;
```

Note that the application name has to be included in the certificate as “Common Name” (CN) and has to match with the value of the *AssemblyTitle* attribute:

```
[assembly: AssemblyTitle("<Common Name (CN) in Certificate>")]
```

If that isn't the case you have to set the name used in the certificate via the **ApplicationName** property of the Client instance. If the “Domain Component” (DC) part is used in the certificate the value of the **ApplicationUri** property of the application has to show the same value:

```
client.ApplicationName = "<Common Name (CN) in Certificate>";
client.ApplicationUri = new Uri("<Domain Component (DC) in Certificate>");
```

If you don't already have an appropriate certificate you can use as an application certificate for your Client you should at least create and use a self-signed certificate via the Certificate Generator of the OPC Foundation. The Certificate Generator (Opc.Ua.CertificateGenerator.exe) included in the SDK of the Framework is opened as follows:

```
Opc.Ua.CertificateGenerator.exe -sp . -an MyClientAppName
```

The first parameter (-sp) sets saving the certificate in the current directory. The second parameter (-an) sets the name of the Client application using the application certificate. Replace “MyClientAppName” by the name of your Client application. Note that **the Framework for chosing the application certificate uses the value of the *AssemblyTitle* attribute and therefore the same value as stated in this attribute is used for “MyClientAppName”**. In alternative to the value in the *AssemblyTitle* attribute the value used in the application certificate can be set via the **ApplicationName** property of the Client instance:

```
client.ApplicationName = "MyDifferentClientAppName";
```

It is important that either the value of the *AssemblyTitle* attribute or the value of the **ApplicationName** property equals the value of the second parameter (-an). If you want to set further properties of the certificate as, for example, the validity in months (default 60 months) or the name of the company or the names of the domains the Client will be working on, call the generator with the parameter “/?” in order to receive a list of all further / possible parameter values:

```
Opc.Ua.CertificateGenerator.exe /?
```

After the Certificate Generator was opened with the corresponding parameters, the folders “certs” and “private” are in the current directory. Without changing the names of the folders and the files, copy both folders in the directory that you set as Store for the application certificates. By default that is the folder “Trusted” in the folder “CertificateStores” next to the application.

If you have set the parameter “ApplicationUri” (-au) you have to set the same value on the **ApplicationUri** property of the Client instance:

```
client.ApplicationUri = new Uri("<ApplicationUri>");
```

Configuration Surroundings - *All files necessary for an XML-based configuration*

If the application shall be configurable through a random XML file referenced in the App.config, App.config has to be in the same directory as the application and hold the name of the application as a prefix:

```
<MyClientAppName>.exe.config
```

If the application is configured through a (certain) XML file, ensure that the file is accessible for the application.

Licensing

The OPC UA SDK comes with an **evaluation license which can be used unlimited for each application run for 30 minutes**. If this restriction limits your evaluation options, you can request another evaluation license from us.

After receiving your personalized **license key for OPC UA Client development** it has to be committed to the framework. Hereto insert the following code line into your application **before** accessing the **OpcClient class** for the first time. Replace *<insert your license code here>* with the license key you received from us.

```
Opc.UaFx.Client.Licenser.LicenseKey = "<insert your license code here>";
```

If you purchased a **bundle license key for OPC UA Client and Server development** from us, it has to be committed to the framework as follows:

```
Opc.UaFx.Licenser.LicenseKey = "<insert your license code here>";
```

Additionally you receive information about the license currently used by the framework via the *LicenseInfo* property of the **Opc.UaFx.Client.Licenser class** for Client licenses and via the **Opc.UaFx.Licenser class** for bundle licenses. This works as follows:

```
ILicenseInfo license = Opc.UaFx.Client.Licenser.LicenseInfo;

if (license.IsExpired)
    Console.WriteLine("The OPA UA SDK license is expired!");
```

Note that a once set **bundle license becomes ineffective by additionally committing a Client license key**!

In the course of development/evaluation, it is mostly irrelevant whether the test license or the license already purchased is being used. However, as soon as the application goes into productive use, it is annoying if the application stops working during execution due to an invalid license. For this reason, we recommend implementing the following code snippet in the Client application and at least executing it when the application is started:

```
#if DEBUG
    Opc.UaFx.Client.Licenser.FailIfUnlicensed();
#else
    Opc.UaFx.Client.Licenser.ThrowIfUnlicensed();
#endif
```

[1)] The *OPC UA Wrapper Server* is automatically started by the OPC UA Client or reused if it already exists. The *OPC UA Wrapper Server* 'wraps' the accesses of the OPC UA Client and sends them to the *OPC Classic Server* the answers received from the *OPC Classic Server* are sent to the *OPC UA Wrapper Server* as OPC UA responses to *OPC UA Client* back again.

Server Development Introduction

The Server

Start

This is happening on calling 'Start':

1. Checking, if an **address was set** (Address Property).
2. The Server changes its status (**OpcServer.State** property) to the value ***Starting***.
3. The Server **checks its configuration** for validity and conclusiveness.
4. Next the Server tries to **create a host for every endpoint description**.
5. What follows is the **start of all Managers** (NodeManager, SessionManager, ...)
6. Finally, **every created host** responsible for the endpoint-specific communication with the Client gets **started**.
7. The Server changes its status (**OpcServer.State** property) to the value ***Started***.

Stop

This is happening on calling 'Stop':

1. The Server changes its status (**OpcServer.State** property) to the value ***Stopping***.
2. **Closing all Managers** (NodeManager, SessionManager, ...)
3. The Server **releases** all **gathered resources**.
4. **Closing** the **hosts of endpoint descriptions**.
5. The Server changes its status (**OpcServer.State** property) to the value ***Stopped***.

Parameters

In order for the Server to be able to give the Clients access to its OPC UA Services, the right parameters have to be determined. **In general** the **server address** (**OpcServer.Address** property) **is needed**. The Uri instance (= Uniform Resource Identifier) supplies all Clients the primarily necessary information via the server. For example, the server address “opc.tcp://192.168.0.80:4840” contains the information of the concept “opc.tcp” (possible are “http”, “https”, “opc.tcp”, “net.tcp” and “net.pipe”), which determines via which protocol the data shall be exchanged. Generally, “opc.tcp” is advisable for OPC UA Servers in a local network. Servers out of the local network should use “http”, even better “https”. Furthermore the address defines that the server is carried out on the computer with the IP address “192.168.0.80” and listens to requests via the port with the number “4840” (which is default for OPC UA, customized port numbers are also possible). Instead of the static IP address the DNS name of the computer can also be used, so instead of “127.0.0.1” you could also use “localhost”.

If the server shall provide **no endpoint** for data exchange with savety mode **“None”** (also additionally possible are “Sign” and “SignAndEncrypt”) as its policy, **at least one Endpoint-Policy has to be** manually **configured** (**OpcServer.Security.EndpointPolicies** property). If, however, an **endpoint with the Property “None”** is supplied by the Server, a Client can select this one automatically for an easy and quick connection. When a policy level (a number) is **assigned according to the OPC Foundation** to the separate Endpoint Policies during the definition of the endpoints, Clients can handle those appropriately. Here the OPC intends that the higher the level of the Policy of an endpoint, the “better” that endpoint (note that this is merely a neither watched nor imposed guideline).

If the Server shall use an access control, for example via an ACL (= Access Control List), **the user data has to be determined for identification of possible / valid identities of users** of the Server (this also works in a running system). Here it is possible to determine the identities of users through a username-password pair (**OpcServerIdentity** class) or through a certificate (**OpcCertificateIdentity** class). Those identities have then to be **communicated to the Server** (**OpcServer.Security.UserNameAcl/CertificateAcl** property). Those access control lists have to be activated in order for the server to recognize them (**OpcServer.Security.UserNameAcl/CertificateAcl.IsEnabled** property).

Endpoints

Endpoints result from the crossing of the used Base-Addresses of the Server and the security strategies supported by the Server. The results are the Base-Addresses of every scheme-port pair supported, while several schemes (possible are “http”, “https”, “opc.tcp”, “net.tcp” and “net.pipe”) can be determined for data exchange on different ports. The hereby linked policies determine the procedure during the data exchange. Consisting of the Policy Level, the Security-Mode and the Security-Algorithm, every policy determines the kind of secure data exchange.

For example, when two Security-Policies are followed, they can be defined as follows:

- Security-Policy A: Level=0, Security-Mode=None, Security-Algorithm=None
- Security-Policy B: Level=1, Security-Mode=Sign, Security-Algorithm=Basic256

When furthermore, for example, three Base-Addresses are combined for different schemes as follows:

- Base-Address A: "https://mydomain.com/"
- Base-Address B: "opc.tcp://192.168.0.123:4840/"
- Base-Address C: "opc.tcp://192.168.0.123:12345/"

The results will be the following endpoint descriptions through the crossing:

- Endpoint 1: Address="https://mydomain.com/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 2: Address="https://mydomain.com/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256
- Endpoint 3: Address="opc.tcp://192.168.0.123:4840/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 4: Address="opc.tcp://192.168.0.123:4840/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256
- Endpoint 5: Address="opc.tcp://192.168.0.123:12345/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 6: Address="opc.tcp://192.168.0.123:12345/", Level=1, Security-Mode=Sign, Security-

Algorithm=Basic256

Here the address part of the endpoint is always determined by the Server (via constructor or via **Address** property). While the Server defines an endpoint with the Security-Mode “None” by default, the policy of the endpoint has to be configured manually (**OpcServer.Security.EndpointPolicies** property) when none of this kind or additional ones shall be used.

Information about Certificates

Certificates in OPC UA

Certificates are used to **ensure** the **authenticity** and **integrity** of Client and Server applications. Therefore they act as a kind of identity card for Client as well as Server application. This “identification card” has to be stored somewhere as it exists as a form or data. The decision on where certificates are stored is individual.

There are different types of Stores for certificates:

- **Store for user certificates**
  The Store also called **Application Certificate Store** exclusively contains certificates of those applications that use this Store as an Application Certificate Store. Here a Client / Server application saves its own certificate.
- **Store for certificates from trustworthy certificate issuers**
  The Store also called **Trusted Issuer Certificate Store** exclusively contains certificates from certificate issuers that issues further certificates. Here a Client / Server application saves all certificates from issuers whose certificates shall be treated as trusted by default.
- **Store for trustworthy certificates**
  The Store also called **Trusted Peer Store** exclusively contains certificates treated as trusted. Here a Client saves the **certificates from trusted Servers** and a Server saves the **certificates from trusted Clients**.
- **Store for rejected certificates**
  The Store also called **Rejected Certificate Store** exclusively contains certificates that are decreed as not trusted. Here a Client saves the **certificates from not trusted Servers** and a Server saves the **certificates from not trusted Clients**.

Regardless of the Store being located somewhere in the system or in the data system via a list, generally certificates in the **Trusted Store** are **trusted** and certificates in the **Rejected Store** are untrusted. Certificates not belonging to eeither of the former are automatically saved in the Trusted Store, if the certificate of the certificate issuer mentioned in the certificate is deposited in the Trusted Issuer Store; otherwise it is automatically saved in the Rejected Store. Even if a trustworthy certificate has expired or if its deposited information cannot be successfully verified through the certification center the certificate is graded as not trustworthy and saved in the Rejected Store. During this process it also is removed from the Trusted Peer Store. A certificate can also expire when it is listed in a CRL (=Certificate Revocation List), which can be kept separately in the concerning store.

A certificate that the Client receives from the Server or the other way around is **for the moment always** classified as *unknown* and therefore also treated as **untrusted**. In order for a certificate to be treated as trusted it must be declared as such. This happens by saving the certificate of the Client in the Trusted Store of the Server and the certificate of the Server in the Trusted Store of the Client.

Dealing with a Server certificate at the Client:

1. The Client establishes the certificate on the Server on whose Endpoint it shall connect with.
2. The Client verifies the certificate of the Server.
    1. Is the certificate valid?
        1. Has the effective date expired?
        2. Is the issuer's certificate valid?
    2. Does the certificate exist in the Trusted Peer Store?
        1. Is it listed in a CRL?
    3. Does the certificate exist in the Rejected Store?
3. When the certificate is trusted, the Client establishes a connection to the server.

Dealing with a Client certificate at the Server:

1. The Server receives the Client's certificate from the Client while connecting.
2. The Server verifies the certificate of the Client.
    1. Is the certificate valid?
        1. Has the effective date expired?
        2. Is the issuer's certificate valid?
    2. Does the certificate exist in the Trusted Peer Store?
        1. Is it listed in a CRL?
    3. Does the certificate exist in the Rejected Store?
3. When the certificate is trusted, the Server allows the connection of the Client and operates it.

In case the verification of the certificate fails at the respective counterpart the verification can be extended by custom mechamisms and still decided on user scale, if the certificate gets accepted or not.

Types of Certificates

General: Self-Signed Certificates vs. Signed Certificates

A certificate is comparable to a document. A document can be issued by everybody and can also be signed by everybody. However, the main difference here is, if the signee of a document really vouches for its correctness (like a notary) or if the signee is the owner of the document itself. Especially documents of the latter are not really inspiring confidence because no (legally) recognized instance as e.g. a notary vouches for the owner of the document.

As certificates are comparable to documents and also have to show a (digital) signature, the situation here is the same. The signature of a certificate has to tell the recipient of the certificate copy, who vouches for this certificate. Herefore it always applies that the issuer of a certificate also signs it. When the **issuer of a certificate equals the subject** of the certificate, you call this a **self-signed certificate** (subject equals issuer). When the **issuer of a certificate does not equal the subject** of the certificate, you call this a **(simple / normal / signed) certificate** (subject does not equal issuer).

As certificates are used especially in the context of the OPC UA authentication of an identity (of a certain Client or Server application), signed certificates should be used as application certificates for the own application. If, however, the issuer of the certificate also its owner, this self-signed certificate should only be trusted when the owner is rated as trusted. Such certificates were, as described, signed by the issuer of the certificate. Therefore, the issuer certificate has to be located in the **Trusted Issuer Store** of the application. When the issuer certificate cannot be found there , the certificate chain is declared incomplete and the certificate is not accepted by the counterpart. Yet, if the issuer certificate of the issuer of the application certificate is not a self-signed certificate, the certificate of its issuer has to be available in the

Trusted Issuer Store.

User Identification

User Identification through Certificates

Next to the use of a certificate as an *identification card* for Client / Server applications, a certificate can also be used to identify a user. A Client application is always operated by a certain user by whom it operates with the Server. Depending on the Server configuration a Server can request additional information about the identity of the Client's user from the Client. The user has the possibility to prove his identity through a certificate. How thoroughly a Server is examining the certificate on validity, authenticity and confidentiality depends on the Server. The Server provided by the Framework exclusively checks, if the Thumbprint information of the user identity can be found in its ACL (=Access Control List) for certificate-based user identities.

Aspects of Security

Productive use

The primary goal of the Framework is to make getting the grips of the OPC UA as easy as possible. This basic thought sadly also leads to the fact that without secondary configuration of the Server a completely save connection / communication between Client and Server does not occur. Yet, if the final Spike has been implemented and tested, second thought should be given to the *aspects of security*.

Even if the Server is *only* run within a local network one should consider the use of access control lists (**OpcServer.Security.UserNameAcl/CertificateAcl** property). Here user identities can be defined via a certificate or a username-password pair. A Certificate Identity increases security in signed data transmission, for example.

Especially in cases of the Server being accessible publicly, other Security-Policies with appropriately higher Security-Mode and a matching Security-Algorithm should be negotiated. The Security-Policy-Mode “None” used by default is in this matter literally the “Great Wide Open” into your Server (**OpcServer.Security.EndpointPolicies** Properties). Last but not least one should consider the access via an anonymous user identity (**OpcServer.Security.AnonymousAcl.IsEnabled** property). According to the OPC Foundation every Endpoint Policy used above its level should stress its “quality”, in which the rule applies that the higher the level, the “better” the endpoint this policy uses.

For simplified handling of certificates the Server accepts every certificate by default (**OpcServer.Security.AutoAcceptUntrustedCertificates** property), also those it should deny under productive conditions because only certificates known to the Server (located in the Trusted Peer Store) apply as truly trusted. Apart from that the validity of a certificate should always be verified, including the “expiration date” of the certificate, for example. Other properties of the certificate or looser rules for the validity and trustworthiness of a Client certificate can be furthermore carried out manually (**OpcServer.CertificateValidationFailed** event).

OPC UA SDK
Client + Server Development

Server Development Guide

The Server Frame

1. Add reference to the **Opc.UaFx.Advanced** Server Namespace:
```
using Opc.UaFx.Server;
```
2. Instance of the OpcServer Class with desired standard base address:
```
var server = new OpcServer("opc.tcp://localhost:4840/");
```
3. Start Server and create Clients:
```
server.Start();
```
4. Your code to process Client requests:
```
// Your code to process client requests.
```
5. Close all sessions before closing the application and shut down the Server:
```
server.Stop();
```
6. Using the using block this looks as follows:
```
using (var server = new OpcServer("opc.tcp://localhost:4840/")) {
    server.Start();
    // Your code to process client requests.
}
```

Node Management

Node Creation

The following types are used: OpcServer, OpcNode, OpcNodeId, OpcNodeManager, OpcFolderNode, OpcVariableNode, OpcDataVariableNode, OpcDataVariableNode and OpcFileNode.

An **OpcNode** defines a data point of the Server. This can be a logical folder (**OpcFolderNode**), a variable (**OpcVariableNode**), a method (**OpcMethodNode**), a file (**OpcFileNode**) and much more. An **OpcNode** is unambiguously identified by an **OpcNodeId**. It exists of a value (a text, a number, ...) - the original ID - and of an index of the Namespace to which a Node is assigned. The Namespace is determinated by a Uri (= Uniform Resource Identifier). The Namespaces available are decided by the Node-Manager used by the Server.

Every Node-Manager defines at least one Namespace. Those Namespaces are used for the categorization of the Nodes of a Node-Manager, by which in return a Node can be assigned to a particular Node-Manager.

The Default-Namespace of a Node-Manager is used in case no other Namespace is assigned to a Node. The Nodes defined by a Node-Manager are also called *Nodes in the Address Space of the Node-Manager*.

During the starting procedure of the Server the Server asks its Node-Managers to produce their Address Space, meaning their (static) Nodes. More (dynamic) Nodes can also be added to or removed from the Address Space of a Node-Manager during the execution of the Server. An always static Address Space can also be generated without an explicit custom Node-Manager by telling the Server the static Nodes for the Namespace *http://{host}/{path}/nodes/* directly. Instead of the Nodes of the static Address Space custom Node-Managers can be defined.

- Create a custom Address Space with a Root Node for the Default Namespace *http://{host}/{path}/nodes/*:

