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# TECHNICAL NOTE

## Cross Support Transfer Service API - Developer's Guide

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**Table of contents:**

<b>1 INTRODUCTION.....</b>	<b>5</b>
1.1 Purpose and Scope .....	5
1.2 Document Overview.....	5
<b>2 APPLICABLE AND REFERENCE DOCUMENTS.....</b>	<b>6</b>
2.1 Applicable and Reference Documents.....	6
<b>3 USAGE OF THE CSTS API .....</b>	<b>7</b>
3.1 Importing the CSTS API .....	7
3.2 Implementing a Service Application .....	8
<b>4 ARCHITECTURAL DESIGN.....</b>	<b>10</b>
4.1 CSTS API Instances.....	10
4.2 Procedures.....	10
<b>5 WORKFLOWS WITHIN THE CSTS API.....</b>	<b>12</b>
5.1 State Machine.....	12
5.2 Parameters .....	13
5.3 Events.....	13
<b>6 EXTENDING THE CSTS API.....</b>	<b>15</b>
6.1 Suggested Approach.....	15
6.2 Essential Methods .....	16
6.2.1 Initialization of Operation Types .....	16
6.2.2 Type and Version.....	16
6.2.3 Termination of Procedures .....	16
6.2.4 Creation of Operations .....	16
6.2.5 Initiation and Information of passed Operations.....	17
6.2.6 Encoding and Decoding Operations .....	17
6.3 Diagnostics .....	18
6.4 Procedure States .....	18
6.5 Parameters .....	19
6.6 Procedure Configuration Parameters .....	20
6.7 Procedure Events .....	21
<b>7 PREDEFINED CCSDS TYPE CLASSES.....</b>	<b>22</b>
7.1 Object Identifier .....	22
7.2 Name .....	22
7.3 Label .....	23
7.4 Label List.....	23
7.5 Qualified Parameters .....	23
7.6 Time.....	26
7.7 Conditional Time .....	26
7.8 Duration .....	26
7.9 Extension.....	26

**Table of figures:**

Figure 1: CSTS API Import .....	7
---------------------------------	---



Figure 2: CSTS API Architecture ..... 10

Figure 3: Procedure Architecture ..... 11

Figure 4: State Machine ..... 12

Figure 5: CSTS Parameters ..... 13

Figure 6: CSTS Events..... 14

Figure 7: Suggested Approach for extending Procedures ..... 15

Figure 8: Architecture of Parameters .....20

Figure 9: Qualified Parameters Mapping .....24

Figure 10: Parameter Type Mapping ..... 25

**Table of tables:**

**NO TABLE OF FIGURES ENTRIES FOUND.**



## **1 INTRODUCTION**

The Cross Support Transfer Service (CSTS) API is a Java 8 framework implementing the defined standards of the CCSDS Blue Book *Cross Support Transfer Service – Specification Framework* (CCSDS 921.1-B-1).

### **1.1 Purpose and Scope**

This document is the Developer's Guide for version 1.0 of the CSTS API. It provides necessary information on how to use the CSTS API to build new services as well as the extension of CSTS framework procedures to add new procedures conforming the provided API.

### **1.2 Document Overview**

The Developer's Guide is structured as follows:

- Section 2 lists applicable and referenced documents
- Section 3 introduces the usage of the CSTS API by building a service based upon provided and extended procedures
- Section 4 outlines the architectural design to provide an overview of necessary information relevant while extending the CSTS framework
- Section 5 describes and visualizes workflows within the CSTS API
- Section 6 provides information on how to extend the CSTS framework by new procedures
- Section 7 lists predefined CCSDS types and how they are being used in their Java context within the CSTS API



## **2 APPLICABLE AND REFERENCE DOCUMENTS**

This section lists applicable and referenced documents with their issue, revision and date.

### **2.1 Applicable and Reference Documents**

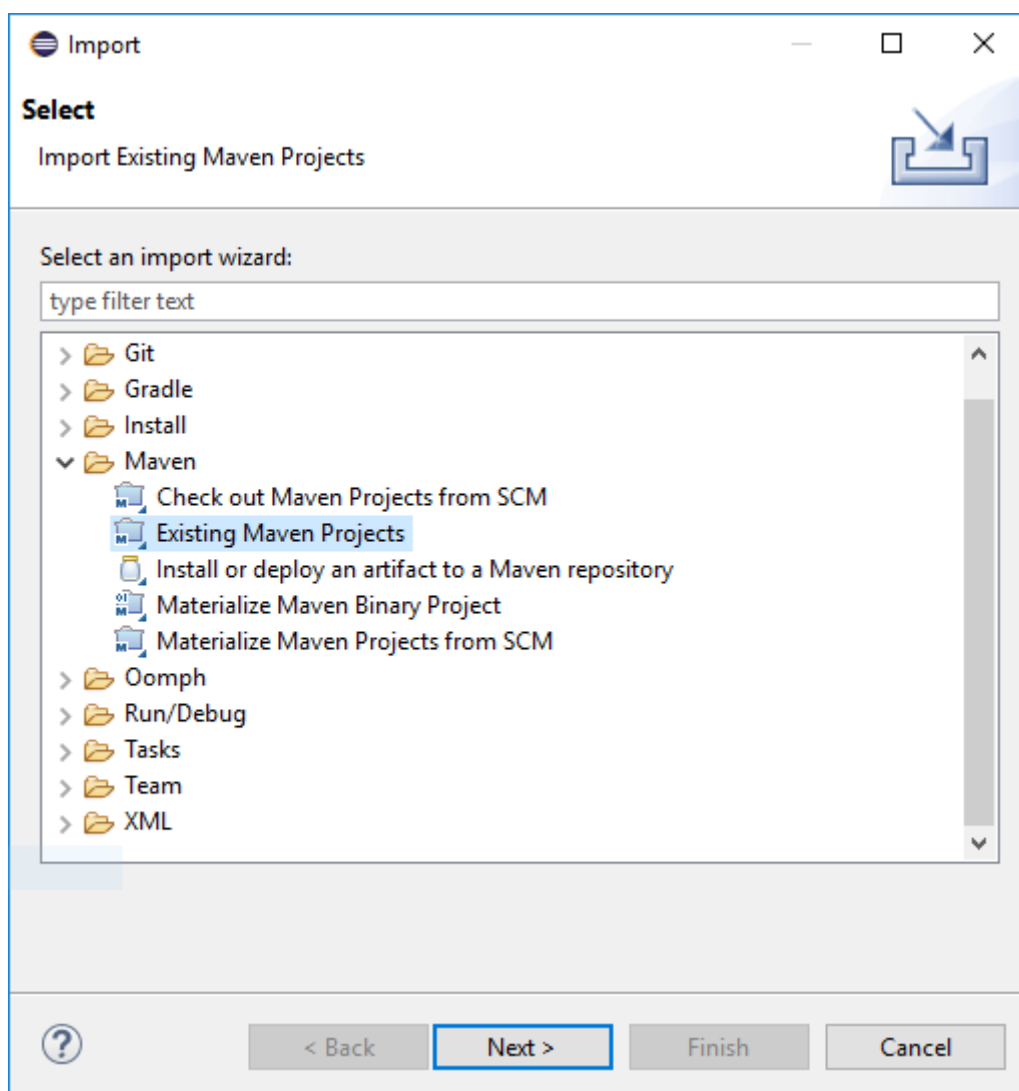
<b>Ref.</b>	<b>Document Title</b>	<b>Issue and Revision, Date</b>
[AD-1] CCSDS 921.1-B-1	Cross Support Transfer Service – Specification Framework	Original issue, April 2017

