Project no. 004758

GORDA

Open Replication Of Databases

Specific Targeted Research Project

Software and Services

Draft Standard
(GORDA Group Communication Service Specification)

GORDA Deliverable 6.4b

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Revision 0.1

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Preface

This document, GORDA Group Communication Service Specification, specifies the programming interfaces for generic group communication systems.

Revision History

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<td>2007-04-04</td>
<td>0.1</td>
<td>Initial Draft</td>
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Who Should Use This Specification

The audience for this document are:

- implementors of database replication protocols;
- implementors of distributed systems that require group communication.

How This Specification Is Organized

Section 1 introduces the interface in the context of the GORDA project as well as document conventions used. Section 2 describes the goals, scope, and requirements of the proposed interface. Section 3 presents the abstract model of transaction processing underlying the interface as well as key design patterns. Section 4 discusses the interface in detail. Finally, Section 5 is a guide to sample code distributed with the interface.
1 Introduction and Background

1.1 Introduction

This document specifies a programming interface for Group Communication as well as minimum semantics that allow application portability. This interface accommodates existing group communication services, enabling implementation independence. The interface is called Group Communication Service, or simply GCS.

Group Communication is understood as a coordination paradigm that eases the development of multi-participant applications. Some examples are replicated servers, cooperative caches and multi-user cooperative applications.

1.2 The GORDA Project

The goal of the GORDA project is to foster database replication as a means to address the challenges of trust, integration, performance, and cost in current database systems underlying the information society. This is to be achieved by standardizing architecture and interfaces, and by sparking their usage with a comprehensive set of components ready to be deployed.

GORDA is supported by the European Community under the Sixth European Union Framework Programme for Research and Technological Development, thematic priority Information Society Technologies, contract number 004758. The consortium is composed by U. Minho, U. della Svizzera Italiana, U. Lisboa, INRIA Rhône-Alpes, Continuent, and MySQL.

More information is available at:

- http://gorda.di.uminho.pt

1.3 Relation with GCS

The specification is based on the GORDA Architecture and Programming Interfaces as described in GORDA deliverables D2.2 and D2.3. The main difference is that a new interface to handle the exclusion of a member from a group was created.

In the scope of the project, the presented interfaces were implemented using several group communication toolkits. A Java version of the interfaces and all its implementations are available as open source code in the URL: http://jgcs.sf.net.
1.4 Document Conventions

1.4.1 Definitions

This document uses definitions based upon those specified in RFC-2119 (See http://www.ietf.org/). For a better reading experience these terms are written in small letters.

Table 1: Specification terms.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>MUST</td>
<td>The associated definition is an absolute requirement of this specification.</td>
</tr>
<tr>
<td>MUST NOT</td>
<td>The definition is an absolute prohibition of this specification.</td>
</tr>
<tr>
<td>SHOULD</td>
<td>Indicates a recommended practice. There may exist valid reasons in particular circumstances to ignore this recommendation, but the full implications must be understood and carefully weighed before choosing a different course.</td>
</tr>
<tr>
<td>SHOULD NOT</td>
<td>Indicates a non-recommended practice. There may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.</td>
</tr>
<tr>
<td>MAY</td>
<td>Indicates that an item is truly optional.</td>
</tr>
</tbody>
</table>

1.4.2 Formatting Conventions

This specification uses the following formatting conventions.

Table 2: Formatting conventions.

<table>
<thead>
<tr>
<th>Convention</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>fixed</td>
<td>Used in all Java code including keywords, data types, constants, method names, variables, class names, and interface names.</td>
</tr>
<tr>
<td>italic</td>
<td>Used for emphasis and to signify the first use of a term.</td>
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</tbody>
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1.5 Contributors

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- Nuno Carvalho, U. Lisboa
- Nuno A. Carvalho, U. Minho
1.6 Feedback

Please send any comments and questions concerning this specification to:

community@gorda.di.uminho.pt

or

jgcs@lasige.di.fc.ul.pt
2 Scope and Requirements

2.1 Goals

No changes to payload required. No assumptions or changes should be made on message payload. This means that implementing GCS does not require specific data formats, additional message headers or additional messages exchanged. The toolkits that adopt GCS as their native interface can implement GCS-specific optimizations. As a result, applications that use a specific protocol through GCS should be interoperable with legacy versions using native interfaces. Furthermore, no specific constructors or data formats are forced on the application. It must be possible to translate the interface to languages in the same family such as C++ or C#.

