PRISMTECH
AN ADLINK COMPANY

Vortex OpenSplice RnR API Reference

Release 6.x

Contents

1

Preface

1.1 About The Record and Replay API Reference

The *Record and Replay (RnR) API Reference* provides a complete description of the functions available *via* the API of the OpenSplice Record and Replay Service (RnR Service).

This API Reference is intended to be used after the Vortex OpenSplice software including the RnR Service has been installed on the network and configured according to the instructions in the Vortex OpenSplice *Getting Started Guide*.

1.2 Intended Audience

The API Reference is intended to be used by all Record and Replay Service users, including programmers, testers, system designers and system integrators.

1.3 Organisation

The *Introduction* gives an overview of the purpose and design of the Record and Replay Service.

The *Scenarios* section explains the key concept of the 'scenario' used in the RnR Service.

All of the functions of the RnR Service are then described in full detail.

There is a (very short) list of *known issues* which describes current limitations of the RnR Service.

The next section describes how the RnR Service is designed to minimize its *intrusiveness* on existing systems.

The *RnR Topic API IDL specification* contains the complete IDL definition of the RnR Service API.

Finally, there is a *bibliography* which lists all of the publications referred to in this *Guide*.

1.4 Conventions

The icons shown below are used in PrismTech product documentation to help readers to quickly identify information relevant to their specific use of Vortex OpenSplice.

Icon	*Meaning*
	Item of special significance or where caution needs to be taken.
	Item contains helpful hint or special information.
	Information applies to Windows (*e.g.* XP, 2003, Windows 7) only.
	Information applies to Unix-based systems (*e.g.* Solaris) only.
	Information applies to Linux-based systems (*e.g.* Ubuntu) only.
	C language specific.
	C++ language specific.
	C# language specific.
	Java language specific.

2

Introduction

*The Vortex OpenSplice * Record and Replay Service *is a pluggable service of the Vortex OpenSplice middleware which is capable of recording and/or replaying DDS data-sets (i.e. topic-samples) in a DDS system.*

As a DDS service, the Record and Replay Service (*RnR Service*, or just *RnR*) benefits from the inherent 'decoupling in time and space' that the DDS architecture offers, with respect to automatic discovery of the service's dynamic interest in subscribing or publishing data as well as the transparent routing of information to/from the service.

The RnR Service operates in conjunction with storages, which can be configured statically in a configuration file or dynamically through interaction with the service. To interact with the service, a command-topic and various status-topics are available.

2.1 Features

You can use the Record and Replay Service to:

- Control and monitor the service using regular DDS topics.
- Use expressions with wildcards to select partitions and topics of interest, for record and/or replay.
- Store data in XML records for easy post-analysis and data-mining.
- Store data in CDR records for a smaller footprint and high throughput.
- Create scenarios, grouping multiple commands into a logical set.
- Use replay filters to replay only the data recorded in a specific time-range.
- Use conditions to delay the execution of a command.
- Subscribe to statistics on the data that is replayed and/or recorded.
- Dynamically change the speed at which data is replayed.
- Modify the QoS settings of recorded data on-the-fly during replay
- Modify the partition of recorded data on-the-fly during replay

3

Scenarios

The actions of a Record and Replay service are organized in **scenarios**.

A *scenario* is an instance of the scenario topic, a group of commands sharing the same `scenarioName`. Each service subscribes to the command topic and uses a content filter to only process commands with an `rnrId` matching the service name (or $\star$).

It is possible to create an intricate nesting of scenarios by defining a scenario that includes control commands targeting other scenarios.

3.1 Different versions of the scenario topic

Starting with Vortex OpenSplice V6.5.2, the Record and Replay service provides two versions of the scenario topic: `rr_scenario` and `rr_scenario_v2`. The new `rr_scenario_v2` topic is contained in the `RnR_V2` IDL module, please see *the RnR Topic API IDL specification* in the *Appendix* for details of the changes between the original and version 2 of the data-model. Both versions will co-exist until a major version upgrade allows the merging of all features into a single module and topic. This will probably coincide with a migration of the data-model to Google Protocol Buffers (*GPB*) or a different extensible type scheme supported by Vortex OpenSplice at that time.

The original topic is still supported for backwards compatibility with applications developed for a previous version of OpenSplice or Record and Replay scenarios stored for re-use, *i.e.* in a persistent store. Also, because of the nature of the RnR service, the topic definitions of RnR may have been introduced in production environments that cannot easily be upgraded and/or restarted to replace the old topics with new ones. A topic mis-match would prevent a new version of RnR from starting on any node attached to the same domain. In those circumstances a new topic using new type-names is the only viable approach to support new RnR features. Transformations (partition, QoS) of data during replay are only available on the `rr_scenario_v2` topic because these new features require an extension of the `ADD_REPLAY` and `REMOVE_REPLAY` commands.

The next chapter describes all command-types, highlighting differences between the original and version 2.

Since all original features are also available using the `rr_scenario_v2` topic, it is not recommended to mix usage of the two topics in a single application. The service does support scenarios that use both original and V2 commands but order preservation cannot be guaranteed, since a scenario is no longer contained in a single instance but is in two instances on two different topics, necessitating two individual readers. In practice this can only introduce order reversal of commands when both `rr_scenario` and `rr_scenario_v2` commands arrive at the same time.

3.2 BuiltinScenario

Since commands are targeted at a service *and* a scenario, the service must start an initial scenario. If not, there wouldn't be anything to address commands to.

During startup, the service starts this initial scenario, called the `BuiltinScenario`. This is a special scenario that is always running while the service is operational. It serves as the starting hook for any new scenarios. To run a new scenario, a *start* command must be published for the `BuiltinScenario`. Like any scenario, the `BuiltinScenario` can also process other commands like record and/or replay commands.

 Note that the `BuiltinScenario` can not be stopped.

Since one can assume that the `BuiltinScenario` is always available and running, it is a safe choice to address config and control commands to the `BuiltinScenario`. In a dynamic and distributed environment, in which DDS is regularly used, this can be especially helpful when interacting with the service through scripts or perhaps when injecting commands stored in a persistent store.

3.3 Command durability

The command subscriber of the service is capable to read commands of any durability (`VOLATILE`, `TRANSIENT`, `PERSISTENT`). If commands are published with a *transient* and/or *persistent* durability, it is important to understand that these commands are managed by the middleware in addition to the service. Immediately after a scenario is started, any commands still managed by the middleware in transient or persistent stores are delivered to the service and processed as part of the scenario.