### 3 USAGE OF THE CSTS API

This section introduces the usage of the CSTS API by building a service based on provided procedures as well as procedures, which were created by extending existing procedures as suggested as in Section 6.

#### 3.1 Importing the CSTS API

The CSTS API is delivered as a Maven project. The import functionality for Maven projects of Eclipse is sufficient to import the delivered CSTS API and resolve all dependencies.



**Figure 1: CSTS API Import**

### 3.2 Implementing a Service Application

Applications using the CSTS API need to implement the **IServiceInform** interface. This interface informs the service about incoming operations. The operations are forwarded to the application through the following three methods depending on their type:

```
void informOpInvocation(IOperation operation)
```

```
void informOpAcknowledgement(IAcknowledgedOperation operation)
```

```
void informOpReturn(IConfirmedOperation operation)
```

The actual type of the forwarded operation is queried by the

```
OperationType getType()
```

method of the **IOperation** interface. The returned enumeration type contains all available CSTS operation types, as well as the forward buffer and return buffer types relevant to the **Buffered Data Delivery** and the **Buffered Data Processing** procedures.

Following sample demonstrates the implementation of a sample service built upon the **Information Query**, **Cyclic Report** and **Notification** procedures:

```
ICstsApi api;
IServiceInstance serviceInstance;
IInformationQuery informationQuery;
ICyclicReport cyclicReport;
INotification notification;

api = new CstsApi("Test Service", AppRole.PROVIDER);
api.initialise(configFile);

ObjectIdentifier spacecraftId = ObjectIdentifier.of(1,3,112,4,7,0);
ObjectIdentifier facilityId = ObjectIdentifier.of(1,3,112,4,6,0);
ObjectIdentifier typeId = ObjectIdentifier.of(1,3,112,4,4,1,2);
int instanceNumber = 0;

IServiceInstanceId identifier = new ServiceInstanceId(spacecraftId,
facilityId, typeId, instanceNumber);
serviceInstance = api.createServiceInstance(identifier, this);

informationQuery = serviceInstance.createProcedure(InformationQueryProvider.class);
informationQuery.setRole(ProcedureRole.PRIME, 0);
serviceInstance.addProcedure(informationQuery);

cyclicReport = serviceInstance.createProcedure(CyclicReportProvider.class);
cyclicReport.setRole(ProcedureRole.SECONDARY, 0);
serviceInstance.addProcedure(cyclicReport);
cyclicReport.getMinimumAllowedDeliveryCycle().initializeValue(50);
```





```
notification = serviceInstance.createProcedure(NotificationProvider.class);
notification.setRole(ProcedureRole.SECONDARY, 0);
serviceInstance.addProcedure(notification);

// the application needs to make sure that it chooses valid values from the proxy
configuration
serviceInstance.setPeerIdentifier(serviceInstance.getApi().getProxySettings().getRemote
PeerList().get(0).getId());
serviceInstance.setResponderPortIdentifier(serviceInstance.getApi().getProxySettings().
getLogicalPortList().get(0).getName());

serviceInstance.configure();
```

The configuration file parameter which is passed to the CSTS API is the specified path of the XML file provided by the application to configure the provider or user and its underlying communications service.

The example above can be analogously used for user instances. It is sufficient to exchange the AppRole by the user indicator and instantiate user classes of procedures while creating them. Additionally configuration parameters (if the procedure has any) does not need to be initialized for user instances. Configuration parameters only need to be initialized in provider instances and only in the case if they are not initialized by default.

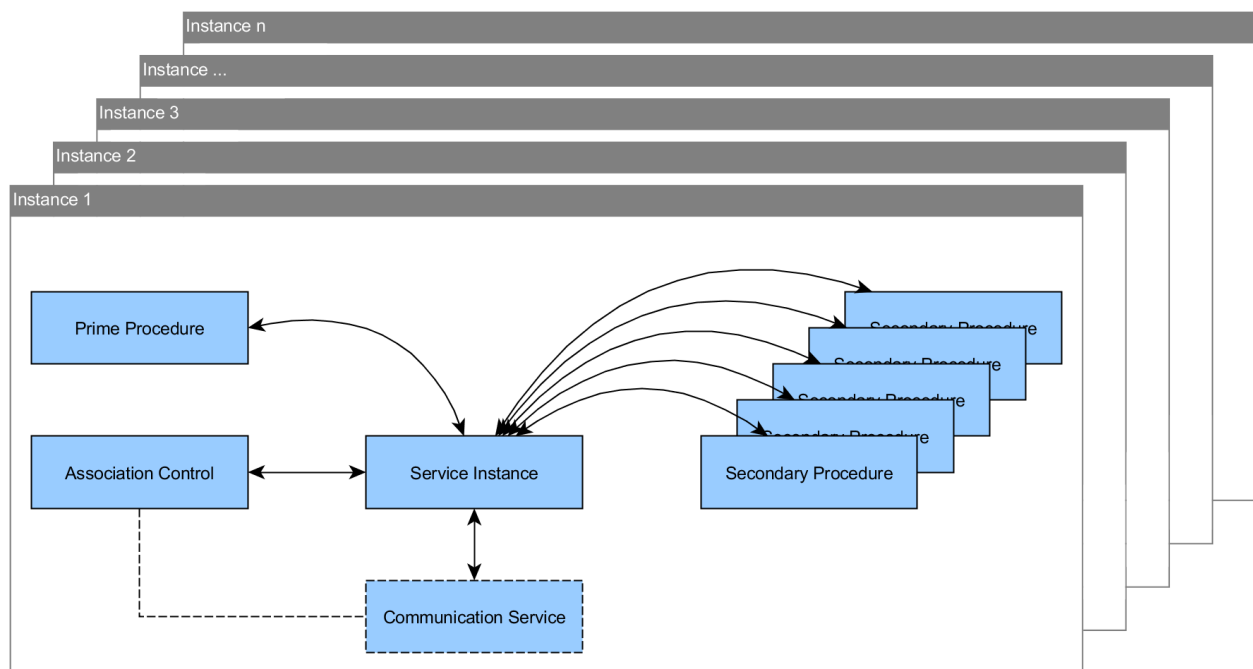
In the provider example above the **Cyclic Report** procedure has two configuration parameters of which one need to be initialized. The initialization needs to take place after adding the procedure to the service instance. The second configuration parameter does not need to be initialized since its type is a list of labels, which is initialized by default and is empty at initialization.