Support service locator and dependency injection patterns. All details regarding protocol configuration and service selection must be encapsulated in objects that may be supplied to the application by a third party (i.e. the configurator) using a service locator or the dependency injection patterns. As an example, this allows substitution by a stronger service, when the exact service required by the application is not available in the target environment.

Support multiple group-based programming paradigms. The GCS interface should be flexible enough to support different flavors of multicast communication based on process groups. The GCS should support both open groups (where any process can send messages to the group) and closed groups (where only group members can send messages to the group). It should also support peer groups, in which messages are target to specific members of the group. As an example, a multicast group is useful for data replication while a peer group is useful in a load balancing application. Note that both flavors require precise knowledge of current membership to function properly.

Export a flexible subsetable interface. The GCS should support the deployment of just parts of the interface to avoid redundancy. The GCS has been designed to be subsetable, in the sense that parts can be independently reused, without carrying along with partially implemented interfaces and runtime exceptions.

Non-blocking input/output and container-managed concurrency. GCS supports an event-driven interface. The application registers a number of callback listener interfaces to be notified of messages arriving and changes to group composition. This avoids the requirement to have threads blocked on input/output. It also allow the GCS implementations to cooperate with application containers to optimize the number of concurrent threads, when concurrency requirements arise.

Accommodate latest research results. The interface should allow recent research results, such as support semantic annotations and early delivery, to be easily accommodated. In fact, the goal is to foster programming idioms that naturally take advantage of such results as they become available.
2.2 Non-Goals

Specify a common set of service guarantees. The GCS avoids this pitfall by assuming a configuration step that matches available service guarantees to application requirements.

Exclusively reuse existing standard interfaces. It is a better option to provide a syntactically incompatible interface that embodies similar structure and the same patterns such that programmers can easily make the transition.

Provide interfaces for protocol composition. The main problem is that the mapping of an existing implementation to a component interface is not straightforward and thus the approach is not general. Furthermore, interfaces that allow efficient assembly of fine-grained protocol components are likely to impose a specific runtime that is not acceptable as a general purpose application programming interface.
3 Design

3.1 Approach and Terminology

This specification is based on the basis needed to implement group communication in general. We use Java to illustrate the interfaces, but any object oriented language may be used to implement the GCS.

3.2 Overview

The GCS interface is organized in four complementary interfaces, namely: the configuration interface, the common interface, the data interface, and the control interface. Each of these interfaces is described below.

3.3 Configuration Interface

The configuration interface decouples the application code from specific implementations by requiring that a third party, the configurator, matches available services with application requirements. It is composed by opaque objects as follows:

ProtocolFactory The protocol factory must serve as the interface entry point and triggers the initialization of runtime instances of a protocol implementation. At the semantic level, it encapsulates an implicit service guarantee specification which is enforced for all sessions.

GroupConfiguration A group configuration encapsulates the configuration of a group that can be used to open a session that subsequently allows messages to be sent or received, or the membership to be observed. As the ProtocolFactory, at the semantic level it also encapsulates an implicit service guarantee specification which is enforced for all messages exchanged. This object may be used as a key in hashtables.

Service A service encapsulates a specification of the guarantees to be enforced on a particular message. Upon encountering a service specification that is unknown or incompatible with group or protocol configuration, the implementation must return some error. A partial order must be defined on guarantees provided by services (i.e., some services may be stronger than, and subsume, other services). Therefore, the application may use the service interface to discover if a service guarantee is subsumed by some other.