```
var machineNode = new OpcFolderNode("Machine");
var machineIsRunningNode = new OpcDataVariableNode<bool>(machineNode, "IsRunning");

// Note: An enumerable of nodes can be also passed.
var server = new OpcServer("opc.tcp://localhost:4840/", machineNode);
```

- Define a custom Node-Manager:

```
public class MyNodeManager : OpcNodeManager
{
    public MyNodeManager()
        : base("http://mynamespace/")
    {
    }
}
```

- Create a custom Address Space with a Root Node by custom Node-Manager:

```
protected override IEnumerable<IOpcNode> CreateNodes(OpcNodeReferenceCollection
references)
{
    // Define custom root node.
    var machineNode = new OpcFolderNode(new OpcName("Machine",
this.DefaultNamespaceIndex));

    // Add custom root node to the Objects-Folder (the root of all server nodes):
    references.Add(machineNode, OpcObjectTypes.ObjectsFolder);

    // Add custom sub node beneath of the custom root node:
    var isMachineRunningNode = new OpcDataVariableNode<bool>(machineNode,
"IsRunning");

    // Return each custom root node using yield return.
    yield return machineNode;
}
```

- Introduce a custom Node-Manager to the Server:

```
// Note: An enumerable of node managers can be also passed.
var server = new OpcServer("opc.tcp://localhost:4840/", new MyNodeManager());
```

Node Accessibility

The following types are used: OpcServer, IOpcNode, OpcNodeId, OpcNodeManager, OpcFolderNode, OpcVariableNode, OpcDataVariableNode and OpcDataVariableNode.

Not all nodes should always be visible to all users of the server. To restrict the visibility of the nodes, any criteria can be applied via the own node manager. Restricting the accessibility by identity and a certain node might already match your needs. The following simple tree should illustrate the use.

```
protected override IEnumerable<IOpcNode> CreateNodes(OpcNodeReferenceCollection references)
{
    var machine = new OpcObjectNode(
            "Machine",
            new OpcDataVariableNode<int>("Speed", value: 123),
            new OpcDataVariableNode<string>("Job", value: "JOB0815"));

    references.Add(machine, OpcObjectTypes.ObjectsFolder);
    yield return machine;
}
```

If a user shall now have access to all nodes except the “Speed” node, the possible implementation of the `IsNodeAccessible` method can look like this:

```
protected override bool IsNodeAccessible(OpcContext context, OpcNodeId viewId, IOpcNodeInfo
node)
{
    if (context.Identity.DisplayName == "a")
        return true;

    if (context.Identity.DisplayName == "b" && node.Name.Value == "Speed")
        return false;

    return base.IsNodeAccessible(context, viewId, node);
}
```

Node Updates

The following types are used: OpcStatusCode and OpcVariableNode.

During the execution of the Server, various nodes often have to be updated according to the underlying system. Simple Object-, Folder- or Method-Nodes rarely need to be updated - however Variable-Nodes more regular. Depending on the available information it is possible to store the Timestamp and quality of the value together with the actual value of a Variable-Node. The following example outlines the handling.

```
var variableNode = new OpcVariableNode(...);

variableNode.Status.Update(OpcStatusCode.Good);
variableNode.Timestamp = DateTime.UtcNow;
variableNode.Value = ...;

variableNode.ApplyChanges(...);
```

It should be noted that Client applications are only informed about the changes to the node when `ApplyChanges` is called (assuming that a Client have completed an active subscription for the node and the Value attribute).

Values of Node(s)

Reading Values

The following types are used: OpcServer, OpcVariableNode, OpcDataVariableNode, OpcDataVariableNode, OpcReadAttributeValueCallback, OpcAttributeValue, OpcReadAttributeValueContext, OpcReadVariableValueCallback, OpcReadVariableValueContext and OpcVariableValue.

An **OpcNode** defines its metadata by *attributes*. Contrasting the generally always provided *attributes* like *Name*, *DisplayName* or *Description*, the *Value Attribute* is only available on *Variable-Nodes*. The values of *attributes* are saved by the concerning Node-Instances internally by default. If the value of another source of data is to be established, appropriate Callback-Methods for provision of the values can be defined. Here the signature of the ReadVariableValue-Callback-Method differenciates from the other ReadAttributeValue-Callback-Methods. In case of the *Value Attribute* instead of an **OpcAttributeValue** instance a **OpcVariableValue** instance is expected. This instance consists, additionally to the actual value, of a time stamp at which the value was identified at the source of the value (**SourceTimestamp**) and of status information about the quality of the value. Note that the Read-Callbacks are retrieved at every read operation of the metadata by a Client. This is the case when using the services Read and Browse.

- Set the default value of the Value Attribute of a Variable-Node:

```
var machineIsRunningNode = new OpcDataVariableNode<bool>("IsRunning", false);
```

- Set the value of the Value Attribute of a Variable-Node:

```
machineIsRunningNode.Value = true;
```

- Set the value of a Description Attribute:

```
machineIsRunningNode.Description = "My description";
```

- Inform all Clients (in case of an active subscription) about the attribute changes and accept changes:

```
machineIsRunningNode.ApplyChanges(server.SystemContext);
```

- Determine the value of the Description Attribute from another data source than the internal:

```
machineIsRunningNode.ReadDescriptionCallback = HandleReadDescription;
...
private OpcAttributeValue<string> HandleReadDescription(
        OpcReadAttributeValueContext context,
        OpcAttributeValue<string> value)
{
    return ReadDescriptionFromDataSource(context.Node) ?? value;
}
```

- Determine the value of the Value Attribute of a Variable-Node from another data source than the internal:

```
machineIsRunningNode.ReadVariableValueCallback = HandleReadVariableValue;
...
private OpcVariableValue<object> HandleReadVariableValue(
        OpcReadVariableValueContext context,
        OpcVariableValue<object> value)
{
    return ReadValueFromDataSource(context.Node) ?? value;
}
```

Writing Values

The following types are used: OpcServer, OpcVariableNode, OpcDataVariableNode, OpcDataVariableNode, OpcWriteAttributeValueCallback, OpcAttributeValue, OpcWriteAttributeValueContext, OpcWriteVariableValueCallback, OpcWriteVariableValueContext and OpcVariableValue.

An **OpcNode** defines its metadata by *attributes*. Contrasting the generally always provided *attributes* like *Name*, *DisplayName* or *Description*, the *Value Attribute* is only available on *Variable-Nodes*. The values of *attributes* are saved by the concerning Node-Instances internally by default. If the value is to be saved into another data source, appropriate Callback-Methods for saving the values can be defined. Here the signature of the WriteVariableValue-Callback-Method differenciates from the other WriteAttributeValue-Callback-Methods. In case of the *Value Attribute* instead of an **OpcAttributeValue** instance a **OpcVariableValue** instance is expected. This instance consists, additionally to the actual value, of a time stamp at which the value was identified at the source of the value (**SourceTimestamp**) and of status information about the quality of the value. Note that the Write-Callbacks are retrieved at every write operation of the metadata by a Client. This is the case when using the Write service.

- Set the default value of the Value Attribute of a Variable-Node:

```
var machineIsRunningNode = new OpcDataVariableNode<bool>("IsRunning", false);
```

- Set the value of the Value Attribute of a Variable-Node:

```
machineIsRunningNode.Value = true;
```

- Set the value of a Description Attribute:

```
machineIsRunningNode.Description = "My description";
```

- Inform all Clients (in case of an active subscription) about the attribute changes and accept changes:

```
machineIsRunningNode.ApplyChanges(server.SystemContext);
```

- Save the value of the Description Attribute from another data source than the internal:

```
machineIsRunningNode.WriteDescriptionCallback = HandleWriteDescription;
...
private OpcAttributeValue<string> HandleWriteDescription(
        OpcWriteAttributeValueContext context,
        OpcAttributeValue<string> value)
{
    return WriteDescriptionToDataSource(context.Node, value) ?? value;
}
```

- Save the value of the Value Attribute of a Variable-Node from another data source than the internal:

```
machineIsRunningNode.WriteVariableValueCallback = HandleWriteVariableValue;
...
private OpcVariableValue<object> HandleWriteVariableValue(
        OpcWriteVariableValueContext context,
        OpcVariableValue<object> value)
{
    return WriteValueToDataSource(context.Node, value) ?? value;
}
```

Historical Data

The following types are used: OpcServer, OpcNodeManager, IOpcNode, OpcHistoryValue, OpcHistoryModificationInfo, OpcValueCollection, OpcStatusCollection, OpcDeleteHistoryOptions, OpcReadHistoryOptions, IOpcNodeHistoryProvider and OpcNodeHistory<T>.

According to the OPC UA specification every Node of the category **Variable** supports the historical logging of the values of its *Value Attribute*. With every change in value of the *Value Attribute* the new value is saved together with the time stamp of the *Value Attribute*. These **pairs consisting of value and time stamp** are called **historical data**. The Server decides on where to save the data. However, the Client can determine via the *IsHistorizing Attribute* of the Node, if the Server supplies historical data for a Node and / or historically saves value changes. A Client can read, update, replace, delete or create historical data. Mostly, historical data is read by the Client.

The historical data provided by the Server can be administrated either directly in the Node-Manager of the current Node via the in-memory based Node-Historian or via a custom Historian. Note that according to OPC UA historical values always use their time stamp as a key. Correspondingly, it applies that a time stamp under every historical value of a Node is always unambiguous and therefore identifies only one certain value and its status information. Also, the historical data saved this way is distinguished between pure and modified historical data. The latter represents a kind of Changelog regarding to databanks. This Changelog can be used to process historical data that had been valid before a manipulation of the initial historical data. At the same time it is possible to retrace any changes made to the historical data. For example, if a historical value is replaced, the prior value is saved in the modified history. An historical value removed from the history is also saved in the modified history. Additionally, the kind of change, the time stamp of the change and the username of the instructor of the change is saved.

If a Client wants to read the (modified) historical data of a Node:

- the according Node has to be a Variable-Node, the record of historical data has to be activated and access to it must be cleared.
    - If an **OpcNodeHistorian** is used it takes over the activation and release of the historical data record:

      ```
      // "this" points to the Node-Manager of the node.
      var machineIsRunningHistorian = new OpcNodeHistorian(this, machineIsRunningNode);
      ```

    - Manual activation and release of the historical data history:

      ```
      machineIsRunningNode.AccessLevel |= OpcAccessLevel.HistoryReadOrWrite;
      machineIsRunningNode.UserAccessLevel |= OpcAccessLevel.HistoryReadOrWrite;

      machineIsRunningNode.IsHistorizing = true;
      ```

- changes to the *Value Attributs* of the Variable-Node have to be monitored and transferred in a storage for the historical data:

- If an **OpcNodeHistorian** is used it can be hired for automatical updates of the history:

```
machineIsRunningHistorian.AutoUpdateHistory = true;
```

- For manual overwatch of the changes to the *Value Attribute* the *BeforeApplyChanges* event of the Variable-Node should be subscribed to:

```
machineIsRunningNode.BeforeApplyChanges += HandleBeforeApplyChanges;
...
private void HandleBeforeApplyChanges(object sender, EventArgs e)
{
    // Update (modified) Node History here.
}
```

- historical data has to be provided to the Client.
  - If an **IOpcNodeHistoryProvider** like the **OpcNodeHistorian** is used it has to be mentioned to the Server via the Node-Manager:

```
protected override IOpcNodeHistoryProvider RetrieveNodeHistoryProvider(IOpcNode
node)
{
    if (node == machineIsRunnigNode)
        return machineIsRunningHistorian;

    return base.RetrieveNodeHistoryProvider(node);
}
```

  - If a custom **IOpcNodeHistoryProvider** is used its *ReadHistory* Method will be used:

```
public IEnumerable<OpcHistoryValue> ReadHistory(
        OpcContext context,
        DateTime? startTime,
        DateTime? endTime,
        OpcReadHistoryOptions options)
{
    // Read (modified) Node History here.
}
```

  - If the Node-Manager shall itself take care of the history of its Nodes, the *ReadHistory* Method has to be implemented:

```
protected override IEnumerable<OpcHistoryValue> ReadHistory(
        IOpcNode node,
        DateTime? startTime,
        DateTime? endTime,
        OpcReadHistoryOptions options)
{
    // Read (modified) Node History here.
}
```

If a Client wants to generate the historical data of a Node the new values have to be filed in the history as well as in the modified history:

- If an **IOpcNodeHistoryProvider** like the **OpcNodeHistorian** is used it has to be mentioned to the Server via the Node-Manager:

```
protected override IOpcNodeHistoryProvider RetrieveNodeHistoryProvider(IOpcNode node)
{
    if (node == machineIsRunnigNode)
        return machineIsRunningHistorian;

    return base.RetrieveNodeHistoryProvider(node);
}
```

- If a custom **IOpcNodeHistoryProvider** is used its *CreateHistory* Method will be used:

```
public OpcStatusCollection CreateHistory(
        OpcContext context,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Create (modified) Node History here.
}
```

- If the Node-Manager shall itself take care of the history of its Nodes, the *CreateHistory* Method has to be implemented:

```
protected override OpcStatusCollection CreateHistory(
        IOpcNode node,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Create (modified) Node History here.
}
```

If a Client wants to delete the historical data of a Node, the values to be deleted have to be transferred into the modified history and deleted from the actual history. If modified history values are to be deleted this can happen directly in the modified history:

- If an **IOpcNodeHistoryProvider** like the **OpcNodeHistorian** is used it must be mentioned to the Server via the Node-Manager:

```
protected override IOpcNodeHistoryProvider RetrieveNodeHistoryProvider(IOpcNode node)
{
    if (node == machineIsRunnigNode)
        return machineIsRunningHistorian;

    return base.RetrieveNodeHistoryProvider(node);
}
```

- If a custom **IOpcNodeHistoryProvider** is used one of its *DeleteHistory* Methods will be used:

```
public OpcStatusCollection DeleteHistory(
        OpcContext context,
        OpcHistoryModificationInfo modificationInfo,
        IEnumerable<DateTime> times)
{
    // Delete Node History entries and add them to the modified Node History here.
}

public OpcStatusCollection DeleteHistory(
        OpcContext context,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Delete Node History entries and add them to the modified Node History here.
}

public OpcStatusCollection DeleteHistory(
        OpcContext context,
        OpcHistoryModificationInfo modificationInfo,
        DateTime? startTime,
        DateTime? endTime,
        OpcDeleteHistoryOptions options)
{
    // Delete Node History entries and add them to the modified Node History here.
}
```

- If the Node Manager itself shall take care of the history of its Nodes the *DeleteHistory* Methods have to be implemented:

```
protected override OpcStatusCollection DeleteHistory(
        IOpcNode node,
        OpcHistoryModificationInfo modificationInfo,
        IEnumerable<DateTime> times)
{
    // Delete Node History entries and add them to the modified Node History here.
}

protected override OpcStatusCollection DeleteHistory(
        IOpcNode node,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Delete Node History entries and add them to the modified Node History here.
}

protected override OpcStatusCollection DeleteHistory(
        IOpcNode node,
        OpcHistoryModificationInfo modificationInfo,
        DateTime? startTime,
        DateTime? endTime,
        OpcDeleteHistoryOptions options)
{
    // Delete Node History entries and add them to the modified Node History here.
}
```

If a Client wants to replace the historical data of a Node the values to be replaced have to be transferred into the modified history and replaced in the actual history:

- If an **IOpcNodeHistoryProvider** like the **OpcNodeHistorian** is used it has to be mentioned to the Server via the Node-Manager:

```
protected override IOpcNodeHistoryProvider RetrieveNodeHistoryProvider(IOpcNode node)
{
    if (node == machineIsRunnigNode)
        return machineIsRunningHistorian;

    return base.RetrieveNodeHistoryProvider(node);
}
```

- If a custom **IOpcNodeHistoryProvider** is used the *ReplaceHistory* Method is used:

```
public OpcStatusCollection ReplaceHistory(
        OpcContext context,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Replace Node History entries and add them to the modified Node History here.
}
```

- If the Node-Manager itself shall take care of the history of its Nodes the *ReplaceHistory* Methods has to be implemented:

```
protected override OpcStatusCollection ReplaceHistory(
        IOpcNode node,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Replace Node History entries and add them to the modified Node History here.
}
```

If a Client wants to generate historical data of a Node (if it does not exist yet) or replace it (if it already exists) - so according to OPC UA update it - non-existant entries have to be written into the history and modified history. Existant entries have to be replaced in the history and written into the modified history:

- If an **IOpcNodeHistoryProvider** like the **OpcNodeHistorian** is used it has to be mentioned to the Server via the Node-Manager:

```
protected override IOpcNodeHistoryProvider RetrieveNodeHistoryProvider(IOpcNode node)
{
    if (node == machineIsRunnigNode)
        return machineIsRunningHistorian;

    return base.RetrieveNodeHistoryProvider(node);
}
```

- If a custom **IOpcNodeHistoryProvider** is used the *UpdateHistory* Method is used:

```
public OpcStatusCollection UpdateHistory(
        OpcContext context,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Update (modified) Node History entries here.
}
```

- If the Node-Manager itself shall take care of the history of its Nodes the *UpdateHistory* Methods has to be implemented:

```
protected override OpcStatusCollection UpdateHistory(
        IOpcNode node,
        OpcHistoryModificationInfo modificationInfo,
        OpcValueCollection values)
{
    // Update (modified) Node History entries here.
}
```

In use of the Class **OpcNodeHistory<T>** the data of the history and the modified history can be administrated in the Store. Apart from several Methods operating the usual access scenarios to historical data, the separate constructors of the Class allow to set the capacity of the history. Also, the history can be “preloaded” and monitored via several events.

Definition of a history depending on the kind of historical data:

- The Class **OpcHistoryValue**is used as a type parameter for simple history:

```
var history = new OpcNodeHistory<OpcHistoryValue>();
```

- The Class **OpcModifiedHistoryValue** is used as a type parameter for modified history:

```
var modifiedHistory = new OpcNodeHistory<OpcModifiedHistoryValue>();
```

Using the Class **OpcNodeHistory<T>** the usual history scenarios like Read, Create, Delete, Replace and Update can be implemented as follows:

- Szenario: **Create History**:

```
var results = OpcStatusCollection.Create(OpcStatusCode.Good, values.Count);

for (int index = ; index < values.Count; index++) {
    var result = results[index];
    var value = OpcHistoryValue.Create(values[index]);

    if (MatchesValueType(value)) {
        if (history.Contains(value.Timestamp)) {
            result.Update(OpcStatusCode.BadEntryExists);
        }
        else {
            history.Add(value);

            var modifiedValue = value.CreateModified(modificationInfo);
            modifiedHistory.Add(modifiedValue);

            result.Update(OpcStatusCode.GoodEntryInserted);
        }
    }
    else {
        result.Update(OpcStatusCode.BadTypeMismatch);
    }
}

return results;
```

- Scenario: **Delete History**
  - Via time stamp:

```
var results = OpcStatusCollection.Create(OpcStatusCode.Good, times.Count());

int index = ;

foreach (var time in times) {
    var result = results[index++];

    if (this.history.Contains(time)) {
        var value = this.history[time];
        this.history.RemoveAt(time);

        var modifiedValue = value.CreateModified(modificationInfo);
        this.modifiedHistory.Add(modifiedValue);
    }
    else {
        result.Update(OpcStatusCode.BadNoEntryExists);
    }
}

return results;
```

- Via values:

```
var results = OpcStatusCollection.Create(OpcStatusCode.Good, values.Count);

for (int index = ; index < values.Count; index++) {
    var timestamp = OpcHistoryValue.Create(values[index]).Timestamp;
    var result = results[index];

    if (history.Contains(timestamp)) {
        var value = history[timestamp];
        history.RemoveAt(timestamp);

        var modifiedValue = value.CreateModified(modificationInfo);
        modifiedHistory.Add(modifiedValue);
    }
    else {
        result.Update(OpcStatusCode.BadNoEntryExists);
    }
}

return results;
```

- Via time span:

```
var results = new OpcStatusCollection();

bool isModified = (options & OpcDeleteHistoryOptions.Modified)
        == OpcDeleteHistoryOptions.Modified;

if (isModified) {
    modifiedHistory.RemoveRange(startTime, endTime);
}
else {
    var values = history.Enumerate(startTime, endTime).ToArray();
    history.RemoveRange(startTime, endTime);

    for (int index = ; index < values.Length; index++) {
        var value = values[index];
        modifiedHistory.Add(value.CreateModified(modificationInfo));

        results.Add(OpcStatusCode.Good);
    }
}

return results;
```

- Scenario: **Replace History**:

```
var results = OpcStatusCollection.Create(OpcStatusCode.Good, values.Count);

for (int index = ; index < values.Count; index++) {
    var result = results[index];
    var value = OpcHistoryValue.Create(values[index]);

    if (this.MatchesNodeValueType(value)) {
        if (this.history.Contains(value.Timestamp)) {
            var oldValue = this.history[value.Timestamp];
            history.Replace(value);

            var modifiedValue = oldValue.CreateModified(modificationInfo);
            modifiedHistory.Add(modifiedValue);

            result.Update(OpcStatusCode.GoodEntryReplaced);
        }
        else {
            result.Update(OpcStatusCode.BadNoEntryExists);
        }
    }
    else {
        result.Update(OpcStatusCode.BadTypeMismatch);
    }
}

return results;
```

- Scenario: **Update History**:

```
var results = OpcStatusCollection.Create(OpcStatusCode.Good, values.Count);

for (int index = ; index < values.Count; index++) {
    var result = results[index];
    var value = OpcHistoryValue.Create(values[index]);

    if (MatchesValueType(value)) {
        if (history.Contains(value.Timestamp)) {
            var oldValue = this.history[value.Timestamp];
            history.Replace(value);

            var modifiedValue = oldValue.CreateModified(modificationInfo);
            modifiedHistory.Add(modifiedValue);

            result.Update(OpcStatusCode.GoodEntryReplaced);
        }
        else {
            history.Add(value);

            var modifiedValue = value.CreateModified(modificationInfo);
            modifiedHistory.Add(modifiedValue);

            result.Update(OpcStatusCode.GoodEntryInserted);
        }
    }
    else {
        result.Update(OpcStatusCode.BadTypeMismatch);
    }
}

return results;
```

- Scenario: **Read History**:

```
bool isModified = (options & OpcReadHistoryOptions.Modified)
        == OpcReadHistoryOptions.Modified;

if (isModified) {
    return modifiedHistory
            .Enumerate(startTime, endTime)
            .Cast<OpcHistoryValue>()
            .ToArray();
}

return history
        .Enumerate(startTime, endTime)
        .ToArray();
```

Nodes

Method Nodes

The following types are used here: OpcNodeManager, OpcMethodNode and OpcMethodContext.

Code sections that fulfill an isolated task are called subprograms in programming. Those subprograms are often described simply as functions or methods. Those kind of methods can be called via method Nodes in

the OPC UA. A method Node is defined by the **OpcMethodNode** class. Method Nodes are called by an OPC UA Client via the server-sided **Call** service.

The framework defines a method Node through the one-on-one application of a function pointer (delegate in C#) to a Node of the category *OpcNodeCategory.Method*. Herefore the structure of the delegate is examined via .NET reflections and based on that the method Node with its *IN* and *OUT* arguments is defined.

Define a method Node in the Node manager:

1. through a method without a parameter:

```
var startMethodNode = new OpcMethodNode(
        machineNode,
        "StartMachine",
        new Action(this.StartMachine));
...
private void StartMachine()
{
    // Your code to execute.
}
```

2. through a method with a parameter:

```
var startMethodNode = new OpcMethodNode(
        machineNode,
        "StartMachine",
        new Action<int>(this.StartMachine));
...
private void StartMachine(int reasonNumber)
{
    // Your code to execute.
}
```

3. through a method with a callback value:

```
var startMethodNode = new OpcMethodNode(
        machineNode,
        "StartMachine",
        new Func<int>(this.StartMachine));
...
private int StartMachine()
{
    // Your code to execute.
    return statusCode;
}
```

4. through a method with a parameter and a callback value:

```
var startMethodNode = new OpcMethodNode(
        machineNode,
        "StartMachine",
        new Func<int, string, int>(this.StartMachine));
...
private int StartMachine(int reasonNumber, string operatorName)
{
    // Your code to execute.
    return statusCode;
}
```

5. through a method that needs access to contextual information about the actual “Call” (for this the

first parameter has to be of the type **OpcMethodNodeContext**):

```
var startMethodNode = new OpcMethodNode(
        machineNode,
        "StartMachine",
        new Func<OpcMethodNodeContext, int, int>(this.StartMachine));
...
private int StartMachine(OpcMethodNodeContext context, int reasonNumber)
{
    // Your code to execute.

    this.machineStateVariable.Value = "Started";
    this.machineStateVariable.ApplyChanges(context);

    return statusCode;
}
```

Also, there is the option to supply additional information about the arguments (callback values and parameters) of a method via the **OpcArgument attribute**. This information is considered for the definition of the method Node arguments and supplied to every Client when browsing the Node. Such a definition of additional information will look as follows:

```
[return: OpcArgument("Result", Description = "The result code of the machine driver.")]
private int StartMachine(
        [OpcArgument("ReasonNumber", Description = "0: Maintenance, 1: Manufacturing, 2:
Service")]
        int reasonNumber,
        [OpcArgument("OperatorName", Description = "Optional. Name of the operator of the
current shift.")]
        string operatorName)
{
    // Your code to execute.
    return 10;
}
```

File Nodes

The following types are used: OpcNodeManager and OpcFileNode.

Nodes of the type **FileType** define per OPC UA Specification definition certain Property Nodes and Method Nodes allowing to access a data stream as if accessing. Exclusive information about the content of the logical or physical file is provided. According to the specification, a possibly existing path to the data is not provided. The access to the file itself is realized by Open, Close, Read, Write, GetPosition and SetPosition. The data is always processed binarily. As in every other platform in OPC UA you can set a mode that provides the kind of planned data access when opening Open. You can also request exclusive access to a file. After opening the Open Method you receive a numeric key for further file handle. This key always has to be passed in the Methods Read, Write, GetPosition and SetPosition. Once a file is opened it has to be closed again when no longer needed.

Define a File Node in the Node-Manager:

```
var protocollFileNode = new OpcFileNode(
        machineNode,
        "Protocoll.txt",
        new FileInfo(@"..\Protocoll.log"));
```

All other operations to work with the represented file are already provided by the **OpcFileNode** class.

Datatype Nodes

The following types are used: OpcNodeManager, OpcNodeId, OpcDataTypeAttribute, OpcDataTypeNode and OpcEnumMemberAttribute.

In some scenarios it is necessary to describe the Server provided data using user-defined data types. Such a data type can for example be an enumeration. Depending from the entry (differentiable by their name) there can be used a different value or a combination of values which are / can again represented by other entries. In the last case such an enumeration is called a flag-enumeration. Are the bits of an enum-entry bitwise set in its flag enumeration value, then the whole value applies although it does not match the exact value of the entry (because of other enum-entries are applicable). The thereby valid (combinations of) values have to be provided as Name-Value-Pairs by the Server using a specific ID, to enable Read- and Write-Access on Nodes - which are using the type of enumeration - using valid values. To publish a user-defined enumeration as an enumeration in the Address Space of the Server, the enumeration have to use the **OpcDataTypeAttribute**. Using this attribute the data of the **OpcNodeId** associated with the type of enumeration is defined. Finally, the user-defined data type must be published via one of the Server's Node-Managers. How this works in detail can be seen in the following code example:

```
// Define the node identifier associated with the custom data type.
[OpcDataType(id: "MachineStatus", namespaceIndex: 2)]
internal enum MachineStatus : int
{
    Unknown = ,
    Stopped = 1,
    Started = 2,
    Waiting = 3,
    Suspended = 4
}

...

// MyNodeManager.cs
protected override IEnumerable<IOpcNode> CreateNodes(OpcNodeReferenceCollection references)
{
    ...