 **This is of special importance when 're-starting' scenarios.** Note that a scenario, strictly, is *not* restarted. It is removed and a *new scenario* with an identical name is created. If any of the commands of the original scenario were published (whether transient or persistent), these are delivered and processed again by the *new* scenario.

Since transient and persistent commands exist in the middleware and are not stored or processed by the service as long as the corresponding scenario isn't started, the start command for a scenario does not have to be published before the scenario is defined, as one might assume. By changing the durability of different commands compromising a scenario, advanced use cases are possible using relatively simple scenarios.

4

Topic API Overview

The RnR Service can be controlled and monitored using a DDS topic API. All topics are in a separate DDS partition called `RecordAndReplay`.

4.1 Record & Replay topics

Name	Type	Purpose
`rr_scenario`	`RnR::Command`	Controlling the Record and Replay service
`rr_scenario_v2`	`RnR_V2::Command`	Controlling the Record and Replay service (version 2)
`rr_scenarioStatus`	`RnR::ScenarioStatus`	Monitoring status of scenarios
`rr_serviceStatus`	`RnR::ServiceStatus`	Monitoring status of services
`rr_storageStatus`	`RnR::StorageStatus`	Monitoring status of storages
`rr_storageStatistics`	`RnR::StorageStatistics`	Monitoring data-characteristics of storages

4.2 Relevant QoS settings

The following table shows the topic QoS parameters that deviate from the default DDS topic QoS, for the topics used by the Record and Replay Service.

Policy	Scenario Topic	Status + Statistics Topics
`DurabilityQosPolicy`	`PERSISTENT`	`TRANSIENT`
`DurabilityServiceQosPolicy => HistoryQosPolicy`	`KEEP_ALL`	`KEEP_LAST (with DEPTH=1)`
`ReliabilityQosPolicy`	`RELIABLE`	`RELIABLE`
`HistoryQosPolicy`	`KEEP_ALL`	`KEEP_LAST (with DEPTH=1)`

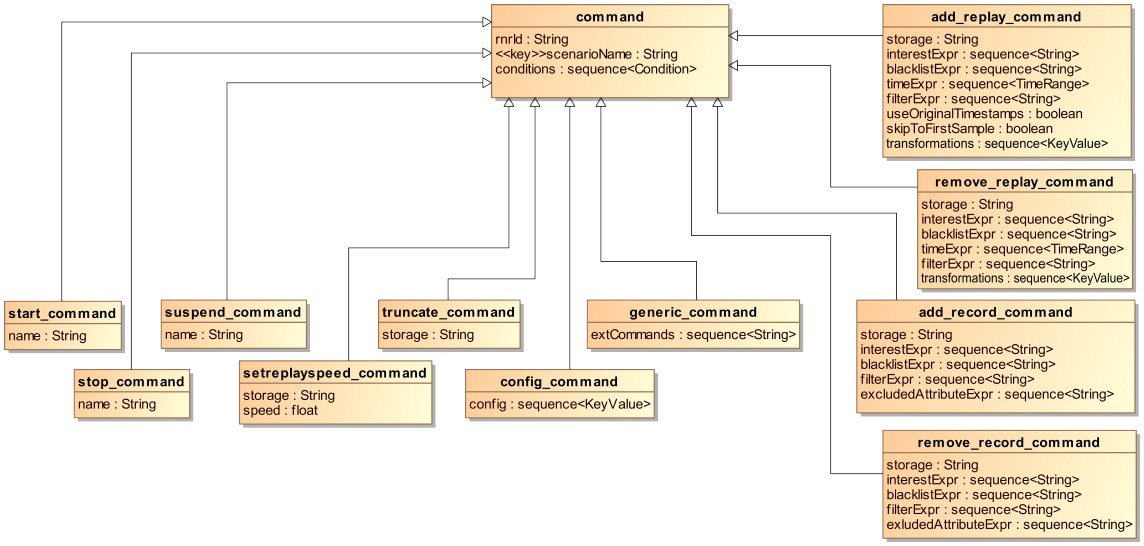
This enables readers and writers to use the `copy_from_topic_qos()` operations or the `USE_TOPIC_QOS` convenience macro to create a reader or writer that is compatible with the topics created by the service. Furthermore the status topic writers use a `KEEP_ALL` history QoS so readers can get a full overview of all status updates instead of only the last state. The scenario readers are created with a `VOLATILE` durability so they are also able to read samples produced by a `VOLATILE` writer in addition to `TRANSIENT` and `PERSISTENT` writers.

The corresponding IDL code can be found in the *RnR Topic API specification*.

Note that the IDL and diagrams in this section describe the *full* API. The other sections of this manual describe *only* the features that have been implemented in the current release of the RnR Service, and omit all members that will be implemented in future releases.

4.3 Command Type

Command Topic



The command type, used by the `rr_scenario` and `rr_scenario_v2` topics, contains a union that allows the command kind to be set. Depending on the command kind, certain members are available that apply only to a specific type of command.

The following command kinds can be set when creating a command:

START_SCENARIO_COMMAND Start a scenario (or continue a paused scenario).

STOP_SCENARIO_COMMAND Stop a running scenario.

SUSPEND_SCENARIO_COMMAND Suspend processing of new commands in a running scenario.

CONFIG_COMMAND Modify the runtime configuration of a RnR service.

SETREPLAYSPEED_COMMAND Change the replay-speed of a storage.

TRUNCATE_COMMAND Remove data from a storage.

ADD_RECORD_COMMAND Specify interest to record data to a storage.

REMOVE_RECORD_COMMAND Remove record-interest from a storage.

ADD_REPLAY_COMMAND Specify interest to replay data from a storage.

REMOVE_REPLAY_COMMAND Remove replay-interest from a storage.

There are a number of common properties that are shared by all commands:

rnrId The `rnrId` is used to address the command to a specific RnR service. It should match the name attribute of the service tag in the OpenSplice configuration. The middleware uses this identifier to resolve the configuration options that apply to the service. A RnR service only accepts commands with an rnrId that matches its service-name. An asterisk `*` can be used as rnrId for commands targeted at all available RnR services in a domain.

scenarioName The `scenarioName` is the key of the scenario topic. It is used to uniquely identify a specific scenario instance of which all samples (commands) together make up the scenario. For more information about scenarios, please see *the section on Scenarios*.

conditions Optionally one or more conditions can be attached to a command. The command is only processed when *all* conditions are met.