Annotation An annotation is an optional field that encapsulates semantic knowledge about a message that may be used by the protocol. The contents of the annotation are therefore implementation specific and protocols should silently ignore unknown annotations without erroneous or unpredictable behavior.

Configuration objects should be easily stored and retrieved in configuration files and directory services. The implementations should provide configuration objects with one or more of the following properties: are serializable and can be constructed from properties files. For the same reason, these objects should not be used to keep session state at runtime.
3.4 Common Interface

A protocol session is represented by a Protocol instance, obtained from the configuration stored in a ProtocolFactory. Using a Protocol instance it is possible to obtain, for a specific GroupConfiguration, a data and a control session. All further operations must be invoked through one of these two interfaces. This sequence is shown in Figure 1. Both data and control sessions identify group members. Protocols may use different address formats and should wrap the addresses.

Finally, exceptions thrown asynchronously within the protocol implementation are delivered to the application using the ExceptionListener interface. This can be registered using either session object.

3.5 Data Interface

The data interface provides the methods for messages to be sent and received. Whenever the application multicasts a message there is always a specific quality of service, i.e. a specific set of guarantees, associated with the request. The guarantees may be implicitly derived from the group or protocol configuration or explicitly set using a Service parameter. The data interface is as follows:

**DataSession**  The data session provides methods for sending messages in both multicast and peer groups. It also allows registering listeners for the various events.

**Message**  This interface wraps payload and sender address. The only payload supported is a byte array. The instances must be created by the DataSession. Implementors may provide this interface as a thin layer on implementation specific objects to avoid having to perform additional buffer copy operations.

**MessageListener**  Handles delivery of message payload. This is the main entry point for incoming data. When no separate ServiceListener is being used, implicitly does service notification.
**ServiceListener** Handles delivery of service notification events. Applications that do not need to be optimized for concurrency may ignore this interface.

The data interface may expose the early delivery feature to the application, using the Services interface. This should be done by delivering the payload to the application as soon as it is received and then later notify the application that the requested service has been ensured. This allows increased concurrency and masking of latency, by allowing the application to start processing the message earlier, at least, by deserializing the message in parallel with the execution of the remaining of the protocol. GCS should support this optimization as described in Figure 2. The application registers a ServiceListener with the DataSession. The protocol may deliver payload without ensuring services. Upon handling the message, the application chooses how to proceed:

- Returns a context reference (any POJO) which the protocol associates with the message. When the service is ensured, the protocol calls back into the application providing references to both the context object and the service object that has been achieved. The application then resumes processing the message.
- Returns a null reference. This informs the protocol that no further notifications or service guarantees are required for this message and no further callbacks should happen.

Protocols that do not natively support this interface may perform both callbacks only after the final delivery.

![Figure 2: Sending and receiving messages with the services.](image)

On the sender side, the GCS also provides mechanisms to prevent the application from being blocked when invoking the interface. For instance, a specific protocol implementation may not accept requests until some service is ensured. Also, an implementation may perform end-to-end flow control, thus throttling the sender in a similar fashion. The non-blocking interface works as follows. Upon sending a message, an application may also specify a context. This means that multicast does not block and the application gets notified using the service listener callback.

GCS does not impose artificial limits to the application concurrency, namely in the processing of incoming messages. This interface allows for concurrent...
message delivery notifications whenever the requested service does not im-
pose ordering on messages. This applies both to payload deliveries, when no
service listener has been registered, as well as to service callbacks. Notice that
in the later, payload deliveries can always be performed concurrently, up to
an optimal concurrency degree, that may be coordinated with application con-
tainers.

Finally, the GCS provides support for the use of semantic knowledge. This
is achieved by letting application annotate messages with control information
that can be used by the group communication toolkit to selectively relax reliabil-
ity, order and view synchrony guarantees. For that purpose, the application
should obtain one or more annotation objects in an implementation specific
fashion. These are then handed to the protocol as parameters in the multicast
operation. Unknown semantic annotations should be ignored by the protocols.