## 4 ARCHITECTURAL DESIGN

This section introduces architectural aspects of the CSTS API.

### 4.1 CSTS API Instances

An instance of the CSTS API is composed by multiple Service Instances. Service Instances consist of one Association Control Procedure, one prime procedure of any type and multiple secondary procedures. Figure 2: CSTS API Architecture illustrates the architecture of the CSTS API.

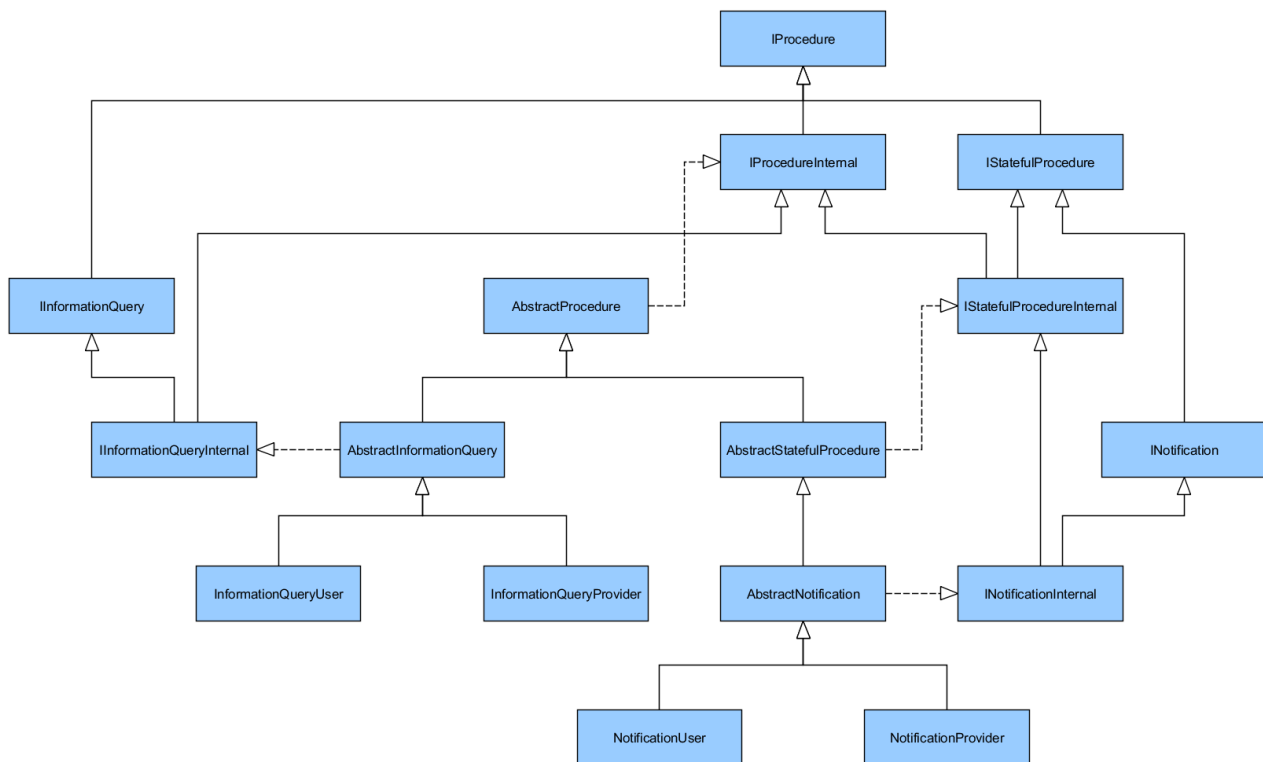


**Figure 2: CSTS API Architecture**

### 4.2 Procedures

Figure 3: Procedure Architecture illustrates the architecture of Procedures within the CSTS API. The Information Query and the Notification Procedures are chosen for demonstration purposes of how stateless (Information Query) and stateful (Notification) Procedures are integrated into the CSTS API architecture.

*Note: continuous lines represent inheritance, dashed lines the implementation of an Interface.*



**Figure 3: Procedure Architecture**

The **AbstractProcedure** class is the base class of all procedures. It transitionally implements the **IProcedure** interface through the **IProcedureInternal** interface. All stateful procedures inherit from the **AbstractStatefulProcedure**, which transitionally implements the **IStatefulProcedure** interface through the **IStatefulProcedureInternal** interface.