Currently only one kind of condition is supported: the time-stamp condition. Future extensions will add other kinds of conditions which is the reason why the API supports attaching multiple conditions to a command.

4.3.1 Control commands

Some kinds of commands are used to control the running state of a scenario: the *start*, *stop* and *suspend* commands.

These all have a single member.

name The name of the target scenario to control.

 Do not confuse this with `scenarioName`, which is the name of the scenario that will process the command.

START_SCENARIO_COMMAND Instructs the service to start processing scenario name. The service will publish a status update that changes the state of the scenario to `RUNNING`. If the target scenario is already known to the service, and is in the suspended state, a start command causes the scenario to resume processing commands, changing the scenario status from `PAUSED` to `RUNNING`.

SUSPEND_SCENARIO_COMMAND Suspends the processing of commands by the scenario. This allows applications to submit a number of commands to a scenario, without any immediate effects. When the scenario is resumed all new commands are processed as if they were published in a batch while in reality they may have been published with varying intervals.

STOP_SCENARIO_COMMAND Stops the execution of a scenario, including any recording and/or replaying that was defined as part of that scenario.

 It is important to understand that a scenario, once stopped, cannot be started again. However, it is possible to start a new scenario with the same name as the stopped scenario. If any commands of the original scenario were published as transient data they will be delivered to and processed by the new scenario, giving the impression that the scenario has been re-started.

4.3.2 Config command

`Config` commands are used to modify the runtime configuration of a RnR service.

config A sequence of `KeyValue` objects.

A `config` command can be used to add a storage to the service or modify properties of an existing storage. Storages can also be configured in the OpenSplice configuration file, but `config` commands provide the opportunity to create and configure storages dynamically.

A single `config` command can apply to multiple storages, if the `config` sequence consists of multiple elements. The key of the `KeyValue` object should always be `Storage`.

 Currently, only storages can be manipulated by `config` commands but future versions may enable `config` commands to modify other aspects of the service, using different keys.

The value for Storage configuration data is a string describing the storage in XML notation. The format of this XML string is identical to the XML used in the configuration file (created by the OpenSplice configuration tool).

An example:

```
command {
 scenarioName = "MyScenario",
 rnrId = "MyService",
 conditions = NULL,
 kind = CONFIG_COMMAND,
 config[0].keyval = "Storage",
 config[0].sValue = "<Storage name='MyStorage'>
                       <rr_storageAttrXML>
                          <filename>my-storage.dat</filename>
                       </rr_storageAttrXML>
                       <Statistics enabled="true" publish_interval="30"/>
                     </Storage>"
 };
```

When a `config` command is issued for an existing storage, the storage properties are modified accordingly.

 Note that storage attributes can only be changed when a storage is unused: it cannot be in the `OPEN` state (see Storage Status). Properties related to statistics can be modified while the storage is in use.

4.3.3 ADD_RECORD_COMMAND

This command is used to add interest to record certain DDS data.

Mandatory properties:

storage The name of the storage in which the data has to be stored. If the storage cannot be resolved the command is ignored.

Available storages can be determined by subscribing to the `StorageStatus` topic.

interestExpr A sequence of strings that describe the record interest. Each expression is a partition-topic combination where the partition- and topic-expression are separated by a period (`'.'`). Wildcards are supported: `'?'` to match a single character and `'*'` to match any number of characters. If expressions overlap, even if only partially, data will only be recorded once.

4.3.4 REMOVE_RECORD_COMMAND

This command mirrors the add record command and is used to remove record interest from a storage.

Mandatory properties:

storage The name of the storage of which record-interest is removed.

interestExpr The interest expressions describing the record interest to remove.

 Note that these interest expressions need to match those used previously in an *add record* command.

4.3.5 ADD_REPLAY_COMMAND

This command is similar to a record command but adds interest to replay data to the Record and Replay service.

Mandatory properties:

storage The name of the storage from which the data will be replayed. If the storage cannot be resolved the command is ignored.

Available storages can be determined by subscribing to the `StorageStatus` topic.

interestExpr A sequence of strings that describe the replay interest. Each expression is a partition-topic combination where the partition- and topic-expression are separated by a period (`'.'`). Wildcards are supported: `'?'` to match a single character and `'*'` to match any number of characters. If expressions overlap, even if only partially, data will only be recorded once.

Optional properties:

timeExpr A sequence of time-ranges that are used in combination with the interest expressions to select a subset of data available in a storage for replay. Each time-range in the sequence is applied to each interest expression. A sample read from a storage is only replayed if its partition and topic can be matched against the interest expressions and its record-time can be matched against the time-range expressions. The time-range expressions are optional; when they are omitted a sample is replayed when an interest expression matches. For more information about time-ranges, see the description of the TimeRange type.

useOriginalTimestamps By default this value is `true`. When a sample is recorded, its original write and allocation timestamps are preserved. When this sample is replayed, it will be delivered to readers with these original timestamps. Depending on resource limits and QoS settings, readers may discard the replayed data

if data with more recent timestamps is available. By setting `useOriginalTimestamps` to `false`, the timestamps will be updated with the current time upon replay.

skipToFirstSample By default this value is `false`. When a sample matches interest expressions but doesn't match any of the supplied time-ranges, the Record and Replay service tries to mimic original timing behaviour by sleeping until the next sample is evaluated based on record timestamps. Sometimes this is not the required behavior and the service should simply skip all non-matching samples and start replaying immediately the first sample that matches an interest expression and time-range. This behaviour can be enabled by setting `skipToFirstSample` to `true`.

 **The following property is only available in version 2 of the RnR scenario topic.**

transformations A sequence of transformations, applied to each sample upon replay. By default, no transformations are applied. Note that samples first have to match interest-expression and time-range before any transformations are evaluated. The transformations sequence consists of `KeyValue` elements. A specific type of transformation is selected by choosing a specific key. Multiple transformations of the same kind can be used in the same sequence. The value is a string describing the new value. The transformation can be applied conditionally by using a `':'` (colon) character to separate original and replacement values in the value-string. Note that the original value needs to be an exact match, wildcards or expressions are not supported. The supported transformations types are listed in the table.