3.6 Control Interface

The control interface is subsetable and the most simple interface should be im-
plemented only by best-effort multicast protocols. The basic interface is com-
posed by the following:

**ControlSession** Provides methods for entering and leaving a group, as well as
for registering a listener for control events.

**ControlListener** Allows a simple notification of members entering and leav-
ing the group. Precise semantics of these events, namely regarding con-
currency with message deliveries, depends on the implementation.

This interface may be used separatly for failure detection or cluster manage-
ment infrastructure, which are not directly related to group communication.
The implementations may choose to distinguish members that have left the
group voluntarily and in a controlled fashion from members that have failed
and thus been forcibly excluded.

If the implementation supports view synchronous, the extensions of the control
session must be used. The extensions are reflected in the following interfaces:

**Membership** Describes a view of the group. This may be used to obtain a
ranked list of all members, whose sort order depends on the implementa-
tion but which should be the same everywhere. It may also be used to
obtain information on the event leading to the view change, namely,
which processes have just been included and excluded and why.

**MembershipID** Provides an opaque unique identifier of the view, suitable for
being exchanged and stored persistently. This may be obtained from the
currently installed Membership object.

**MembershipSession** Provides methods to obtain the current membership and
register the callback for view change events.

**MembershipListener** Handles notifications of view change.
**BlockSession** Should be used only by implementations enforcing sending view delivery, providing methods for signaling that the application has blocked and that view change can proceed.

**BlockListener** Handles requests by the protocol for the application to block.

The Figure 3 shows how the system should work when a member joins a group. Support for view synchronous group communication requires that membership notifications are coordinated with message and service notifications performed by the corresponding data session. The implementation must ensure that the view change notification is mutually exclusive with any other view dependent event, namely, message delivery and service ensured callbacks. This means that notification must not be issued concurrently with the view change. Protocol implementations may allow this restriction to be lifted, but this should be possible only by explicitly selecting a configuration option. Block notifications may be issued without any concurrency restrictions. This means that it is up to the application to synchronize with any other active threads.
The specification is contained in package net.sf.jgcs and net.sf.jgcs.membership. A diagram outlining the relations between individual interfaces is shown in the Figures 4 and 5.

Detailed descriptions of the specification are provided in the following sections.
Figure 4: Group communication interfaces.
Figure 5: Extension interfaces for virtual synchrony.
4.1 Package net.sf.jgcs

4.1.1 Interface Annotation

This class defines a Annotation. An Annotation should be used by the application to give semantic information about the message to the Channel protocols implementation.

Declaration  public interface Annotation

4.1.2 Interface ControlListener

This class defines a ControlListener. This listener must be used by clients that wish to be notified of changes in the members that join, leave or fail in a simple group.

Declaration  public interface ControlListener

Methods

- onFailed
  
  void onFailed( java.net.SocketAddress peer )

  - Description
    Notification of a member that was detected as failed. This notification means also that the member does not belong to the group any more.

  - Parameters
    * peer – the address of the member that failed.

- onJoin
  
  void onJoin( java.net.SocketAddress peer )

  - Description
    Notification of a new member in the group.

  - Parameters
    * peer – the address of the new member.

- onLeave
  
  void onLeave( java.net.SocketAddress peer )

  - Description
    Notification of a member that leaved the group.

  - Parameters
    * peer – the address of the leaved member.
4.1.3 Interface ControlSession

This class defines a ControlSession. This Session is used to join and leave a simple group. It is also used to register a ControlListener. An instance of this session must be created by the Protocol interface.

4.1.4 See also

- 4.1.13, page 25

Declaration  public interface ControlSession

All known subinterfaces  MembershipSession (in 4.2.7, page 37), BlockSession (in 4.2.2, page 33)

Methods

- getLocalAddress
  java.net.SocketAddress getLocalAddress( )
  
  - Description
    Gets the local address. It should return null if the member is not joined to any group.
  