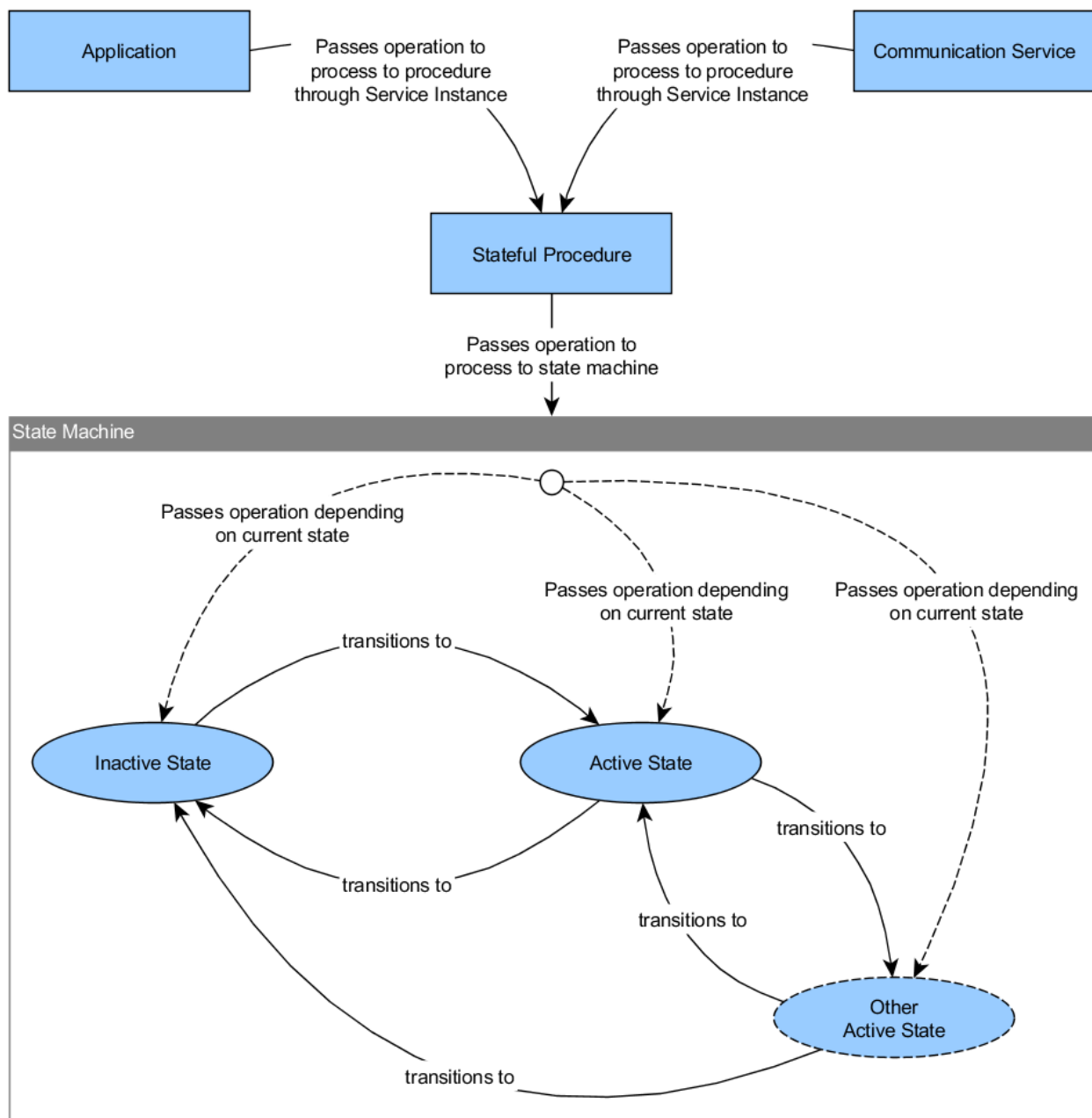
All procedures (abstract as well as concrete) introduce their own interfaces for referring that procedure from outside the CSTS API (e.g. from the application) and additionally implement an internal interface. The internal interface specifies methods which are intended to be used solely from within the CSTS API, as in such cases as the underlying state machine.

## 5 WORKFLOWS WITHIN THE CSTS API

This section provides information about automated workflows within the CSTS API.

### 5.1 State Machine

Figure 4: State Machine shows the workflow of the underlying state machine of procedures.

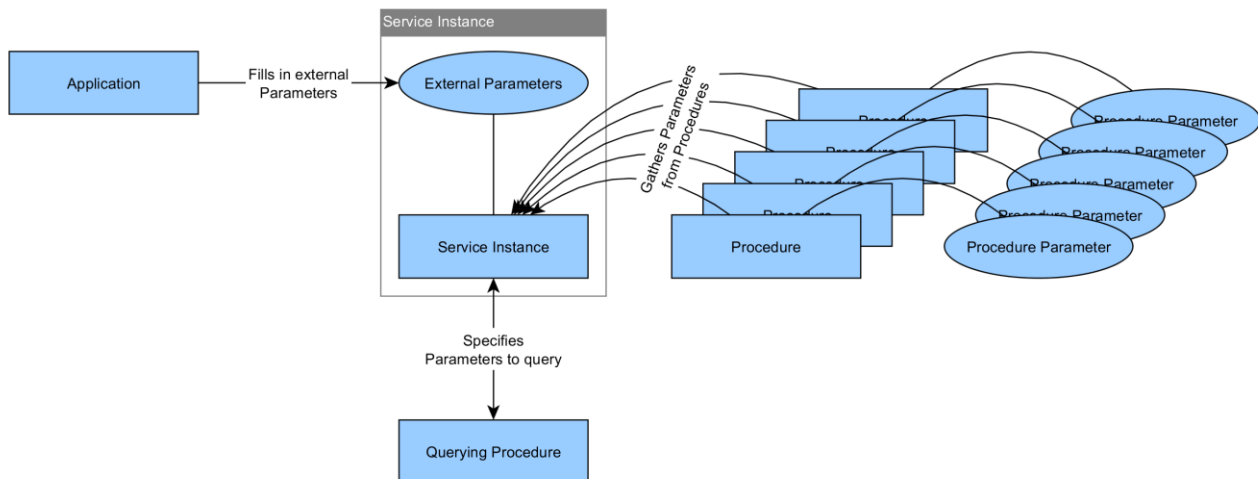


**Figure 4: State Machine**

Depending on the operation and its state, after processing the operation is being forwarded to the application or the underlying communication service.

## 5.2 Parameters

Parameters and their workflow within the CSTS API is shown in Figure 5: CSTS Parameters.



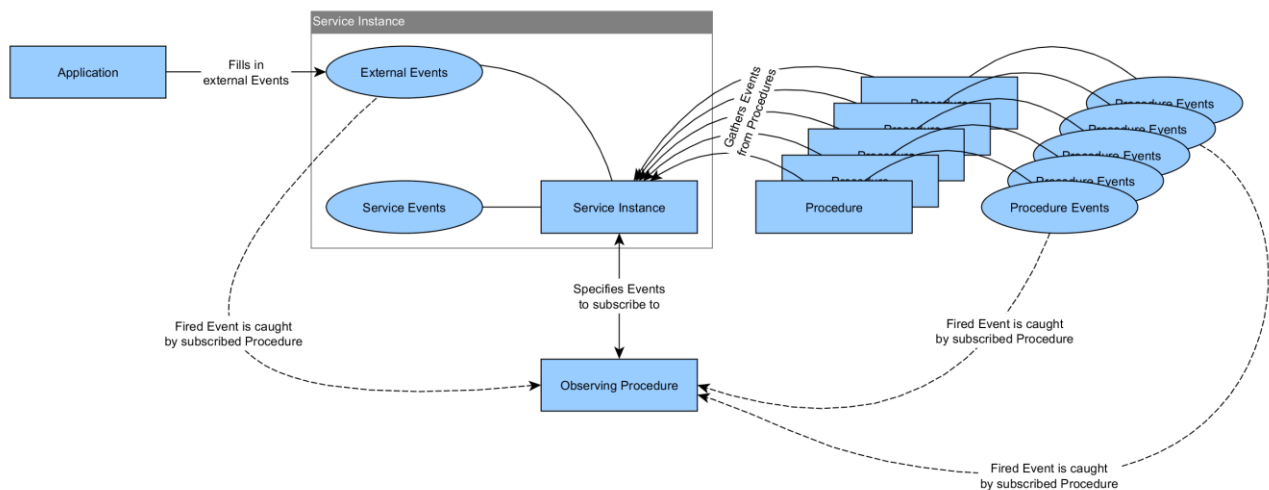
**Figure 5: CSTS Parameters**

Parameters belonging to procedures (configuration parameters) are being observed by the procedure by default. On change, an internal procedure event (not to be confused with CSTS events in Section 5.3) is triggered and the procedure gets a notification and can then further process the change (e.g. by raising a CSTS event).