Key	Description
`partition`	Partition in which the sample is replayed
`deadline_period`	Deadline QoS policy
`latency_period`	Latency budget QoS policy
`ownership_strength`	Ownership strength QoS policy (applies only to samples written with exclusive ownership-kind QoS policy)
`transport_priority`	Transport priority QoS policy
`lifespan_period`	Lifespan QoS policy

Transformations that involve a period can be expressed in either DDS-compliant duration (*sec.nanosec*) or more human-friendly floating-point (*sec.millis*) formats. Floating-point values are interpreted locale-independent, using a period `'.'` (decimal point) character. Partition transformations are supported for partition names consisting of alphanumeric and special characters `'-'`, `'/'` and `'_'`.

4.3.6 REMOVE_REPLAY_COMMAND

This command mirrors the ADD_REPLAY_COMMAND, except for the properties `useOriginalTimestamps` and `skipToFirstSample`, which change the replay behaviour and are not applicable to the *remove replay* command.

The command is used to remove replay interest from a storage. Mandatory members of the *add replay* command are also mandatory in the remove replay command.

Mandatory properties:

storage The name of the storage which replay-interest is removed from.

interestExpr The interest expressions describing the replay interest to remove.

 Note that these interest expressions need to match those used previously in an *add replay* command.

Optional properties:

timeExpr The sequence of time ranges to remove. Similar to the *add replay* command. If this parameter is specified, only the interest that exactly matches the time ranges is removed. As a shortcut, if the time range sequence is empty, any interest that matches the interest expressions in the *remove replay* command is removed regardless of the time ranges attached to that interest.

 **The following property is only available in version 2 of the RnR scenario topic.**

transformations A sequence of transformations to remove. If any replay interest is to be removed completely, this sequence should match exactly the sequence included in *add replay* command(s) responsible for adding the interest. For more details about the contents of the `KeyValue` sequence elements, please see the ADD_REPLAY_COMMAND.

4.3.7 TRUNCATE_COMMAND

This command can be used to clear a storage. When recording samples to an existing storage, by defauilt the data is appended. If instead the required behaviour is to *overwrite* the storage, the truncate command can be used to remove the data recorded to the storage during previous sessions.

Note that the truncate command can only be executed if the storage isn't busy recording and/or replaying data. Thus is may be required to first publish *remove record/replay* commands, in order to remove all interest from a storage so that it gets closed by the RnR service, before the truncate command can be succesfully processed. The `StorageStatus` topic should be monitored to determine if this is the case.

4.3.8 SETREPLAYSPEED_COMMAND

Using this command the replay speed of a storage can be manipulated. The replay speed affects the delay between replayed samples. For example, a replay speed of `2` will cut the delay in half: samples will be replayed twice as fast as originally recorded.

Mandatory properties:

storage The name of the storage of which to change the replay speed. If the storage cannot be resolved the command is ignored.

speed A floating-point value containing the new replay-speed. The following values have a special meaning:

`-1`: *Maximum speed*; delays between samples are skipped and the samples from the storage are inserted into DDS as fast as possible.

`1` : Replay samples with the *same* timing characteristics as when originally recorded.

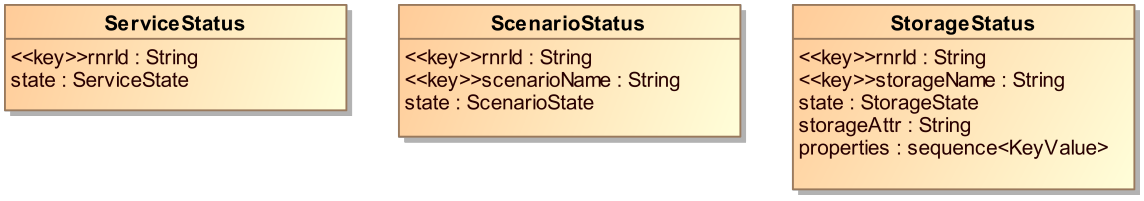
`0` : *Pause the storage*; no samples are replayed until the speed is increased.

The default replay speed is `1` (samples are replayed with the same timing characteristics as when originally recorded).

4.4 Status Types

To monitor the status of various components of the service, applications can take a subscription on the status topics published by the Record and Replay service.

Status Topics



Status topics are state-based, meaning that they are only published when a state changes. Readers normally only need to read the latest sample of an instance to get the latest (current) state. However, a reader can also be created with a `KEEP_ALL` history if it needs to be aware of all states even when state changes occur in quick succession.

4.4.1 Service Status

Each Record and Replay service publishes its own state in the `rr_serviceStatus` topic. The topic uses the `ServiceStatus` type, which has the following members:

rnrId The name identifying the service. This is also the key of the topic. The `rnrId` can be used to identify the service responsible for publishing the status update.

state The current state of the service. The following states are possible:

`INITIALISING`: The service is started and initialising, but not yet able to process commands. During initialization the service processes configuration parameters and joins the DDS domain.

`OPERATIONAL`: The service is successfully initialized and ready to accept commands.

`TERMINATING`: The service is shutting down.

`TERMINATED`: The service is detached from the DDS domain and stopped.

The service status topic reflects the life-cycle of a Record and Replay service. It is published when the `state` field changes, which normally occurs only during service startup or shutdown (*i.e.* when OpenSplice is started or stopped).

4.4.2 Scenario Status

The service publishes the state of each known scenario in the `rr_scenarioStatus` topic. This topic, using the `ScenarioStatus` type, contains the following members:

rnrId The name identifying the service.

scenarioName The name identifying a scenario.

The `scenarioName` combined with the `rnrId` define an instance of the scenario status topic, so each update can be related to the service and scenario responsible for that status.

state The current state of the scenario. The following states are possible:

`RUNNING`: The scenario is running and actively processing commands.

`SUSPENDED`: A scenario enters the suspended state after a suspend-scenario command is processed for the scenario. While suspended, the scenario doesn't process any new commands.

`STOPPED`: The scenario was stopped and removed from the service.

Note that, until a scenario is *started*, a service is unaware of its existence. There may be commands belonging to the scenario, maintained by OpenSplice (in persistent or transient stores), but a scenario status isn't published until the state of a scenario within a service is changed to `RUNNING` by issuing a start-scenario command for that scenario to a specific service.

4.4.3 Storage Status

The service publishes the state of each known storage in the `rr_storageStatus` topic. This topic, using the `StorageStatus` type, contains the following members:

rnrId The name identifying the service. This is a key of the topic.

storageName The name identifying a storage.