  - Returns  the local address.

- isJoined
  boolean isJoined( )
  
  - Description
    Verifies if the member belongs to a group.
  
  - Returns  true if the member is correctly joined, false otherwise.

- join
  void join( )
  throws net.sf.jgcs.ClosedSessionException,
  net.sf.jgcs.JGCSException
  
  - Description
    Joins the group. It must block until the join process is finished.

- leave
  void leave( )
  throws net.sf.jgcs.ClosedSessionException,
  net.sf.jgcs.JGCSException
  
  - Description
    Leaves the group. It must block until the leave process is finished.
- **setControlListener**
  ```java
  void setControlListener( ControlListener listener )
  ```
  
  - **Description**
    Adds a listener to deliver group membership notifications.
  
  - **Parameters**
    * listener – The listener to be bound to the membership service.

- **setExceptionListener**
  ```java
  void setExceptionListener( ExceptionListener exception )
  throws net.sf.jgcs.ClosedSessionException
  ```
  
  - **Description**
    Adds a listener to deliver exceptions related to message reception and membership notifications.
  
  - **Parameters**
    * exception – the exception thrown by the implementation of the interface.

### 4.1.5 Interface DataSession

This class defines a DataSession. This Session must be used to send and receive messages to/from the group. An instance of a DataSession must be created on the Protocol interface.

#### 4.1.6 See also

- 4.1.13, page 25

**Declaration**  public interface DataSession

**Methods**

- **close**
  ```java
  void close( )
  ```
  
  - **Description**
    Closes the session. All resources that the session holds should be freed and therefore no subsequent communication can be done.

- **createMessage**
  ```java
  Message createMessage( )
  throws net.sf.jgcs.ClosedSessionException
  ```
  
  - **Description**
    Creates an empty message that can be used (transmitted) through the session.
• getGroup
  GroupConfiguration getGroup()

  - Description
  Gets the group associated with this session.

  - Returns – the group associated with this session.

• multicast
  void multicast(Message msg, Service service,
  java.lang.Object cookie, Annotation[] annotation)
  throws java.io.IOException, net.sf.jgcs.UnsupportedServiceException

  - Description
  Sends a message to the group.

  - Parameters
    * msg – The message to be sent.
    * service – the service needed by the application for message delivery (e.g. total order) or null to use the default channel service.
    * cookie – a cookie used to identify the message in the future (e.g. service notifications).
    * annotation – semantic information provided by the application to be used by communication protocols (e.g. semantic reliability).

  - Throws
    * java.io.IOException –

• send
  void send(Message msg, Service service,
  java.lang.Object cookie, java.net.SocketAddress destination, Annotation[] annotation)
  throws java.io.IOException, net.sf.jgcs.UnsupportedServiceException

  - Description
  Sends a message to one particular member of the group.

  - Parameters
    * msg – The message to be sent.
    * service – the service needed by the application for message delivery (e.g. total order) or null to use the default channel service.
    * cookie – a cookie used to identify the message in the future (e.g. service notifications).
    * destination – the destination of the message.
4.1 Package net.sf.jgcs

- annotation – semantic information provided by the application to be used by communication protocols (e.g. semantic reliability).
- Throws
  * java.io.IOException –

- setExceptionListener
  void setExceptionListener( ExceptionListener exception )
  throws net.sf.jgcs.ClosedSessionException

  - Description
    Adds a listener to deliver exceptions related to message reception.
  - Parameters
    * exception – the exception thrown by the implementation of the interface.

- setMessageListener
  void setMessageListener( MessageListener listener )
  throws net.sf.jgcs.ClosedSessionException

  - Description
    Adds a listener to deliver messages from this channel.
  - Parameters
    * listener – The listener to be bound to the channel.