External parameters are being passed to the service instance by the application. Passing parameters to the service instance is also possible at runtime. These parameters are immediately available to the querying procedures such as the **Information Query** procedure. The parameters are always queried through the service instance, where all parameters are gathered.

## 5.3 Events

CSTS events and their workflow is shown in Figure 6: CSTS Events. As parameters in Section 5.2, events follow a similar principle. Procedures can contain events and external events are being passed from the application to the service instance. Additionally the service instance contains events such as the production status change event.



### Figure 6: CSTS Events

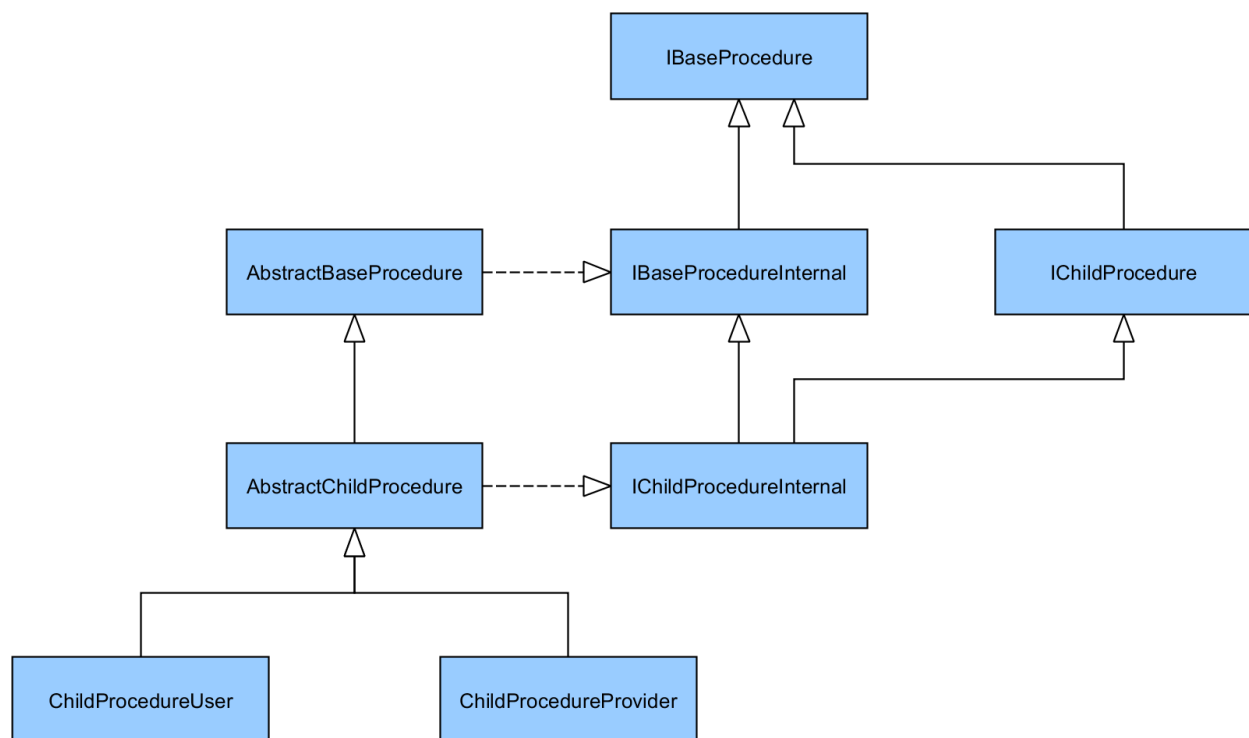
Observing procedures can query all available events (or specific ones if desired) and put itself on the list of its observers. As soon as the event is fired, the observing procedure is notified and can use the received notification and its included event, which is composed by an identifier, a value and its time. These information can for example be used to create a NOTIFY operation and notify a user instance as in such procedures as the **Notification** procedure.

## 6 EXTENDING THE CSTS API

This section describes necessary steps to be taken when extending a procedure within the CSTS framework.

### 6.1 Suggested Approach

The inheritance hierarchy in Figure 7: Suggested Approach for extending Procedures is suggested to implement new procedures. The base procedure is the procedure being extended and the child procedure is the procedure being implemented.



**Figure 7: Suggested Approach for extending Procedures**

Depending on the procedure, the CSTS API enforces all relevant methods to be implemented or already provides necessary methods which are optional to override. In case a procedure is open for extension at one point, the procedures already provide key methods to override for child procedures and integrate them in their workflow (e.g. the extension of the data processing status in the **Data Processing** procedure by the **Sequence-Controlled Data Processing** procedure).

## 6.2 Essential Methods

### 6.2.1 Initialization of Operation Types

Every procedure is forced to implement the method

```
protected abstract void initOperationTypes()
```

in which supported operation types are initialized. Supported operation types can be added by the

```
protected void addSupportedOperationType(OperationType type)
```

method. No more actions are needed to be taken by the procedure to support operation types.

### 6.2.2 Type and Version

The methods

```
public ProcedureType getType()
```

```
public int getVersion()
```

are enforced by the CSTS API to return the type and the version of the procedure. The **ProcedureType** class wraps an object identifier (see 7.1).

### 6.2.3 Termination of Procedures

All procedures are forced to implement the

```
public void terminate()
```

method which should cleanup procedure internals and initialize its state.

### 6.2.4 Creation of Operations

All procedures are able to create operations through their own factory methods. The operations will have valid internals and are ready to be parametrization and extension. The methods to create an operation are prefixed by *create*:

```
protected IBind createBind()
```

```
protected IUnbind createUnbind()
```

```
protected IPeerAbort createPeerAbort()
```

```
protected IStart createStart()
```



```
protected IStop createStop()
protected ITransferData createTransferData()
protected IProcessData createProcessData()
protected IConfirmedProcessData createConfirmedProcessData()
protected INotify createNotify()
protected IGet createGet()
protected IExecuteDirective createExecuteDirective()
```

### 6.2.5 *Initiation and Information of passed Operations*

Depending on the procedure and its role, following methods can be used to override and implement the functionality of how operations passed from the service instance or application are processed:

```
public CstsResult forwardInvocationToProxy(IOperation operation)
public CstsResult
forwardAcknowledgementToProxy(IAcknowledgedOperation acknowledgedOperation)
public CstsResult forwardReturnToProxy(IConfirmedOperation confirmedOperation)
public CstsResult forwardInvocationToApplication(IOperation operation)
public CstsResult
forwardAcknowledgementToApplication(IAcknowledgedOperation acknowledgedOperation)
public CstsResult forwardReturnToApplication(IConfirmedOperation confirmedOperation)
```

Provider procedures usually pass the operation to the underlying state machine (see 6.3), while user procedures simply forward operations to the service instance or application. The result of type **CstsResult** is an enumerated type to indicate the processing result of operations.