    // Publish a new data type node using the custom type.
    return new IOpcNode[] { ..., new OpcDataTypeNode<MachineStatus>() };
}
```

Additional information about the individual enum-entries can be defined using the **OpcEnumMemberAttribute**. The thereby optional supported *Description* property is only used in case there the entry is part of a flag enumeration. The previously represented enumeration could then look like as follows:

```
[OpcDataType(id: "MachineStatus", namespaceIndex: 2)]
internal enum MachineStatus : int
{
    Unknown = ,
    Stopped = 1,
    Started = 2,

    [OpcEnumMember("Paused by Job")]
    WaitingForOrders = 3,

    [OpcEnumMember("Paused by Operator")]
    Suspended = 4,
}
```

Data Nodes

The following types are used: OpcNodeManager, OpcDataVariableNode and OpcDataVariableNode.

With the help of the **OpcDataVariableNode** it is possible to provide simple scalar as well as complex data structures. In addition to the value itself, these self-describing nodes also provide information about the data types valid for the value. This includes, for example, the length of an array. Such a data node is created as follows:

```
// Node of the type Int32
var variable1Node = new OpcDataVariableNode<int>(machineNode, "Var1");

// Node of the type Int16
var variable2Node = new OpcDataVariableNode<short>(machineNode, "Var2");

// Node of the type String
var variable3Node = new OpcDataVariableNode<string>(machineNode, "Var3");

// Node of the type float-array
var variable4Node = new OpcDataVariableNode<float[]>(machineNode, "Var4", new float[] {
0.1f, 0.5f });

// Node of the type MachineStatus enum
var variable5Node = new OpcDataVariableNode<MachineStatus>(machineNode, "Var5");
```

Data-Item Nodes

The following types are used: OpcNodeManager, OpcDataItemNode and OpcDataItemNode.

The data provided by an OPC UA Server often does not come directly 1: 1 from the underlying system of the server. Even though these data variables can be provided by means of instances of **OpcDataVariableNodes**, the origin or the *Definition* - how a value of a data point is established - is of interest for the correct further processing and interpretation. Especially when used by third parties, this information is not only a part of the documentation, but also a helpful tool for internal data processing. This is exactly where the **OpcDataItemNode** comes in and provides the *Definition* property with the necessary information about the realization of the values of the Data-Item Node. In addition, the *ValuePrecision* property provides a value that tells you how accurate the values can be. This Node is defined as follows:

```
var statusNode = new OpcDataItemNode<int>(machineNode, "Status");
statusNode.Definition = "Status Code in low word, Progress Code in high word encoded in
BCD";
```

In general, the value of the *Definition* property depends on the manufacturer.

Data-Item Nodes for analog Values

The following types are used: OpcNodeManager, OpcAnalogItemNode, OpcAnalogItemNode, OpcValueRange and OpcEngineeringUnitInfo.

Nodes of the type **AnalogItemType** essentially represent a specialization of the **OpcDataItemNode**. The additionally offered properties allow the provided analog values to be specified more precisely. The *InstrumentRange* serves as the definition of the range of values used by the source of the analog data. The *EngineeringUnit* is used to classify the unit of measure associated with the value in accordance with the UNECE Recommendations N° 20. These recommendations are based on the International System of Units, short SI Units. These two properties are supplemented by the *EngineeringUnitRange* which can be provided according to the *EngineeringUnit* value range valid during normal operation. Such a node can then be defined in the Node-Manager as follows:

```
var temperatureNode = new OpcAnalogItemNode<float>(machineNode, "Temperature");

temperatureNode.InstrumentRange = new OpcValueRange(80.0, -40.0);
temperatureNode.EngineeringUnit = new OpcEngineeringUnitInfo(4408652, "°C", "degree
Celsius");
temperatureNode.EngineeringUnitRange = new OpcValueRange(70.8, 5.0);
```

The UnitID expected in the constructor of the **OpcEngineeringUnitInfo** can be taken from the UNECE table for measurement units at the OPC Foundation:UNECE units of measure in OPC UA

NodeSets

NodeSets describe the contents of the address space of a server in the form of the XML (eXtensible Markup Language). Part of the description is the definition of data types and their transported logical (data-dependent information) as well as physical (in memory) structure. In addition, the definitions of node types as well as concrete node instances can be found in a NodeSet. The root element “UANodeSet” also describes the relationships between the individual nodes defined in the NodeSet, but also defined in other NodeSets, as well as in the specification.

Companion specifications not only extend the general definition of the address space, but also provide their own data types and node types. As a result, one or more NodeSets exist for each companion specification. For a server to meet a companion specification, the server must implement the types and behaviors defined in this specification.

Another case in which NodeSets are used as a description of the address space is the configuration of controllers. This means that the entire configured configuration of a controller can be exported from configuration software such as TIA Portal and used to initialize the OPC UA server of a controller.

Regardless of the source of a NodeSet, if a NodeSet is to be used by a server, it must provide the necessary logic to import and implement the address space described in the NodeSet. How it works shows the next sections.

Import NodeSets

The following types are used here: OpcNodeSet, OpcNodeSetManager and OpcNodeManager.

Nodes which are described in a NodeSet can be imported via the **OpcNodeSetManager** 1: 1:

```
var umatiManager = OpcNodeSetManager.Create(
        OpcNodeSet.Load(@".\umati.xml"),
        OpcNodeSet.Load(@".\umati-instances.xml"));

using (var server = new OpcServer("opc.tcp://localhost:4840/", umatiManager)) {
    server.Start();
    ...
}
```

When calling **OpcNodeSetManager.Create(...)**, 1-n NodeSets can be specified. The OpcNodeManager created when calling OpcNodeSetManager.Create takes care of importing the NodeSets and thus generates the nodes defined in the NodeSets within the address space of the server when starting the server. On the other hand, if you want a custom NodeManager to handle the import of a NodeSet, you can do so simply by overriding the ImportNodes method of the OpcNodeManager class:

```
protected override IEnumerable<OpcNodeSet> ImportNodes()
{
    yield return OpcNodeSet.Load(@".\umati.xml");
    yield return OpcNodeSet.Load(@".\umati-instances.xml");
}
```

Implement NodeSets

The following types are used here: OpcNodeManager and IOpcNode.

Often the simple import of a NodeSet is not enough, as the associated logic for the connection of the underlying system is still missing. This logic is necessary, for example, to map the reading of a node to the reading of, for example, a word in a data block. The same applies again to the writing of a node.

To implement this logic, the **OpcNodeManager.ImplementNode** method within a custom NodeManager will be overridden as follows:

```
protected override void ImplementNode(IOpcNode node)
{
    // Implement your Node(s) here.
}
```

For example, in the case of a UMATI node set, the logic for simulating the status of a lamp could be implemented as follows:

```
private static readonly OpcNodeId LampTypeId = "ns=2;i=1041";
private readonly Random random = new Random();

protected override void ImplementNode(IOpcNode node)
{
    if (node is OpcVariableNode variableNode && variableNode.Name == "2:Status") {
        if (variableNode?.Parent is OpcObjectNode objectNode && objectNode.TypeDefinitionId
== LampTypeId) {
            variableNode.ReadVariableValueCallback = (context, value) => new
OpcVariableValue<object>(this.random.Next(, 2));
        }
    }
}
```

Events

Event Reporting

The following types are used: OpcServer, OpcNodeManager, OpcEventSeverity and OpcText.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

Events inform a subscriber about operations, conditions, and system specific circumstances. Such information can be delivered directly through **global events** to interested parties. A global event can be triggered and dispatched either by a **OpcNodeManager** or by a **OpcServer** instance. For this, the framework offers various method overloads of the *ReportEvent(...)*- method. To trigger a global event using a **OpcServer** instance, you have the following options:

```
var server = new OpcServer(...);
// ...

server.ReportEvent(
        OpcEventSeverity.Medium,
        "Recognized a medium urgent situation.");

// Same usage as before + arguments support.
server.ReportEvent(
        OpcEventSeverity.Medium,
        "Recognized a medium urgent situation at machine {0}.",
        machineId);

// Sames usage as before + source node.
server.ReportEvent(
        sourceNode,
        OpcEventSeverity.Medium,
        "Recognized a medium urgent situation.");

// Same usage as before + arguments support.
server.ReportEvent(
        sourceNode,
        OpcEventSeverity.Medium,
        "Recognized a medium urgent situation at machine {0}.",
        machineId);

// Same usage as before + explicit source information.
server.ReportEvent(
        sourceNodeId,
        sourceNodeName,
        OpcEventSeverity.Medium,
        "Recognized a medium urgent situation.");

// Same usage as before + arguments support.
server.ReportEvent(
        sourceNodeId,
        sourceNodeName,
        OpcEventSeverity.Medium,
        "Recognized a medium urgent situation at machine {0}.",
        machineId);
```

The same method overloads can also be found as instance methods of a **OpcNodeManager** instance.

Event Nodes

The following types are used: OpcServer, OpcNodeManager and OpcEventNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

It is not always appropriate to send events globally through the Server to all subscribers. Often the context therefore plays a crucial role in whether an event is of interest to a subscriber. Event Nodes are used to define local events. The base class of all Event Nodes represents the class **OpcEventNode**. Using these it is possible to provide simple events in the form of local events, as shown in the 'Providing Events' section. Since this is a Node, the Event Node (**OpcEventNode**) must first be created in the **OpcNodeManager** like any other Node:

```
var activatedEvent = new OpcEventNode(machineOne, "Activated");
```

So that an event can now be sent by this Event Node, it have to be defined as a 'Notifier'. For this purpose, the Event Node is registered as a 'Notifier' for each Node via which a subscription is to be able to receive the local event. This works as follows:

```
machineOne.AddNotifier(this.SystemContext, activatedEvent);
```

Before an event is triggered, all information relevant for the event must be entered on the Event Node. Which information is changed and how it is determined depends on the individual case of application. In general, this works as follows:

```
activatedEvent.SourceNodeId = sourceNodeId;
activatedEvent.SourceName = sourceNodeName;
activatedEvent.Severity = OpcEventSeverity.Medium;
activatedEvent.Message = "Recognized a medium urgent situation.";
```

Additionally the Event Node **OpcEventNode** offers further properties:

```
// Server generated value to identify a specific Event
activatedEvent.EventId = ...;

// The time the event occured
activatedEvent.Time = ...;

// The time the event has been received by the underlaying system / device
activatedEvent.ReceiveTime = ...;
```

After configuring the event to be created, only the *ReportEvent(...)*- method of the **OpcEventNode** instance needs to be called:

```
activatedEvent.ReportEvent(this.SystemContext);
```

This will automatically invoke the *ApplyChanges(...)* method on the Node, creates a snapshot of the Node and send it to all subscribers. After calling the *ReportEvent(...)* method, the properties of the **OpcEventNode** can be changed as desired.

Generally, after a subscriber is only informed of events, as long as he is in contact with the Server and has subscribed events, a subscriber will not know what events have already occurred prior to establishing a connection to the Server. If a Server is to inform subscribers retrospectively about past events, these can be provided by the Server on request from the subscriber as follows:

```
machineOne.QueryEventsCallback = (context, events) => {
    // Ensure that an re-entrance upon notifier cross-references will not add
    // events to the collection which are already stored in.
    if (events.Count != )
        return;

    events.Add(activatedEvent.CreateEvent(context));
};
```

It should be noted at this point that each Node under which an Event Node has been registered as 'Notifier' must separately specify such a callback. **In general, however, the Server is not obliged to provide past events.** In addition, it is always possible to create a snapshot of the Node using the *CreateEvent(...)* method of the **OpcEventNode**, to cache it and to provide the cached snapshots when the *QueryEventsCallback* is called.

Event Nodes with Conditions

The following types are used: OpcServer, OpcNodeManager and OpcConditionNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A specialization of the **OpcEventNode** (presented in section 'Providing Event Nodes') is the class **OpcConditionNode**. It serves the definition of events to which certain conditions are attached. Only in case the condition given to the Event Node is true an event should be triggered. Information associated with the Node also includes information about the state of this condition, as well as information associated with the evaluation of the condition. Since this information can vary in complexity depending on the scenario, the **OpcConditionNode** represents the base class of all Event Nodes to which a condition is attached. Such a Node is created like an **OpcEventNode**. In the following, therefore, only the specific further properties are shown:

```
var maintenanceEvent = new OpcConditionNode(machineOne, "Maintenance");

// Interesting for a client yes or no
maintenanceEvent.IsRetained = true; // = default

// Condition is enabled or disabled
maintenanceEvent.IsEnabled; // use ChangeIsEnabled(...)