- setServiceListener
  void setServiceListener( ServiceListener listener )
  throws net.sf.jgcs.ClosedSessionException

  - Description
    Adds a listener to deliver notifications from this channel.
  - Parameters
    * listener – the listener to be bound to the channel.

4.1.7 Interface ExceptionListener

This class defines a ExceptionListener. This listener must be used to receive exceptions that could occur on message reception.

Declaration
  public interface ExceptionListener

Methods
- onException
  void onException( JGCSException exception )

  - Description
    Notification of an exception that occurred when the underlying implementation was receiving a message.
  - Parameters
    * exception – the exception.
4.1.8 **Interface GroupConfiguration**

This class defines a GroupConfiguration. Interface that provides a Group configuration to open Sessions (in 4.1.5, page 21). This Interface must be used together with the Protocol (in 4.1.13, page 25) to create a DataSession (in 4.1.5, page 21) and a ControlSession (in 4.1.3, page 20).

4.1.9 **See also**

- 4.1.5, page 21
- 4.1.3, page 20
- 4.1.13, page 25

**Declaration**  
public interface GroupConfiguration

4.1.10 **Interface Message**

This class defines a Message. Messages exchanged using the underlying toolkit must implement this interface. Instances of this interface must be retrieved from the DataSession (in 4.1.5, page 21).

**Declaration**  
public interface Message

**Methods**

- **getPayload**
  
  byte[] getPayload( )

  - **Description**
    
    Gets the payload from the message.
  
  - **Returns**
    
    the payload from the message.

- **getSenderAddress**
  
  java.net.SocketAddress getSenderAddress( )

  - **Description**
    
    Gets the sender address.
  
  - **Returns**
    
    the sender address

- **setPayload**
  
  void setPayload( byte[] buffer )

  - **Description**
    
    Sets the payload for the message.
  
  - **Parameters**
    
    * buffer – The payload to be stored in the message.
• setSenderAddress
  void setSenderAddress( java.net.SocketAddress sender )

  – Description
    Sets the sender address.
  – Parameters
    * sender – the sender address.

4.1.11 Interface MessageListener

This class defines a MessageListener. This listener must be used to receive messages.

4.1.12 See also
  - 4.1.5, page 21
  - 4.1.16, page 27
  - 4.1.17, page 27

Declaration  public interface MessageListener

All known subinterfaces  ServiceListener (in 4.1.17, page 27)

Methods

• onMessage
  java.lang.Object onMessage( Message msg )

  – Description
    Delivers a message from the channel to the application. To use this listener together with the Services, a cookie must be returned by the application.
  – Parameters
    * msg – The message received from the channel.
  – Returns – the cookie of the message.

4.1.13 Interface Protocol

This interface defines a Protocol represents an instance of the toolkit used to implement the Group Communication Service (GCS). This interface must be used to create instances of DataSession and Control Session.

4.1.14 See also
  - 4.1.5, page 21
  - 4.1.3, page 20
  - 4.1.8, page 24
Declaration  public interface Protocol

Methods

- **openControlSession**
  
  ControlSession openControlSession( GroupConfiguration group )
  throws net.sf.jgcs.JGCSException

  - **Description**
    Creates a new Control Session. This session must be used to join a
    group and register a listener to receive asynchronous notifications
    about the other members of the group (join, leave, fail).

  - **Parameters**
    * group – the group configuration.

  - **Returns** – a new control session.

  - **Throws**
    * net.sf.jgcs.JGCSException –

- **openDataSession**
  
  DataSession openDataSession( GroupConfiguration group )
  throws net.sf.jgcs.JGCSException

  - **Description**
    Creates e new Data Session. This session must be used to send mes-
    sages and to register a listener to receive messages from the other
    members of the group.

  - **Parameters**
    * group – the configuration.

  - **Returns** – a new data session.

  - **Throws**
    * net.sf.jgcs.JGCSException –

4.1.15 Interface ProtocolFactory

This class defines a ProtocolFactory This factory must be used to create in-
stances of Protocols. It should be stateless and represents one toolkit.