### 6.2.6 *Encoding and Decoding Operations*

The encoding and decoding with the use of generated Java classes read from the specified ASN.1 file, takes place in the following functions:

```
byte[] encodeOperation(IOperation operation, boolean isInvocation)
IOperation decodeOperation(byte[] encodedPdu)
```



These two methods are implemented by default in base classes and in many cases and an override should not be needed except in cases where additional functionality (*note: extension are not considered additional functionality*) needs to be added.

All procedures being inherited from provide protected methods with the prefix `encode` to override from inheriting classes and extend their internals.

### 6.3 Diagnostics

All operations when acknowledged or returned with a negative result need to have valid diagnostics set (also by the application in cases the implemented service is responsible for acknowledging or returning operations as in such cases as the Throw Event procedure).

This is done by the

```
void setDiagnostic(Diagnostic diagnostic)
```

```
void setDiagnostic(EmbeddedData diagnosticExtension)
```

methods. The **EmbeddedData** class is used for extensions on any occasions within the CSTS API (see 7.9).

Many operations (e.g. the START operation) have their own diagnostics, where provided methods automatically encodes their diagnostics into the higher-level diagnostics. If procedures implement their own diagnostics, they need to make sure, they are encoded and passed to the corresponding diagnostic structure within the operation to ensure correct encoding.

### 6.4 Procedure States

All stateful procedures are automatically suitable for usage in the context of state machines. All procedures are forced to initialize its state. The abstract and parametrized class **State** represents all states and serves as the base class for all states. The generic parameter passed to the base class is an interface inheriting from **IStatefulProcedureInternal**.

All states are forced to implement the method

```
public CstsResult process(IOperation operation)
```

where the processing of passed operations take place and a result is returned.

The constructor of a state takes the procedure itself as an argument to guarantee access to the procedure and its internals within the state machine. Querying the current state and transitioning to another state can be done by the following methods of stateful procedures:

```
State<? extends IStatefulProcedureInternal> getState()
void setState(State<? extends IStatefulProcedureInternal> state)
```

Since states in the CSTS framework are not applicable in the role of a user, the API provides the class `UserState`, to initialize user roles with a dummy state. The user procedures are required to pass the operations to the underlying communication service or the application by bypassing the state machine.

The forwarding of operations take place in the following six methods:

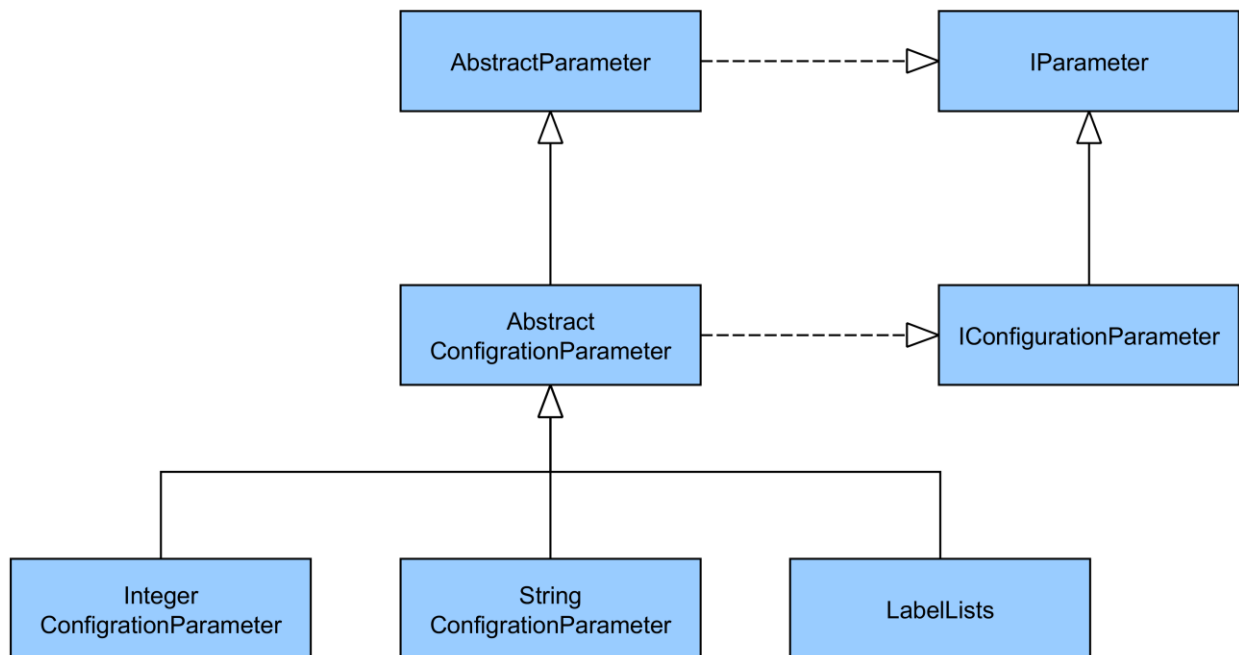
```
CstsResult forwardInvocationToProxy(IOperation operation)
CstsResult forwardReturnToProxy(IConfirmedOperation confirmedOperation)
CstsResult forwardAcknowledgementToProxy(IAcknowledgedOperation acknowledgedOperation)
CstsResult forwardInvocationToApplication(IOperation operation)
CstsResult forwardReturnToApplication(IConfirmedOperation confirmedOperation)
CstsResult
forwardAcknowledgementToApplication(IAcknowledgedOperation acknowledgedOperation)
```

These methods are available to all procedures, stateful as well as stateless, user as well as provider and from within as well as from outside the underlying state machine.

## 6.5 Parameters

The CSTS API provides structures and mechanisms to implement parameters which are automatically integrated and used within the framework.

Figure 8: Architecture of Parameters shows the structure of parameters and procedure configuration parameters.



**Figure 8: Architecture of Parameters**

It is suggested to inherit from the **AbstractParameter** class if a new parameter type is being added or to inherit from the **AbstractConfigurationParameter** class in case new procedure configuration parameters are added to the CSTS framework.

Since parameters can be observed and procedure configuration parameters are being observed by their belonging procedures by default, these classes and their interfaces conform the structure and workflows within the CSTS API.