The `storageName` combined with the `rnrId` define an instance of the storage status topic and can be used to relate an update of the topic to the service and storage responsible.

state The current state of the storage. A storage may have the following states:

`READY`: This is the initial state after configuring a storage, when the configuration is deemed valid. It means the storage was defined and available when configured. In the case of a pre-existing storage, properties are available in the status update for this state.

`OPEN`: The storage is in use by one or more scenarios identified by the `scenarioNames` sequence in the status update for this state.

`ERROR`: The storage is invalid and cannot be used. This can either mean an error in the storage configuration or an issue related to resources claimed by the storage. Most notably in case of an XMLstorage, the service may not have permission to open a file that is part of the storage.


Note that it is not currently possible to determine the reason for an `ERROR` state directly from the status update, but a descriptive message is written to the OpenSplice log files. A future release will make this message available in the status update.

`OUTOFRESOURCES`: When a storage is used for recording, it may run out of resources.

`CLOSED`: A storage may enter the closed state for two reasons. Usually it is closed when all record and/or replay interest has been detached from the storage. This occurs when all scenarios that were using the storage are stopped. If the storage is used for replay, it may also be closed when all data in the storage has been evaluated and the end of the storage was reached.

storageAttr The XML string describing the attributes currently used by the storage. This is identical to the attributes section of a storage configuration.

properties Properties of the data contained in a storage. The following properties are available per recorded topic:

- Partition and topic names
- Number of samples and number of bytes
- Record timestamps of the first and last occurrence
- Average data rate

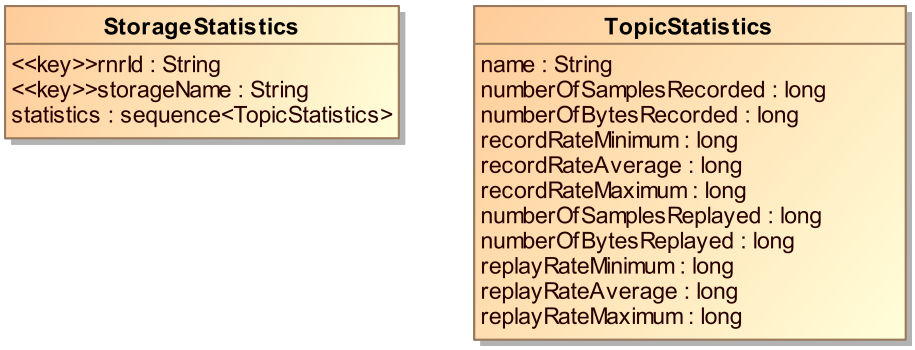

Note that properties are not updated while a storage is open, *they are only updated when the state of a storage changes*.

Unlike the other status topics, the storage status is determined by more than just the `state` field. The attributes and sequence of scenario names are also part of the state. Therefore storage status updates not only occur when the `state` field itself is changed but also when the attributes are changed or when a scenario starts (or stops) using the storage.

4.5 Storage Statistics

The Record and Replay service can optionally maintain runtime statistics regarding the data that is recorded to and/or replayed from a storage. These statistics can be published in the `rr_storageStatistics` topic.

Storage Statistics Topic



Statistics are enabled per storage. Publication in the `rr_storageStatistics` topic is optional and can be managed by the `publish_interval` attribute of the statistics configuration element.

Publish_interval This is the number of seconds between each publication of the statistics from a specific storage. The value `-1` has a special meaning: if set, the statistics will only be published when the storage is closed.

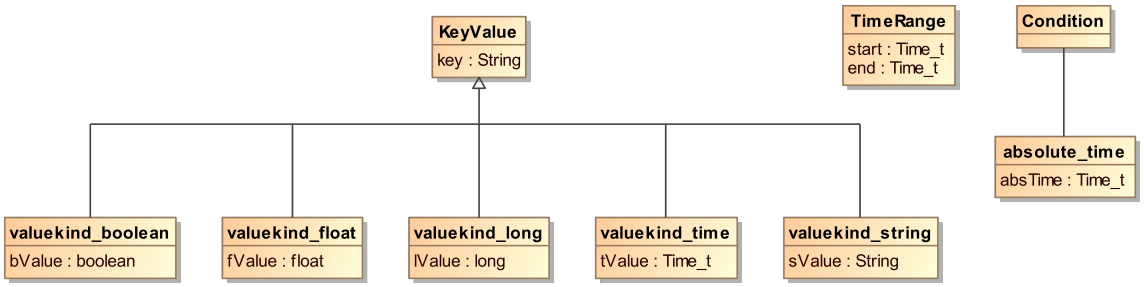
Setting the `publish_interval` to `0` will also prevent the publication of statistics. Note that a config command can be issued to change the publication interval on the fly.

The statistics values can be reset by setting the `reset` attribute in the XML configuration string of the storage statistics.

4.6 Miscellaneous Types

The API contains a number of utility types used as members in one or more topics. These helper types are described in this section.

Miscellaneous Types



4.6.1 KeyValue

The `KeyValue` type is a generic *key:value* container. It is used for the transformations sequence in add and remove replay commands and as the config sequence of a config command, to send configuration values to a Record and Replay service and/or scenario.

key A string that selects a specific configuration value to add or update.

Depending on the `KeyValue` kind, a value can take on a number of representations: `boolean`, `string`, `long` or `float`.

4.6.2 TimeRange

The `TimeRange` type can be used to limit the selection of data in a replay command. Interest expressions select data based on partition and topic names, time-ranges filter this selection based on record timestamps.

The `DDS::Time_t` type is used to express a timestamp. A range is defined by a start and an end timestamp.

start The start timestamp of the range. When `TIME_INVALID_SEC` and `TIME_INVALID_NSEC` are specified, the start time is considered to be `-infinity`. This means that any sample recorded before the `end` timestamp is matched.

end The end timestamp of the range. When `TIME_INVALID_SEC` and `TIME_INVALID_NSEC` are specified, the end time is considered to be `+infinity`. This means that any sample recorded after the `start` timestamp is matched.

5

Known Issues

This section summarizes known issues and limitations of the current release of the Record and Replay Service. Please see the Release Notes *supplied with the product for additional information.*

5.1 Ability to create topics

The service does not yet have the ability to implicitly create topics for the data it replays. To bypass this limitation, the `DCPSTopic` built-in topic can be included in the recording (and replaying) of data.