Declaration  public interface ProtocolFactory

Methods

- **createProtocol**
  
  Protocol createProtocol( )
  throws net.sf.jgcs.JGCSException
API DESCRIPTION

4.1 Package net.sf.jgcs

- Description
  Creates a new Protocol that represents a toolkit.

- Returns
  - a new protocol.

- Throws
  * net.sf.jgcs.JGCSException

4.1.16 Interface Service

This class defines a Service. A Service is some functionality that the channel needs to provide to the application. One example is the optimistic total order. If an application creates a channel that provides optimistic total order, the application will receive the message payload with out guarantees and will be notified later about optimistic delivery, regular delivery, uniform delivery, etc. These notifications must implement this interface. All related services must be comparable with each other (e.g. uniform delivery is a stronger service than regular delivery, so if the message is uniform, it’s also regular and optimistic – optimistic lower than regular lower than uniform).

Declaration

    public interface Service

Methods

- compare
  
  `int compare(Service service)`
  throws net.sf.jgcs.UnsupportedServiceException

  - Description
    Compares two Services of the same protocol. return 0 if the services are the same, -1 if the service has lower properties than the given service, 1 if the service has greater properties than the given service.

  - Parameters
    * service – the service to compare.

  - Returns
    - 0 - same service, 1 greater service, -1 otherwise

  - Throws
    * net.sf.jgcs.UnsupportedServiceException – if the service is not comparable.

4.1.17 Interface ServiceListener

This class defines a ServiceListener. Listeners interested in receiving notifications about guarantees of requested services on messages must implement this interface.
4.18 See also

- 4.1.5, page 21
- 4.1.16, page 27

Declaration  public interface ServiceListener
extends MessageListener

Methods

- onServiceEnsured
  void onServiceEnsured( java.lang.Object context, Service service )
  
  - Description
  Notifies the application that one certain service to a message delivery is already ensured. The message is identified by the context. This context must be previously provided by the application.

  - Parameters
    * context – context previously provided by the application that identifies a message.
    * service – service ensured.

4.19 Exception ClosedSessionException

This class defines a ClosedSessionException.

Declaration  public class ClosedSessionException
extends net.sf.jgcs.JGCSException (in 4.1.21, page 29)

Constructors

- ClosedSessionException
  public ClosedSessionException()  

- ClosedSessionException
  public ClosedSessionException( java.lang.String s )  

- ClosedSessionException
  public ClosedSessionException( java.lang.String s, java.lang.Throwable t )  

4.20 Exception DataSessionException

This class defines a DataSessionException.
4 API DESCRIPTION

4.1 Package net.sf.jgcs

Declaration  public class DataSessionException
extends net.sf.jgcs.JGCSException (in 4.1.21, page 29)

Constructors

- DataSessionException
  public DataSessionException ( )
  - Description
    Creates a new DataSessionException.

- DataSessionException
  public DataSessionException ( java.lang.String message )
  - Description
    Creates a new DataSessionException.
  - Parameters
    * message – the error message.

- DataSessionException
  public DataSessionException ( java.lang.String message,
                        java.lang.Throwable cause )
  - Description
    Creates a new DataSessionException.
  - Parameters
    * message – the error message
    * cause – the throwable that caused this exception.

4.1.21 Exception JGCSException

This class defines a JGCSException.

Declaration  public class JGCSException
extends java.io.IOException

All known subclasses  UnsupportedServiceException (in 4.1.23, page 32),
NotJoinedException (in 4.1.22, page 31), DataSessionException (in 4.1.20, page 28),
ClosedSessionException (in 4.1.19, page 28)

Constructors

- JGCSException
  public JGCSException ( )
  - Description
    Creates a new JGCSException.

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4.1 Package net.sf.jgcs

- **JGCSException**
  public JGCSException( java.lang.String s )
  
  - Description
    Creates a new JGCSException.
  
  - Parameters
    * s – the error message.