## 6.6 Procedure Configuration Parameters

Every procedure is able to implement configuration parameters. Procedure configuration parameters conform the **IConfigurationParameter** interface. The

```
protected void initializeConfigurationParameters()
```

method should be overridden by child procedures if configuration parameters need to be initially added to the procedure. Therefore the method

```
protected void addConfigurationParameter(IConfigurationParameter configurationParameter)
```



is used to add the configuration parameter to the procedure. Also the configuration parameter is being added to an internal list where it is being observed by the procedure. In case the configuration parameter has been changed the

```
protected void processConfigurationChange(IConfigurationParameter parameter)
```

is being called automatically, where the overriding procedure and process on the changed configuration parameter.

## 6.7 Procedure Events

Procedures are able to add procedure events and subscribe to other events and being notified in case they are being fired.

To initially add procedure events the method

```
protected void initializeEvents()
```

needs to be overridden. Events can be added to and removed from the procedure by the

```
protected void addEvent(ObjectIdentifier event)
```

```
protected void removeEvent(ObjectIdentifier event)
```

```
protected void removeEvent(IEvent event)
```

methods. Procedures can subscribe to or unsubscribe from events (independent if procedure events, or service events, or any other events) by calling the

```
protected void observeEvent(IEvent event)
```

```
protected void unsubscribeFromEvent(IEvent event)
```

methods. If a subscribed event is being fired, the

```
protected void processIncomingEvent(IEvent event)
```

gets called automatically and the procedure overriding that method is able to process on that event.

## 7 PREDEFINED CCSDS TYPE CLASSES

This section introduces Java equivalents of predefined CCSDS types and how to use them in applications as well as in extended procedures.

### 7.1 Object Identifier

The CSTS API provides the **ObjectIdentifier** class as a representation of all object identifiers used and to be used within the API and extending procedures as well as applications built upon the API.

There are two possibilities of creating object identifier. By stating all numbers sequentially as in

```
ObjectIdentifier css = ObjectIdentifier.of(1, 3, 112, 4, 4)
```

or by using previously defined object identifier as a prefix as in

```
ObjectIdentifier csts = ObjectIdentifier.of(css, 1)
```

where the prefixed identifier is being extended by the numbers provided after.

The **OIDs** class provides all defined object identifiers of the provided ASN.1 file of the CSTS framework as static object identifier. It can be referenced as in the following:

```
ProcedureType type = new ProcedureType(OIDs.associationControl)
```

The CSTS API provides the **OIDReader** utility class which is able to generate the OIDs class from a passed ASN.1 file. The generation is possible as hierarchical as well as a flat object identifiers. The following sample demonstrate the difference:

```
public static final ObjectIdentifier csts = ObjectIdentifier.of(css, 1);
```

```
public static final ObjectIdentifier csts = ObjectIdentifier.of(1, 3, 112, 4, 4, 1);
```

### 7.2 Name

Names are instantiated by passing an object identifier and either a functional resource name or a procedure instance identifier. Therefore the two methods

```
public static Name of(ObjectIdentifier objectIdentifier, FunctionalResourceName  
functionalResourceName)
```



```
public static Name of(ObjectIdentifier objectIdentifier, ProcedureInstanceIdentifier  
procedureInstanceIdentifier)
```

are provided by the CSTS API.

### 7.3 Label

Labels (similar to Names) are instantiated by passing an object identifier and either a functional resource type or a procedure type. Again the two methods

```
public static Label of(ObjectIdentifier objectIdentifier, FunctionalResourceType  
functionalResourceType)
```

```
public static Label of(ObjectIdentifier objectIdentifier, ProcedureType procedureType)
```

are provided by the CSTS API.

### 7.4 Label List

A Label list is used within the label lists procedure configuration parameter. It consists of a name of the type String, an indicator if the list is the default list and the list of labels.

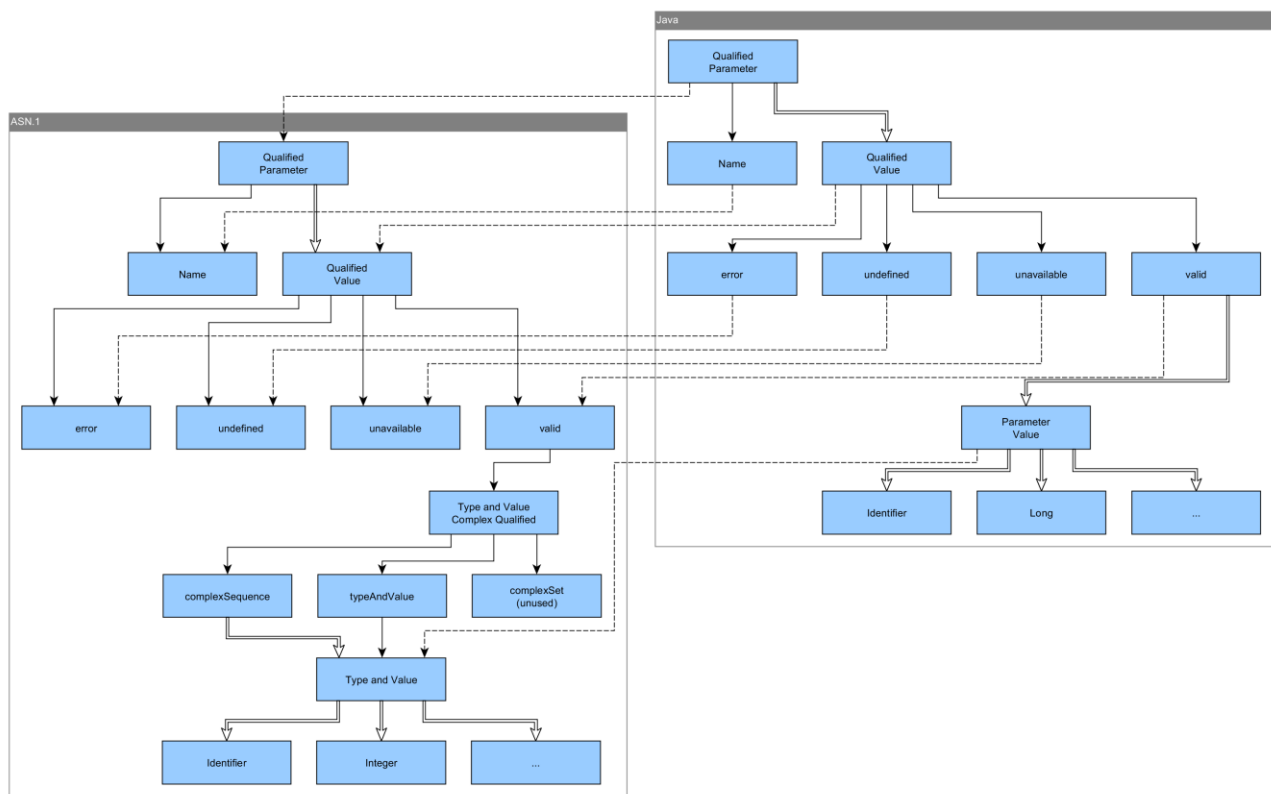
The instantiation of a label list takes place in its constructor:

```
public Labellist(String name, boolean defaultList)
```

### 7.5 Qualified Parameters

Qualified Parameters consisting of the type and value type have direct equivalents in Java to aid the use and encoding of type and values. Figure 9: Qualified Parameters Mapping visualizes how the Java equivalents are mapped to the ASN.1 types.