The following interest-expression should be used:

```
__BUILT-IN PARTITION__.DCPSTopic
```

To ensure that a topic is re-created at replay before any data belonging to that topic gets replayed, the `DCPSTopic` expression should be the *first* interest-expression that is added to a particular storage using the add record/replay commands.

6

Impact on DDS Domain

This section describes additional aspects of the Record and Replay Service and its interaction with other systems.

6.1 Intrusiveness

Relevant characteristics of the Record and Replay Service with respect to 'intrusiveness' for an existing system are:

- The service can be optionally configured on any DDS node in the system.
  - When run as part of an existing federation of applications, it utilizes the federation's shared-memory segment to obtain the data (so locally-published data is not required to travel over the network to be recorded by the service, and *vice-versa* for replaying towards co-located subscribers).
  - When run on a dedicated RnR node, data to be recorded is transparently forwarded to that RnR node, typically using multicast network features (and so not inducing extra network traffic).
- Services are controlled in 'the DDS way', *i.e.* a data-centric way where command and status topics allow DDS-based 'remote control' over the service from anywhere in the system.
  - A dedicated `RecordAndReplay` partition is utilized by RnR to bound (contain) the control/status flows.
  - In the case of a dedicated RnR node, this partition can be configured to be a so-called 'local Partition' thus bounding (containing) all control/status traffic to the RnR node.
- Replaying (subsets) of recorded data *'by definition'* has impact on an existing system:
  - It can induce unanticipated traffic-flows towards subscribing applications
  - It typically triggers application-processing of such replayed data...
  - which can be considered 'intentional' and inherent to the purpose of replaying recorded data

Summarizing, it can be stated that when dedicating a specific computing node for Record and Replay and confining the control and status traffic to control the service to stay 'inside' that node, recording of data in a multicast-enabled network is non-intrusive.


Note that the few shared topic-definitions (definitions *only*, not actual samples of these topics when these are 'confined' to the RnR node) that would be visible system-wide when inspecting the built-in topics of the system (for instance with a tool like the Vortex OpenSplice Tuner) are considered non-intrusive as they only imply a small and static amount of data occupied by the related built-in topic samples.