// Status of the source the condition is based upon
maintenanceEvent.Quality = ...;
```

With the *AddComment(...)* method and the child Node of the same name, the *Comment* property of the Node can be changed. The result of the change can be evaluated using the following properties:

```
// Identifier of the user who supplied the Comment
maintenanceEvent.ClientUserId = ...;

// Last comment provided by a user
maintenanceEvent.Comment = ...;
```

If the same Event Node is to be processed in multiple tracks, then a new event branch can be opened. For this the *CreateBranch(...)* method of the Node can be used. The unique key for the branch is stored in the *BranchId* property. The following snippet shows the most important parts to work with branches of a **OpcConditionNode**:

```
// Uses a new GUID as BranchId
var maintenanceBranchA = maintenanceEvent.CreateBranch(this.SystemContext);

// Uses a custom NodeId as BranchId
var maintenanceBranchB = maintenanceEvent.CreateBranch(this.SystemContext, new
OpcNodeId(10001));

...

// Identifies the branch of the event
maintenanceEvent.BranchId = ...;

// Previous severity of the branch
maintenanceEvent.LastSeverity = ...;
```

Event Nodes with Dialog Conditions

The following types are used: OpcServer, OpcNodeManager and OpcDialogConditionNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A specialization of the **OpcConditionNode** is the **OpcDialogConditionNode**. The condition associated with this Node is a dialog with the subscribers. In this case, such a condition consists of a prompt, response options as well as information which option is selected by default (*DefaultResponse* property), which option to confirm the dialog (*OkResponse* property) and which is used to cancel the dialog (*CancelResponse* property). When such a dialog-driven event is triggered, the Server waits for one of the subscribers to provide it with an answer in the form of the choice made based on the given response options. The condition for further processing, the operations linked to the dialog, is thus the answer to a task, a question, an information or a warning. If a Node has been created as usual, the corresponding properties can be defined according to the scenario:

```
var outOfMaterial = new OpcDialogConditionNode(machineOne, "MaterialAlert");

outOfMaterial.Message = "Out of Material"; // Generic event message
outOfMaterial.Prompt = "The machine is out of material. Refill material supply to
continue.";
outOfMaterial.ResponseOptions = new OpcText[] { "Continue", "Cancel" };
outOfMaterial.DefaultResponse = ; // Index of ResponseOption to use
outOfMaterial.CancelResponse = 1;  // Index of ResponseOption to use
outOfMaterial.OkResponse = ;      // Index of ResponseOption to use
```

A dialog condition answered by a subscriber is then handled by the Node's *RespondCallback* as follows.

```
outOfMaterial.RespondCallback = this.HandleOutOfMaterialResponse;

...

private OpcStatusCode HandleOutOfMaterialResponse(
        OpcNodeContext<OpcDialogConditionNode> context,
        int selectedResponse)
{
    // Handle the response
    if (context.Node.OkResponse == selectedResponse)
        ContinueJob();
    else
        CancelJob();

    // Apply the response
    context.Node.RespondDialog(context, response);

    return OpcStatusCode.Good;
}
```

Event Nodes with Feedback Conditions

The following types are used: OpcServer, OpcNodeManager and OpcAcknowledgeableConditionNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

Based on the **OpcConditionNode**, the **OpcAcknowledgeableConditionNode** is a specialization used as the base class for conditions with feedback requirements. Events of this type define that, when their condition is met, a “report with acknowledgment of receipt” is issued. The “return receipt” - that is the feedback - can serve to control further processes as well as to easily acknowledge hints and warnings. The

specified feedback mechanism provided for this purpose is divided into two stages. While the first stage is a kind of “read receipt”, the second level is a kind of “read receipt with a nod”. OPC UA defines the read receipt as a simple confirmation and the read receipt as a nod with acknowledgment. For both types of recognition, the Node provides two child Nodes *Confirm* and *Acknowledge*. By definition, the execution of the “acknowledge” process should make an explicit execution of the “confirm” process unnecessary. On the other hand, it is possible to first send a confirmation and then, separately, an acknowledgment. Regardless of the order and the type of feedback, a comment from the operator can optionally be specified for the confirm or acknowledge. Such a Node is created as already known:

```
var outOfProcessableBounds = new OpcAcknowledgeableConditionNode(machineOne,
"OutOfBoundsAlert");

// Define the condition as: Needs to be acknowledged
outOfProcessableBounds.ChangeIsAcked(this.SystemContext, false);

// Define the condition as: Needs to be confirmed
outOfProcessableBounds.ChangeIsConfirmed(this.SystemContext, false);
```

During the further process flows, an incoming feedback can be checked using the Node's *IsAcked* and *IsConfirmed* property:

```
if (outOfProcessableBounds.IsAcked) {
    ...
}

if (outOfProcessableBounds.IsConfirmed) {
    ...
}
```

It should be noted that a Server must always define the interpretation itself as well as the logic following the respective feedback. So whether a Server makes use of both feedback options or only one is left to the respective developer. In the best case, a Server should at least use the *Acknowledge* method, as it is defined by the specification as “stronger”.

Event Nodes with Alarm Conditions

The following types are used: OpcServer, OpcNodeManager and OpcAlarmConditionNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

The most important implementation of the **OpcAcknowledgeableConditionNode** in OPC UA may be the **OpcAlarmConditionNode**. With the help of the **OpcAlarmConditionNode** it is possible to define Event Nodes whose behavior is comparable to a bedside timer. Accordingly, this Node becomes active (see *IsActive* property) if the condition associated with it is met. In the case of an alarm clock, for example, “reaching the alarm time”. For example, an alarm that has been set with a wake-up time, but should not be active when it is reached, is called a suppressed alarm (see *IsSuppressed* and *IsSuppressedOrShelved*). But if an alarm becomes active, it can be shelved (see *IsSuppressedOrShelved* property). In this case, an alarm can be reset once (“One Shot Shelving”) or timed (“Timed Shelving”) (see *Shelving* property). Alternatively, a reset alarm can also be “unshelved” again (see *Shelving* property). An example of the **OpcAlarmConditionNode** API is shown in the following code:

```
var overheating = new OpcAlarmConditionNode(machineOne, "OverheatingAlert");
var idle = new OpcAlarmConditionNode(machineOne, "IdleAlert");

...

overheating.ChangeIsActive(this.SystemContext, true);
idle.ChangeIsActive(this.SystemContext, true);

...

if (overheating.IsActive)
    CancelJob();

if (!idle.IsActive)
    ProcessJob();
else if (idle.IsSuppressed)
    SimulateJob();
```

Event Nodes with discrete Alarm Conditions

The following types are used: OpcServer, OpcNodeManager, OpcDiscreteAlarmNode, OpcOffNormalAlarmNode and OpcTripAlarmNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

Starting from the **OpcAlarmConditionNode**, there are several specializations that have been explicitly defined for specific types of alarms to specify the form, reason or content of an alarm more precisely by the nature of the alarm. A subclass of such self-describing alarms are the discrete alarms. The basis for a discrete alarm is the **OpcDiscreteAlarmNode** class. It defines an alarm Node that is used to classify types into alarm states, where the input for the alarm can only accept a certain number of possible values (e.g. true / false, running / paused / terminated). If an alarm is to represent a discrete condition that is considered abnormal, consider using the **OpcOffNormalAlarmNode** or one of its subclasses. Based on this alarm class, the framework offers a further concretization with the **OpcTripAlarmNode**. The **OpcTripAlarmNode** becomes active when, for example, an abnormal fault occurs on a monitored device, e.g. when the motor is shut down due to overload. The aforementioned Nodes are created as follows:

```
var x = new OpcDiscreteAlarmNode(machineOne, "discreteAlert");
var y = new OpcOffNormalAlarmNode(machineOne, "offNormalAlert");
var z = new OpcTripAlarmNode(machineOne, "tripAlert");
```

Event Nodes with Alarm Conditions for Limits

The following types are used: OpcServer, OpcNodeManager and OpcLimitAlarmNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

If process-specific limit values are to be checked and the output of the test is to be published in the case of limit value overruns / underruns, the **OpcLimitAlarmNode** class provides the central starting point for entering the classes of limit alarms. With this class limits can be divided into up to four levels. To differentiate them, they are called LowLow, Low, High and HighHigh (called in order of their metric order). By definition, it is not necessary to define all limits. For this reason, the class offers the possibility to set the desired limits from the beginning:

```
var positionLimit = new OpcLimitAlarmNode(
        machineOne, "PositionLimit", OpcLimitAlarmStates.HighHigh |
OpcLimitAlarmStates.LowLow);

positionLimit.HighHighLimit = 120; // e.g. mm
positionLimit.LowLowLimit = ;     // e.g. mm
```

Event Nodes with Alarm Conditions for exclusive Limits

The following types are used: OpcServer, OpcNodeManager and OpcExclusiveLimitAlarmNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A subclass of the **OpcLimitAlarmNode** is the class **OpcExclusiveLimitAlarmNode**. As its name suggests, it serves to define limit alerts for exclusive boundaries. Such a limit alarm uses values for the boundaries that are mutually exclusive. This means that if a limit value has been exceeded / undershot, it is not possible for another limit value to be exceeded or undershot at the same time. The thereby violated boundary is described with the *Limit* property of the Node.

In the OPC UA, there are three further specializations of the **OpcExclusiveLimitAlarmNode**.

OpcExclusiveDeviationAlarmNode
This type of alarm should be used when a slight deviation from defined limits is detected.

OpcExclusiveLevelAlarmNode
This type of alarm is typically used to report when a limit is exceeded. This typically affects an instrument - such as a temperature sensor. This type of alarm becomes active when the observed value is above an upper limit or below a lower limit.

OpcExclusiveRateOfChangeAlarmNode
This type of alarm is commonly used to report an unusual change or absence of a measured value in relation to the rate at which the value has changed. The alarm becomes active if the rate at which the value changes exceeds or falls below a defined limit.

Event Nodes with Alarm Conditions for non-exclusive Limits

The following types are used: OpcServer, OpcNodeManager and OpcNonExclusiveLimitAlarmNode.
This section describes a part of the API for topics related to: Alarm & Events, Alarm & Conditions.

A subclass of the **OpcLimitAlarmNode** is the class **OpcNonExclusiveLimitAlarmNode**. As its name suggests, it serves to define limit alerts for non-exclusive boundaries. Such a limit alarm uses values for the limits that do **not exclude each other**. This means that when a limit has been exceeded / undershot, that at the same time another limit may be exceeded / undershot. The limits that are thereby violated can be checked with the properties *IsLowLow*, *IsLow*, *IsHigh* and *IsHighHigh* of the Node.

As part of the OPC UA, there are three further specializations of the **OpcNonExclusiveLimitAlarmNode**.

OpcNonExclusiveDeviationAlarmNode
This type of alarm should be used when a slight deviation from defined limits is detected.

OpcNonExclusiveLevelAlarmNode
This type of alarm is typically used to report when a limit is exceeded. This typically affects an instrument - such as a temperature sensor. This type of alarm becomes active when the observed value is above an upper limit or below a lower limit.

OpcNonExclusiveRateOfChangeAlarmNode

This type of alarm is commonly used to report an unusual change or absence of a measured value in relation to the rate at which the value has changed. The alarm becomes active if the rate at which the value changes exceeds or falls below a defined limit.

Monitoring Request and Response Messages

The following types are used: OpcServer, OpcRequestValidatingEventArgs, OpcRequestValidatingEventHandler, OpcRequestProcessingEventArgs, OpcRequestProcessingEventHandler, OpcRequestProcessedEventArgs, OpcRequestProcessedEventHandler, OpcRequestValidatedEventArgs, OpcRequestValidatedEventHandler, IOpcServiceRequest and IOpcServiceResponse.

The requests sent by Clients to a Server are processed by the Server as instances of the IOpcServiceRequest interface, validated and answered by instances of the IOpcServiceResponse interface. The requests received by the Server can be additionally monitored, logged, routed or denied via the events RequestProcessing, RequestValidating, RequestValidated and RequestProcessed via user-defined methods. This is particularly useful in situations when the mechanisms provided by the framework are not sufficient for the project-specific requirements, in particular for certain restrictions. The procedure of processing up to the answer of inquiries runs through the following steps:

1. Receiving the raw data of a Request (Protocol Level of the framework)
2. Deserialization of the raw data for a Request (Message Level of the framework)
3. Preprocessing request: **RequestProcessing event**
4. Delegation of the request to the corresponding service (Service Level of the framework)
5. Validation of the Request
    1. Default validations (Session, Identity, ...)
    2. userdefined validation: **RequestValidating event**
    3. final validation (check of custom validation)
    4. custom completion of validation: **RequestValidated event**
6. Processing the request (Application Level of the framework)
7. Generating the answer via the corresponding service (Service Level of the framework)
8. Post processing of the Request and its Response: **RequestProcessed event**
9. Serialization of the Response to raw data (Message Level of the framework)
10. Sending the raw data of the Response (Protocol Level of the framework)

The events mentioned under points 3, 5.2, 5.4 and 8. offer the developer of the Server the opportunity to monitor or influence the processing of Requests via user-defined code. The user-defined code of the RequestProcessing event is executed immediately after receipt and processing of the user data in the form of an IOpcServiceRequest instance. The information provided here is used for the primary diagnosis of message traffic between Client and Server. An event handler registered here should not throw an exception:

```
private static void HandleRequestProcessing(object sender, OpcRequestProcessingEventArgs e)
{
    Console.Write("Processing: " + e.Request.ToString());
}

// ...

server.RequestProcessing += HandleRequestProcessing;
```

The context provided in the OpcRequestProcessingEventArgs always corresponds to an instance of the

OpcContext class, which describes only the general environment of message processing. The information provided in this event handler is also supplemented in the subsequent RequestValidating event with information about the Session and Identity. In the case of Requests that require a Session, the OpcContext object provided is the specialization OpcOperationContext. The OpcOperationContext can be used to perform additional session-related validations:

```
private static nodesPerSession = new Dictionary<OpcNodeId, int>();

private static void HandleRequestValidating(object sender, OpcRequestValidatingEventArgs e)
{
    Console.Write(" -> Validating: " + e.Request.ToString());

    if (e.RequestType == OpcRequestType.AddNodes) {
        var sessionId = e.Context.SessionId;
        var request = (OpcAddNodesRequest)e.Request;

        lock (sender) {
            if (!nodesPerSession.TryGetValue(sessionId, out var count))
                nodesPerSession.Add(sessionId, count);

            count += request.Commands.Count;
            nodesPerSession[sessionId] = count;

            e.Cancel = (count >= 100);
        }
    }
}

// ...

server.RequestValidating += HandleRequestValidating;
```

The example shows how to limit the number of “AddNodes” requests per session to 100 “AddNode” commands. Any further Rrequest will be refused once the restriction has been reached. This is done by setting the Cancel property of the event's arguments to “true”, which automatically sets the Result property code of the event's arguments to the “BadNotSupported” value. It is also possible to cancel the Request by (additional) setting a “Bad” code. An event handler registered at the RequestValidating event may throw an exception. However, if an exception is raised in the event handler or the Cancel property is set to “true” or the Result property of the event's arguments is set to a “Bad” code, then the event handlers of the RequestValidated event are not executed (which is the .NET Framework known Validating-Validated-Pattern). If, on the other hand, the Request is not aborted, the event handlers of the RequestValidated event are executed:

```
void HandleRequestValidated(object sender, OpcRequestValidatedEventArgs e)
{
    Console.Write(" -> Validated");
}

// ...

server.RequestValidated += HandleRequestValidated;
```

Again, as with the RequestProcessing event, the information provided serves as the primary diagnostic of message traffic between Client and Server. The benefit of the event is that only after calling the event the Server also tries to process and answer the Request. An event handler registered here should not throw an exception. After completing the query processing performed by the Server, the Request is finally answered

with the resulting results. The resulting Response can be evaluated together with the Request in the RequestProcessed event:

```
private static void HandleRequestProcessed(object sender, OpcRequestProcessedEventArgs e)
{
    if (e.Response.Success)
        Console.WriteLine(" -> Processed!");
    else
        Console.WriteLine(" -> FAILED: {0}!", e.Exception?.Message ??
e.Response.ToString());
}

// ...

server.RequestProcessed += HandleRequestProcessed;
```

As shown in the above example, the arguments of the event additionally provides information about an exception that may have occurred during the processing. An event handler registered here should not throw an exception.

Server Configuration

General Configuration

The following types are used here: OpcServer, OpcCertificateStores and OpcCertificateStoreInfo.

In all code snippets depicted the Server is always configured via the code (if the default configuration of the Server is not used). The **OpcServer** instance is the central port for the configuration of the Server application. All settings concerning security can be found as an instance of the **OpcServerSecurity** class via the *Security* property of the Server. All settings concerning the Certificate Store can be found as an instance of the **OpcCertificateStores** class via the *CertificateStores* property of the Server.

If the Server shall be configurable via XML you can load the configuration of the Server either from a selected or a random XML file. Instructions are provided in the section “Preparations of Server Configuration via XML”.

As soon as preparations for configuring the Server configuration via XML have been made, the settings can be loaded as follows:

- Loading the configuration file via App.config
  ```
  server.Configuration =
  OpcApplicationConfiguration.LoadServerConfig("Opc.UaFx.Server");
  ```
- Loading the configuration file via the path to the XML file
  ```
  server.Configuration =
  OpcApplicationConfiguration.LoadServerConfigFile("MyServerAppNameConfig.xml");
  ```

For configuring the Server application amongst others are the following options:

- Configurating the application
  - via Code:

```
// Default: Value of AssemblyTitleAttribute of entry assembly.
server.ApplicationName = "MyServerAppName";

// Default: A null reference to auto complete on start to "urn::" +
ApplicationName
server.ApplicationUri = "http://my.serverapp.uri/";
```

- via XML (underneath the *OpcApplicationConfiguration* element):

```
<ApplicationName>MyServerAppName</ApplicationName>
<ApplicationUri>http://my.serverapp.uri/</ApplicationUri>
```

- Configuring the Certificate Store
  - via Code:

```
// Default: ".\CertificateStores\Trusted"
server.CertificateStores.ApplicationStore.Path
        = @"%LocalApplicationData%\MyServerAppName\App Certificates";

// Default: ".\CertificateStores\Rejected"
server.CertificateStores.RejectedStore.Path
        = @"%LocalApplicationData%\MyServerAppName\Rejected Certificates";

// Default: ".\CertificateStores\Trusted"
server.CertificateStores.TrustedIssuerStore.Path
        = @"%LocalApplicationData%\MyServerAppName\Trusted Issuer Certificates";

// Default: ".\CertificateStores\Trusted"
server.CertificateStores.TrustedPeerStore.Path
        = @"%LocalApplicationData%\MyServerAppName\Trusted Peer Certificates";
```

  - via XML (underneath the *OpcApplicationConfiguration* element):

```
  <SecurityConfiguration>
    <ApplicationCertificate>
      <StoreType>Directory</StoreType>
      <StorePath>%LocalApplicationData%\MyServerAppName\CertificateStores\App
Certificates</StorePath>
      <SubjectName>MyServerAppName</SubjectName>
    </ApplicationCertificate>

    <RejectedCertificateStore>
      <StoreType>Directory</StoreType>
<StorePath>%LocalApplicationData%\MyServerAppName\CertificateStores\Rejected
Certificates</StorePath>
    </RejectedCertificateStore>

    <TrustedIssuerCertificates>
      <StoreType>Directory</StoreType>
      <StorePath>%LocalApplicationData%\MyServerAppName\CertificateStores\Trusted
Issuer Certificates</StorePath>
    </TrustedIssuerCertificates>

    <TrustedPeerCertificates>
      <StoreType>Directory</StoreType>
      <StorePath>%LocalApplicationData%\MyServerAppName\CertificateStores\Trusted
Peer Certificates</StorePath>
    </TrustedPeerCertificates>
  </SecurityConfiguration>
```

Certificate Configuration

The following types are used here: OpcServer, OpcCertificateManager, OpcServerSecurity, OpcCertificateStores and OpcCertificateStoreInfo.

Recommended are certificates of types .der, .pem, **.pfx** and **.p12**. If the Server shall provide a secure endpoint (in which the **OpcSecurityMode** equals *Sign* or *SignAndEncrypt*), the certificate has to have a private key.

1. An **existing certificate** is loaded from any path:
```
var certificate = OpcCertificateManager.LoadCertificate("MyServerCertificate.pfx");
```
2. A **new certificate** is generated (in storage):
```
var certificate = OpcCertificateManager.CreateCertificate(server);
```
3. Save a certificate in any path:
```
OpcCertificateManager.SaveCertificate("MyServerCertificate.pfx", certificate);
```
4. Set the Server certificate:
```
server.Certificate = certificate;
```
5. The certificate has to be stored in the **Application Store**:
```
if (!server.CertificateStores.ApplicationStore.Contains(certificate))
    server.CertificateStores.ApplicationStore.Add(certificate);
```
6. If **no or an invalid certificate** is used, a new certificate is generated / used by default. If the Server shall only use the mentioned certificate this function has to be deactivated. For **deactivating the function** set the property **AutoCreateCertificate** to the value *false*:
```
server.CertificateStores.AutoCreateCertificate = false;
```

User Identity Configuration

The following types are used here: OpcServer, OpcUserIdentity, OpcServerIdentity, OpcCertificateIdentity, OpcServerSecurity, OpcAccessControlList, OpcAnonymousAcl, OpcUserNameAcl, OpcCertificateAcl, OpcAccessControlEntry, OpcOperationType, OpcRequestType and OpcAccessControlMode.

By default a Server allows access without a concrete user identity. This kind of authentication is called anonymous authentication. When a user identity is mentioned it has to be known to the Server in order to access the Server with this identity. For example, if a username-password pair or a certificate shall be used for user identification, the according ACLs (Access Control Lists) have to be configured and activated. Part of the configuration of control lists is the configuration of ACEs (Access Control Entries). Those are defined by a principal with a certain identity (username-password pair or certificate) and registered in a list.

- Deactivating the anonymous ACL:
```
server.Security.AnonymousAcl.IsEnabled = false;
```
- Configuring the **username-password pair**-based ACL:

```
var acl = server.Security.UserNameAcl;

acl.AddEntry("username1", "password1");
acl.AddEntry("username2", "password2");
acl.AddEntry("username3", "password3");
...
acl.IsEnabled = true;
```

- Configuring the **certificate**-based ACL:

```
var acl = server.Security.CertificateAcl;

acl.AddEntry(new X509Certificate2(@".\user1.pfx"));
acl.AddEntry(new X509Certificate2(@".\user2.pfx"));
acl.AddEntry(new X509Certificate2(@".\user3.pfx"));
...
acl.IsEnabled = true;
```

All Access Control Lists defined by the Framework up until now use the mode “Whitelist” as Access Control Mode. In this mode every entry has - only by defining an Access Control Entry - access to all Types of Requests, even if the access was not explicitly allowed to the entry. Therefore all non-allowed actions have to be denied to the entries. Allowed and denied operations can be set directly on the entry which is available after the note in the ACL.

1. Remember an Access Control Entry:

```
var user1 = acl.AddEntry("username1", "password1");
```

2. Deny the Access Control Entry two rights:

```
user1.Deny(OpcRequestType.Write);
user1.Deny(OpcRequestType.HistoryUpdate);
```

3. Allow a previously denied right:

```
user1.Allow(OpcRequestType.HistoryUpdate);
```

Server Endpoint Configuration

The following types are used here: OpcServer, OpcServerSecurity, OpcSecurityPolicy, OpcSecurityMode and OpcSecurityAlgorithm.

Endpoints of a Server are defined through the cross product of used Base-Addresses and configured security strategies for endpoints. The Base-Addresses consist of supported scheme-port pairs and the host (IP address or DNS name), where several schemes (possible are “http”, “https”, “opc.tcp”, “net.tcp” and “net.pipe”) can be set for data exchange on different ports. By default the Server does not use a special policy to supply a secure endpoint. Therefore there are as many endpoints as there are Base-Addresses. If a Server defines exactly one Base-Address there is only one endpoint with this Base-Address and the security policy with the mode *None*. If there are n different Base-Addresses there are n different endpoints with exactly the same security policy, even if only one special security policy is set. But if there are m different security policies (s_1, s_2, s_3, …, s_m), n different Base-Addresses (b_1, b_2, …, b_n) create the endpoints that are created by a pairing of policy and Base-Address (s_1+b_1, s_1+b_2, …, s_1+b_n, s_2+b_1, s_2+b_2, …, s_2+b_n, s_3+b_1, s_3+b_2, …, s_3+b_n, s_m+b_n, …).

Additional to the Security-Mode of the protection of communication to be used, an Endpoint-Policy defines a Security-Algorithm and a level. According to the OPC Foundation the level of policy of an endpoint exists

as a relative measure for security policies used for the endpoint. An endpoint with a higher level is defined more secure as an endpoint with a lower level (note that this is merely a neither watched nor imposed guideline).

If two Security-Policies are followed, they could be defined like this:

- Security-Policy A: Level=0, Security-Mode=None, Security-Algorithm=None
- Security-Policy B: Level=1, Security-Mode=Sign, Security-Algorithm=Basic256

If furthermore three Base-Addresses are set for different schemes:

- Base-Address A: "https://mydomain.com/"
- Base-Address B: "opc.tcp://192.168.0.123:4840/"
- Base-Address C: "opc.tcp://192.168.0.123:12345/"

The result of the cross product will be these endpoint descriptions:

- Endpoint 1: Address="https://mydomain.com/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 2: Address="https://mydomain.com/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256
- Endpoint 3: Address="opc.tcp://192.168.0.123:4840/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 4: Address="opc.tcp://192.168.0.123:4840/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256
- Endpoint 5: Address="opc.tcp://192.168.0.123:12345/", Level=0, Security-Mode=None, Security-Algorithm=None
- Endpoint 6: Address="opc.tcp://192.168.0.123:12345/", Level=1, Security-Mode=Sign, Security-Algorithm=Basic256

For configuring the (primary) Base-Address either the constructor of the **OpcServer** Class or the **Address** property of an **OpcServer** instance can be used:

```
var server = new OpcServer("opc.tcp://localhost:4840/");
server.Address = new Uri("opc.tcp://localhost:4840/");
```

If the Server shall support further Base-Addresses these can be administrated through the methods **RegisterAddress** and **UnregisterAddress**. All of those Base-Addresses used (therefore registered) by the Server can be called via the **Addresses** property. If the value of the **Address** property was not set primarily the first address defined through **RegisterAddress** will be used for the **Address** property.

Define two more Base-Addresses:

```
server.RegisterAddress("https://mydomain.com/");
server.RegisterAddress("net.tcp://192.168.0.123:12345/");
```

Unregister two Base-Addresses from the Server in order for the “main” Base-Address to change:

```
server.UnregisterAddress("https://mydomain.com/");

// server.Address becomes: "net.tcp://192.168.0.123:12345/"
server.UnregisterAddress("opc.tcp://localhost:4840/");
```

If all addresses of the **Addresses** property are unregistered the value of the **Address** property is not set.

Definition of a secure security policy for endpoints of the Server:

```
server.Security.EndpointPolicies.Add(new OpcSecurityPolicy(
        OpcSecurityMode.Sign, OpcSecurityAlgorithm.Basic256, 3));
```

By defining a concrete security policy for endpoints the default policy with the mode *None* is lost. In order for this policy (not recommended for the productive use) to be supported by the Server it has to be registered explicitly in the Endpoint-Policy list:

```
server.Security.EndpointPolicies.Add(new OpcSecurityPolicy(
        OpcSecurityMode.None, OpcSecurityAlgorithm.None, ));
```

Further Security Settings

The following types are used here: OpcServer, OpcServerSecurity, OpcCertificateValidationFailedEventArgs, OpcCertificateStores und OpcCertificateStoreInfo.

A Client sends its certificate to the Server for authentification during the connecting. The Server can decide if to approve a connection and trust or untrust a Client using the certificate.

- If the Server shall accept **only trusted** certificates the default acceptance of all certificates must be deactivated as follows:

  ```
  server.Security.AutoAcceptUntrustedCertificates = false;
  ```

- As soon as the default acceptance of all certificates has been deactivated a custom check of certificates is necessary:

  ```
  server.CertificateValidationFailed += HandleCertificateValidationFailed;
  ...
  private void HandleCertificateValidationFailed(object sender,
  OpcCertificateValidationFailedEventArgs e)
  {
      if (e.Certificate.SerialNumber == "...")
          e.Accept = true;
  }
  ```

- If the Client certificate is judged as **untrusted** it can be declared **trusted** manually by saving it in the TrustedPeerStore:

  ```
  // In context of the event handler the sender is an OpcServer.
  var server = (OpcServer)sender;

  if (!server.CertificateStores.TrustedPeerStore.Contains(e.Certificate))
      server.CertificateStores.TrustedPeerStore.Add(e.Certificate);
  ```

Configuration via XML

If the Server shall also be configurable via XML the Server configuration can be loaded either from a specific or a random XML file.

Using a certain XML file, it has to show the following default XML tree:

```
<?xml version="1.0" encoding="utf-8" ?>
<OpcApplicationConfiguration xmlns="http://opcfoundation.org/UA/SDK/Configuration.xsd"
                             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                             xmlns:ua="http://opcfoundation.org/UA/2008/02/Types.xsd">
</OpcApplicationConfiguration>
```

If a random XML file shall be used for configuration a .config file (referring to an XML file from which the configuration for the Server shall be loaded) has to be created. This section shows which entries the .config file has to have and how the XML file must be structured.

Compiling and preparing the App.config of the application:

1. Add an App.config (if not already existing) to the project
2. Insert this *configSections* element underneath the *configuration* elements:

```
<configSections>
  <section name="Opc.UaFx.Server"
           type="Opc.Ua.ApplicationConfigurationSection,
                 Opc.UaFx.Advanced,
                 Version=2.0.0.0,
                 Culture=neutral,
                 PublicKeyToken=0220af0d33d50236" />
</configSections>
```

3. Also insert this *Opc.UaFx.Server* element underneath the *configuration* elements:

```
<Opc.UaFx.Client>
  <ConfigurationLocation xmlns="http://opcfoundation.org/UA/SDK/Configuration.xsd">
    <FilePath>MyServerAppNameConfig.xml</FilePath>
  </ConfigurationLocation>
</Opc.UaFx.Client>
```

4. The value of the *FilePath* element can show to a random data path where you will find the XML configuration file needed. The value shown here would show to a configuration file lying next to the application.
5. Save the changes to App.config

Creating and preparing the XML configuration file:

1. Create an XML file with the name used in the App.config and save under the path used in App.config.
2. Insert this default XML tree for XML configuration files:

```
<?xml version="1.0" encoding="utf-8" ?>
<OpcApplicationConfiguration xmlns="http://opcfoundation.org/UA/SDK/Configuration.xsd"
                             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
                             xmlns:ua="http://opcfoundation.org/UA/2008/02/Types.xsd">
</OpcApplicationConfiguration>
```

3. Save changes to XML file

Server Application Delivery

This is how you prepare your OPC UA Server application for the use in productive environment.

Application Certificate - *Using a concrete certificate*
Don't use an automatically Framework-generated certificate in productive use.

If you already have an appropriate certificate for your application you can load your PFX-based certificate from any random Store and assign it to the Server instance via the **OpcCertificateManager**:

```
var certificate = OpcCertificateManager.LoadCertificate("MyServerCertificate.pfx");
server.Certificate = certificate;
```

Note that the application name has to be included in the certificate as “Common Name” (CN) and has to match with the value of the *AssemblyTitle* attribute:

```
[assembly: AssemblyTitle("<Common Name (CN) in Certificate>")]
```

If that isn't the case you have to set the name used in the certificate via the **ApplicationName** property of the Server instance. If the “Domain Component” (DC) part is used in the certificate the value of the **ApplicationUri** property of the application has to show the same value:

```
server.ApplicationName = "<Common Name (CN) in Certificate>";
server.ApplicationUri = new Uri("<Domain Component (DC) in Certificate>");
```

If you don't already have an appropriate certificate you can use as an application certificate for your Server you should at least create and use a self-signed certificate via the Certificate Generator of the OPC Foundation. The Certificate Generator (Opc.Ua.CertificateGenerator.exe) included in the SDK of the Framework is opened as follows:

```
Opc.Ua.CertificateGenerator.exe -sp . -an MyServerAppName
```

The first parameter (-sp) sets saving the certificate in the current list. The second parameter (-an) sets the name of the Server application using the application certificate. Replace “MyServerAppName” by the name of your Server application. Note that **the Framework for chosing the application certificate uses the value of the *AssemblyTitle* attribute and therefore the same value as stated in this attribute is used for “MyServerAppName”**. In alternative to the value in the *AssemblyTitle* attribute the value used in the application certificate can be set via the **ApplicationName** property of the Server instance:

```
server.ApplicationName = "MyDifferentServerAppName";
```

It is important that either the value of the *AssemblyTitle* attribute or the value of the **ApplicationName** property equals the value of the second parameter (-an). If you want to set further properties of the certificate as, for example, the validity in months (default 60 months) or the name of the company or the names of the domains the Server will be working on, call the generator with the parameter !/?“ in order to receive a list of all further / possible parameter values:

```
Opc.Ua.CertificateGenerator.exe /?
```

After the Certificate Generator was opened with the corresponding parameters, the folders “certs” and “private” are in the current list. Without changing the names of the folders and the files, copy both folders in the list that you set as Store for the application certificates. By default that is the folder “Trusted” in the folder “CertificateStores” next to the application.

If you have set the parameter “ApplicationUri” (-au) you have to set the same value on the **ApplicationUri** property of the Server instance:

```
server.ApplicationUri = new Uri("<ApplicationUri>");
```

Configuration Surroundings - *All files necessary for an XML-based configuration*

If the application shall be configurable through a random XML file referenced in the App.config, App.config has to be in the same list as the application and hold the name of the application as a prefix:

```
<MyServerAppName>.exe.config
```

If the application is configured through a (certain) XML file, ensure that the file is accessible for the application.

System Configuration - *Administrative Setup*

Execute the application in the target system once only with administrative rights to ensure that the Server has permission to access the network resources. This is necessary, if e.g. the Server shall use a Base-Address with the scheme “http” or “https”.

Licensing

The OPC UA SDK comes with an **evaluation license which can be used unlimited for each application run for 30 minutes**. If this restriction limits your evaluation options, you can request another evaluation license from us.

After receiving your personalized **license key for OPC UA Server development** it has to be committed to the framework. Hereto insert the following code line into your application **before** accessing the **OpcServer class** for the first time. Replace *<insert your license code here>* with the license key you received from us.

```
Opc.UaFx.Server.Licenser.LicenseKey = "<insert your license code here>";
```

If you purchased a **bundle license key for OPC UA Client and Server development** from us, it has to be committed to the framework as follows:

```
Opc.UaFx.Licenser.LicenseKey = "<insert your license code here>";
```

Additionally you receive information about the license currently used by the framework via the *LicenseInfo* property of the **Opc.UaFx.Server.Licenser class** for Server licenses and via the **Opc.UaFx.Licenser class** for bundle licenses. This works as follows:

```
ILicenseInfo license = Opc.UaFx.Server.Licenser.LicenseInfo;

if (license.IsExpired)
    Console.WriteLine("The OPA UA SDK license is expired!");
```

Note that a once set **bundle license becomes ineffective by additionally committing a Server license key**!

In the course of development/evaluation, it is mostly irrelevant whether the test license or the license already purchased is being used. However, as soon as the application goes into productive use, it is annoying if the application stops working during execution due to an invalid license. For this reason, we recommend implementing the following code snippet in the Server application and at least executing it when the application is started:

```
#if DEBUG
    Opc.UaFx.Server.Licenser.FailIfUnlicensed();
#else
    Opc.UaFx.Server.Licenser.ThrowIfUnlicensed();
#endif
```

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