*Note: continuous lines represent a singular association, wide lines a multiple association and dashed lines an equivalent of the Java types in ASN.1.*



**Figure 9: Qualified Parameters Mapping**

The type of qualified values is also permissible to use within other structures such as the event value.

Qualified Parameters are specified by a name:

```
public QualifiedParameter(Name name)
```

Qualified values can be added to the underlying list of qualified values by specifying their qualifier, which is provided by an enumerated value:

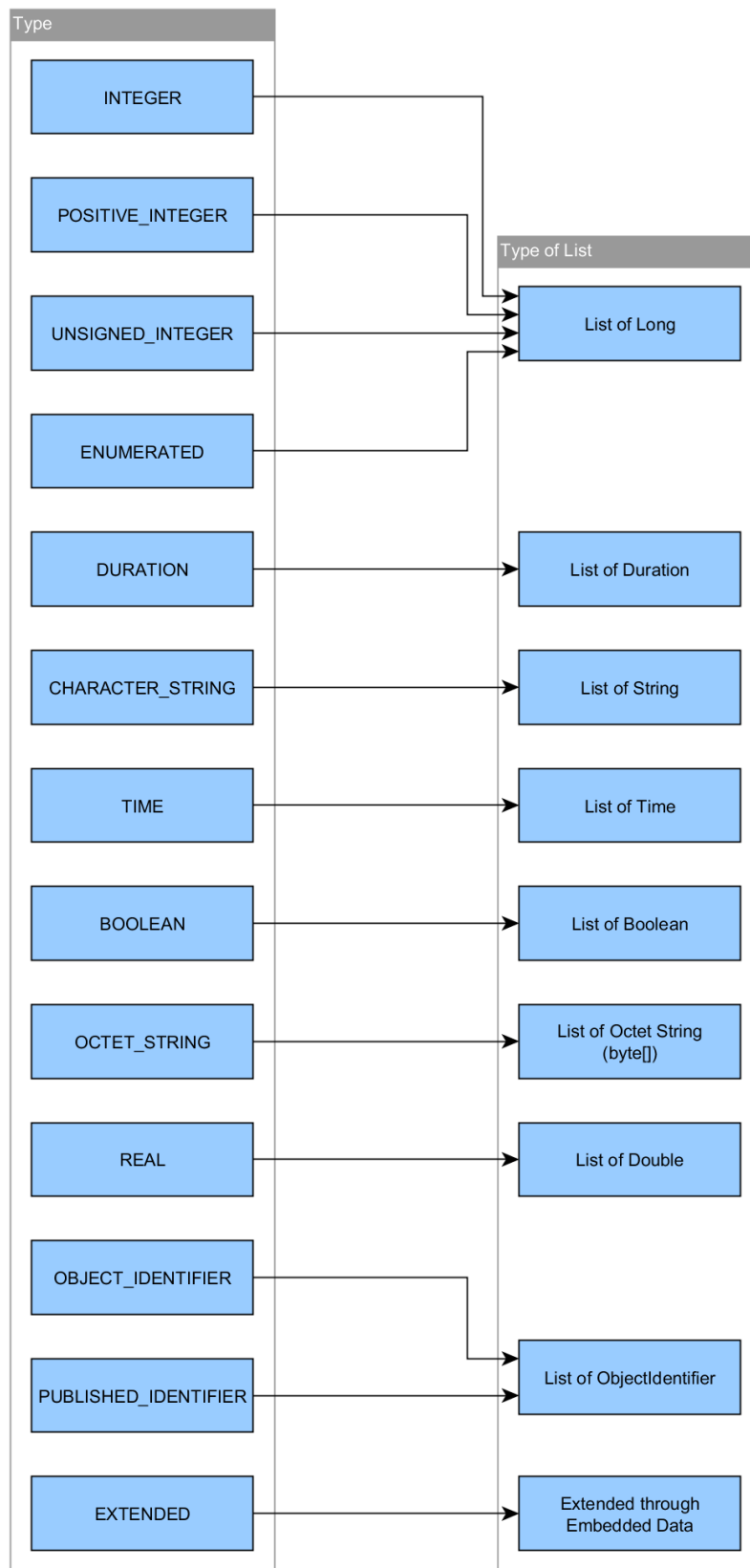
```
public QualifiedValues(ParameterQualifier qualifier)
```

Parameter values are specified by their type:

```
public ParameterValue(ParameterType type)
```

Depending on the type, a list of a suitable type is instantiated which is shown in Figure 10: Parameter Type Mapping.





**Figure 10: Parameter Type Mapping**

## 7.6 Time

The **Time** class wraps the underlying byte array of length 8 or 10, depending on the choice of millisecond or picosecond resolution.

The **Time** class provided by the CSTS API is entirely compatible to the Java 8 Date/Time API.

Times can be instantiated by the following provided factory methods:

```
public static Time of(byte[] value)
```

```
public static Time of(LocalDateTime localDateTime)
```

```
public static Time of(Instant instant)
```

## 7.7 Conditional Time

The conditional time class wraps a time object as an optional value. Conditional times can be created using the following provided factory methods:

```
public static ConditionalTime unknown()
```

```
public static ConditionalTime of(Time time)
```

## 7.8 Duration

The **Duration** class wraps the duration of the Java 8 Date/Time API and provides it functionality in a CSTS context. A duration object is instantiated by specifying its type and a Java 8 duration object:

```
public static Duration of(DurationType type, java.time.Duration duration)
```

Note that Java 8 duration object do not have a specified SI unit and provide an interchangeable usability, depending on how they are accessed. The specified enumerated type is only significant to the CSTS API during encoding.

## 7.9 Extension

The **Extension** class is a key type being used in all aspects of the CSTS API where extension is necessary. Extensions wrap the underlying structure of the type **EmbeddedData** as an optional value. Embedded data types are composed by an object identifier and a byte array.

Extension can be created using the following factory methods:



```
public static Extension notUsed()
```

```
public static Extension of(EmbeddedData embeddedData)
```

An embedded data can also be created by its own factory method:

```
public static EmbeddedData of(ObjectIdentifier oid, byte[] data)
```