7

Appendix A

7.1 RnR Topic API IDL specification

```
/* Record & Replay data model
 *
 * This IDL file contains the R&R data model. The file is divided in two sections:
 * helper types and topics that use these types.
 */

#include "dds_dcps.idl"

module RnR {
    /************************ TYPES ************************/

    /* ValueKind is the discriminator of the 'value' union of a KeyValue */
    enum ValueKind {
        VALUEKIND_STRING,
        VALUEKIND_LONG,
        VALUEKIND_FLOAT,
        VALUEKIND_BOOLEAN,
        VALUEKIND_TIME
    };

    /* ConditionKind the discriminator of the 'Condition' union type */
    enum ConditionKind {
        COND_REL_TIME,
        COND_ABS_TIME,
        COND_DATA,
        COND_LIFECYCLE
    };

    /* CommandKind is the discriminator of the 'kind' union of a Command */
    enum CommandKind {
        ADD_RECORD_COMMAND,
        REMOVE_RECORD_COMMAND,
        ADD_REPLAY_COMMAND,
        REMOVE_REPLAY_COMMAND,
        START_SCENARIO_COMMAND,
        STOP_SCENARIO_COMMAND,
        SUSPEND_SCENARIO_COMMAND,
        CONFIG_COMMAND,
        SETREPLAYSPEED_COMMAND,
        TRUNCATE_COMMAND,
        GENERIC_COMMAND
    };

    /* ServiceState contains the possible states of an R&R service */
    enum ServiceState {
        SERVICE_INITIALISING,    /* Service is starting */
        SERVICE_OPERATIONAL,     /* Builtin-scenario is started, service is able
```

```
                                to receive commands */
    SERVICE_TERMINATING,     /* Service is stopping all scenarios and shutting
                                down */
    SERVICE_TERMINATED       /* Service is terminated */
};

/* ScenarioState contains the possible states of a R&R scenario */
enum ScenarioState {
    SCENARIO_RUNNING,        /* Scenario is active and able to receive and
                                process commands */
    SCENARIO_STOPPED,        /* Scenario is stopped and unable to receive
                                commands */
    SCENARIO_SUSPENDED       /* Scenario is suspended and will resume
                                processing commands when scenario is
                                (re)started or continued */
};

/* StorageState contains the possible states of a R&R storage */
enum StorageState {
    STORAGE_READY,           /* Defined, but not opened yet. */
    STORAGE_OPEN,            /* Storage successfully opened */
    STORAGE_ERROR,           /* An unrecoverable error has occurred in the
                                storage */
    STORAGE_OUTOFRESOURCES,  /* Storage is out-of-resources */
    STORAGE_CLOSED           /* Storage has been closed */
};

/* Condition is a union, used to express conditions in the Command topic */
union Condition switch (ConditionKind) {
    case COND_REL_TIME:             /* Relative time since previous command, */
        DDS::Duration_t relTime;    /* i.e. the time that has passed since the
                                       previous command was processed */
    case COND_ABS_TIME:             /* Absolute (wall) time, */
        DDS::Time_t absTime;        /* i.e. a fixed point in time */
    case COND_DATA:                 /* Content-expression on data samples */
        string dataExpr;            /* i.e. a specific sample matching the
                                       expression, was published in the DDS
                                       domain */
    case COND_LIFECYCLE:            /* Content-expression on data lifecycle, */
        string lifecycleExpr;       /* i.e. a specific instance transitions
                                       from alive to not alive */
};

union Value switch(ValueKind) {
    case VALUEKIND_STRING:       /* Value is a string */
        string sValue;
    case VALUEKIND_LONG:         /* Value is a long number */
        long lValue;
    case VALUEKIND_FLOAT:        /* Value is a floating-point number */
        float fValue;
    case VALUEKIND_BOOLEAN:      /* Value is a boolean */
        boolean bValue;
    case VALUEKIND_TIME:         /* Value is a timestamp */
        DDS::Time_t tValue;
};

/* Generic key:value type, where value is an union supporting various
   kinds of values */
struct KeyValue {
    string keyval;                  /* String key */
    Value value;
};
```

```
/* Used for specifying a range of times */
/* For every valid TimeRange 'start' <= 'end' should hold */
struct TimeRange {
    /* Absolute time (inclusive) indicating the start of the range. When
     * start.sec == TIME_INVALID_SEC and start.nanosec == TIME_INVALID_NSEC,
     * start is considered to be smaller than all times it is compared to
     * (i.e., start is interpreted as -INFINITY). */
    DDS::Time_t start;
    /* Absolute time (inclusive) indicating the end of the range. When
     * end.sec == TIME_INVALID_SEC and end.nanosec == TIME_INVALID_NSEC,
     * end is considered to be greater than all times it is compared to
     * (i.e., end is interpreted as +INFINITY). */
    DDS::Time_t end;
};

/* Command-type to add record-interest to a storage */
struct AddRecordCommand {
    string storage;                          /* Name identifying a storage to
                                                record to */

    /* Meta-filters */
    sequence<string> interestExpr;           /* Sequence of 'partition.topic'
                                                expressions to record */
    sequence<string> blacklistExpr;          /* Sequence of 'partition.topic'
                                                expressions to block from
                                                record */

    /* Content filters */
    sequence<string> filterExpr;             /* Sequence of content-filter-
                                                expressions */
    sequence<string> excludedAttributeExpr; /* Sequence of expressions to
                                                exclude specific members of
                                                topics */
};

/* Command-type to remove record-interest from a storage */
struct RemoveRecordCommand {
    string storage;                          /* Name identifying a storage to
                                                stop recording to */

    /* Meta-filters */
    sequence<string> interestExpr;           /* Sequence of 'partition.topic'
                                                expressions to stop recording */
    sequence<string> blacklistExpr;          /* Sequence of 'partition.topic'
                                                expressions to stop blocking
                                                from record */

    /* Content filters */
    sequence<string> filterExpr;             /* Sequence of content-filter-
                                                expressions */
    sequence<string> excludedAttributeExpr; /* Sequence of expressions to
                                                exclude specific members of
                                                topics */
};

/* Command-type to add replay-interest to a storage */
struct AddReplayCommand {
    string storage;                          /* Name identifying a storage to
                                                replay from */

    /* Meta-filters */
    sequence<string> interestExpr;           /* Sequence of 'partition.topic'
                                                expressions to replay */
```

```
        sequence<string> blacklistExpr;         /* Sequence of 'partition.topic'
                                                   expressions to block from
                                                   replay */
        sequence<TimeRange> timeExpr;           /* Sequence of time-ranges to
                                                   replay. When empty no filtering
                                                   on time is done */

        /* Content filters */
        sequence<string> filterExpr;            /* Sequence of content-filter-
                                                   expressions */

        /* Resource limits */
        boolean useOriginalTimestamps;          /* If true, replay with original
                                                   timestamps. If false use current
                                                   time */

        /* If TRUE, fast-forward to first matching sample. If FALSE, a delay will
         * be introduced before the sample is inserted, to resemble timing
         * behaviour of the recording */
        boolean skipToFirstSample;
    };

    /* Command-type to remove replay-interest from a storage */
    struct RemoveReplayCommand {
        string storage;                         /* Name identifying a storage to
                                                   stop replaying from */

        /* Meta-filters */
        sequence<string> interestExpr;          /* Sequence of 'partition.topic'
                                                   expressions to stop replaying */
        sequence<string> blacklistExpr;         /* Sequence of 'partition.topic'
                                                   expressions to stop blocking
                                                   from replay */
        sequence<TimeRange> timeExpr;           /* Sequence of time-ranges to
                                                   stop replaying */

        /* Content filters */
        sequence<string> filterExpr;            /* Sequence of content-filter-
                                                   expressions */
    };

    /* Command-type to set the replay-speed of a storage */
    struct SetReplaySpeedCommand {
        string storage;                         /* Name identifying a storage to
                                                   replay from */
        float speed;                            /* Replay speed factor */
    };

    /* Container type of the per-topic storage statistics */
    struct TopicStatistics {
        string name;                            /* partition.topic name */
        long numberOfSamplesRecorded;           /* Total number of samples
                                                   recorded */
        long numberOfBytesRecorded;             /* Total number of bytes
                                                   recorded */
        long recordRateMinimum;                 /* Record rates (per publication
                                                   period) */
        long recordRateAverage;
        long recordRateMaximum;
        long numberOfSamplesReplayed;           /* Total number of samples
                                                   replayed */
        long numberOfBytesReplayed;             /* Total number of bytes
                                                   replayed */
```

```
        long replayRateMinimum;                 /* Replay rates (per publication
                                                   period) */
        long replayRateAverage;
        long replayRateMaximum;
    };

    union Kind switch(CommandKind) {
        case ADD_RECORD_COMMAND:                /* Record command */
            AddRecordCommand addRecord;
        case REMOVE_RECORD_COMMAND:
            RemoveRecordCommand removeRecord;
        case ADD_REPLAY_COMMAND:                /* Replay command */
            AddReplayCommand addReplay;
        case REMOVE_REPLAY_COMMAND:
            RemoveReplayCommand removeReplay;
        case CONFIG_COMMAND:                    /* Config command */
            sequence<KeyValue> config;
        case START_SCENARIO_COMMAND:            /* Scenario-control commands */
        case STOP_SCENARIO_COMMAND:
        case SUSPEND_SCENARIO_COMMAND:
            string name;
        case SETREPLAYSPEED_COMMAND:            /* Storage replay-speed command */
            SetReplaySpeedCommand setreplayspeed;
        case TRUNCATE_COMMAND:                  /* Storage truncate command */
            string storage;
        case GENERIC_COMMAND:                   /* For future extensibility */
            sequence<KeyValue> extCommands;
    };

    /*********************** TOPICS ************************/

    /* Topic used to control an R&R service */
    struct Command {
        string scenarioName;        /* Name identifying the scenario to which
                                       this command belongs */
        string rnrId;               /* Name identifying the service, or '*'
                                       to address all services */
        Kind kind;
        sequence<Condition> conditions; /* Sequence of conditions which must
                                           all be true before the command is
                                           executed */
    };
#pragma keylist Command scenarioName

    /* Topic used to monitor the status of an R&R service */
    struct ServiceStatus {
        string rnrId;               /* Name identifying the service */
        ServiceState state;         /* Current state of the service */
    };
#pragma keylist ServiceStatus rnrId

    /* Topic used to monitor the status of an R&R scenario */
    struct ScenarioStatus {
        string rnrId;               /* Name identifying the service */
        string scenarioName;        /* Name identifying the scenario */
        ScenarioState state;        /* Current state of the scenario */
    };
#pragma keylist ScenarioStatus scenarioName rnrId

    /* Topic used to monitor the status of a storage controlled by
       an R&R service */
    struct StorageStatus {
        string rnrId;               /* Name identifying the service */
```

```
        string storageName;         /* Name identifying the storage */
        StorageState state;         /* Current state of the storage */
        string storageAttr;         /* Current storage attributes */

        sequence<KeyValue> properties;  /* key = property name,
                                           value = property value */
    };
#pragma keylist StorageStatus storageName rnrId

    /* Topic used to publish statistics of a storage */
    struct StorageStatistics {
        string rnrId;
        string storageName;
        sequence<TopicStatistics> statistics;
    };
#pragma keylist StorageStatistics storageName rnrId
};

module RnR_V2 {
    /* In v2 of the RnR API, the following changes were made:
     * - a KeyValue sequence 'extensions' has been added for future
     *   extensions of Command.
     * - The Add- and RemoveReplayCommand contain a KeyValue sequence
     *   'transformations' for changing properties
     *   of samples upon replay.
     */

     /************************ TYPES ************************/

    /* Command-type to add replay-interest with transformations to a storage */
    struct AddReplayCommand {
        string storage;                         /* Name identifying a storage
                                                   to replay from */

        /* Meta-filters */
        sequence<string> interestExpr;          /* Sequence of 'partition.topic'
                                                   expressions to replay */
        sequence<string> blacklistExpr;         /* Sequence of 'partition.topic'
                                                   expressions to block from
                                                   replay */
        sequence<RnR::TimeRange> timeExpr;          /* Sequence of time-ranges to
                                                       replay. When empty no
                                                       filtering on time is
                                                       done */

        /* Content filters */
        sequence<string> filterExpr;            /* Sequence of content-filter-
                                                   expressions */

        /* Resource limits */
        boolean useOriginalTimestamps;          /* If true, replay with original
                                                   timestamps. If false use
                                                   current time */

        /* If TRUE, fast-forward to first matching sample.
         * If FALSE, a delay will be introduced before the sample
         * is inserted, to resemble timing behaviour of the recording */
        boolean skipToFirstSample;

        /* Transformations */
        sequence<RnR::KeyValue> transformations;     /* QoS transformations to
                                                        apply to the sample before
                                                        replaying */
```

```
};

/* Command-type to remove replay-interest with transformations */
struct RemoveReplayCommand {
    string storage;                          /* Name identifying a storage to
                                                stop replaying from */

    /* Meta-filters */
    sequence<string> interestExpr;           /* Sequence of 'partition.topic'
                                                expressions to stop replaying */
    sequence<string> blacklistExpr;          /* Sequence of 'partition.topic'
                                                expressions to stop blocking
                                                from replay */
    sequence<RnR::TimeRange> timeExpr;         /* Sequence of time-ranges to
                                                  stop replaying */

    /* Content filters */
    sequence<string> filterExpr;             /* Sequence of content-filter-
                                                expressions */

    /* Transformations */
    sequence<RnR::KeyValue> transformations;     /* QoS transformations
                                                    to stop replaying */
};

union Kind switch(RnR::CommandKind) {
    case ADD_RECORD_COMMAND:                 /* Record command */
        RnR::AddRecordCommand addRecord;
    case REMOVE_RECORD_COMMAND:
        RnR::RemoveRecordCommand removeRecord;
    case ADD_REPLAY_COMMAND:                 /* Replay command */
        AddReplayCommand addReplay;
    case REMOVE_REPLAY_COMMAND:
        RemoveReplayCommand removeReplay;
    case CONFIG_COMMAND:                     /* Config command */
        sequence<RnR::KeyValue> config;
    case START_SCENARIO_COMMAND:             /* Scenario-control commands */
    case STOP_SCENARIO_COMMAND:
    case SUSPEND_SCENARIO_COMMAND:
        string name;
    case SETREPLAYSPEED_COMMAND:             /* Storage replay-speed command */
        RnR::SetReplaySpeedCommand setreplayspeed;
    case TRUNCATE_COMMAND:                   /* Storage truncate command */
        string storage;
    case GENERIC_COMMAND:                    /* For future extensibility */
        sequence<RnR::KeyValue> extCommands;
};

/************************ TOPICS ************************/

/* Topic used to control an R&R service */
struct Command {
    string scenarioName;        /* Name identifying the scenario to which
                                   this command belongs */
    string rnrId;               /* Name identifying the service, or '*' to
                                   address all services */
    Kind kind;
    sequence<RnR::Condition> conditions; /* Sequence of conditions which
                                            must all be true before the
                                            command is executed */
    sequence<RnR::KeyValue> extensions;  /* Sequence reserved for future
                                            enhancements */
};
```

```
#pragma keylist Command scenarioName
};
```

8

References

The following documents are referred to in the text:

OMG DDS 2004

Object Management Group,
'Data Distribution Service for Real-Time Systems',
Final Adopted Specification, ptc/04-04-12
2004

OMG CORBA v3 2002

Object Management Group,
'The Common Object Request Broker: Architecture and Specification',
Version 3.0, formal/02-06-01
2002

OMG C Language 1999

Object Management Group,
'C Language Mapping Specification',
Version 1.0, formal/99-07-35
1999

OMG C++ Language 2003

Object Management Group,
'C++ Language Mapping Specification',
Version 1.1, formal/03-06-03
2003

OMG Java Language 2002

Object Management Group,
'Java Language Mapping Specification',
Version 1.2, formal/02-08-05
2002

OMG ISO/IEC C++ Language 2013

Object Management Group,
'ISO/IEC C++ 2003 Language DDS PSM',
Version 1.0, formal/2013-11-01
2013

OMG DDS XTYPES 2012

Object Management Group,
'Extensible and Dynamic Topic Types for DDS',
Version 1.0, formal/2012-11-10
2012

9

Contacts & Notices

9.1 Contacts

PrismTech Corporation
400 TradeCenter
Suite 5900
Woburn, MA
01801
USA
Tel: +1 781 569 5819

PrismTech Limited
PrismTech House
5th Avenue Business Park
Gateshead
NE11 0NG
UK
Tel: +44 (0)191 497 9900

PrismTech France
28 rue Jean Rostand
91400 Orsay
France
Tel: +33 (1) 69 015354

Web: http://www.prismtech.com

E-mail: info@prismtech.com

9.2 Notices