- **JGCSException**
  public JGCSException( java.lang.String s, int code )
  
  - Description
    Creates a new JGCSException.
  
  - Parameters
    * s – the error message.
    * code – the error code.

- **JGCSException**
  public JGCSException( java.lang.String s, java.lang.Throwable cause )
  
  - Description
    Creates a new JGCSException.
  
  - Parameters
    * s – the error message.
    * cause – the throwable that caused this exception.

- **JGCSException**
  public JGCSException( java.lang.String s, java.lang.Throwable cause, int code )
  
  - Description
    Creates a new JGCSException.
  
  - Parameters
    * s – the error message
    * cause – the throwable that caused this exception.
    * code – the error code

**Methods**

- **getCause**
  public java.lang.Throwable getCause( )
  
  - Description
    Gets the throwable that caused this exception.

- **getErrorCode**
  public int getErrorCode( )
  
  - Description
    Gets the error code that identifies the error occurred.
  
  - Returns – the error code.
4.1.22 Exception NotJoinedException

This class defines a NotJoinedException.

Declaration  

public class NotJoinedException  
extends net.sf.jgcs.JGCSException  
( in 4.1.21, page 29)  

Constructors

• NotJoinedException
  public NotJoinedException( )
  – Description
    Creates a new NotJoinedException.

• NotJoinedException
  public NotJoinedException( java.lang.String s )
  – Description
    Creates a new NotJoinedException.
  – Parameters
    * s – the error message

• NotJoinedException
  public NotJoinedException( java.lang.String s, int code )
  – Description
    Creates a new NotJoinedException.
  – Parameters
    * s – the error message.
    * code – the error code.

• NotJoinedException
  public NotJoinedException( java.lang.String s, 
                           java.lang.Throwable cause )
  – Description
    Creates a new NotJoinedException.
  – Parameters
    * s – the error message.
    * cause – the throwable that caused this exception.

• NotJoinedException
  public NotJoinedException( java.lang.String s, 
                           java.lang.Throwable cause, int code )
  – Description
    Creates a new NotJoinedException.
  – Parameters
    * s – the error message.
    * cause – the throwable that caused this exception.
    * code – the error code.
4.1.23 Exception UnsupportedServiceException

This class defines a UnsupportedServiceException.

Declaration  public class UnsupportedServiceException
extends net.sf.jgcs.JGCSException  (in 4.1.21, page 29)

Constructors

• UnsupportedServiceException
  public UnsupportedServiceException( )
  – Description
    Creates a new UnsupportedServiceException.

• UnsupportedServiceException
  public UnsupportedServiceException( java.lang.String message )
  – Description
    Creates a new UnsupportedServiceException.
  – Parameters
    * message – the error message.

• UnsupportedServiceException
  public UnsupportedServiceException( java.lang.String message,
   java.lang.Throwable cause )
  – Description
    Creates a new UnsupportedServiceException.
  – Parameters
    * message – the error message.
    * cause – the throwable that caused this exception.
4.2 Package net.sf.jgcs.membership

4.2.1 Interface BlockListener

This class defines a BlockListener. This listener must be used to receive notifications that a group membership will block.

**Declaration**  
public interface BlockListener

**Methods**

- **onBlock**  
  void onBlock()
  
  - **Description**  
    Block notification. Upon this notification, the application must flush all pending messages and notify the session with the (in 4.2.2, page 33) method. The view change will not continue if this does not happen. After the group is blocked, the members cannot send more messages until a new Membership view is received.

4.2.2 Interface BlockSession

This class defines a BlockSession. This session should be used by toolkits that implement Group Communication with flush of messages before a view change.

**Declaration**  
public interface BlockSession  
extends MembershipSession

**Methods**

- **blockOk**  
  void blockOk()  
  throws net.sf.jgcs.NotJoinedException,  
  net.sf.jgcs.JGCSException
  
  - **Description**  
    This method must be used by the application after it received a block notification and flushed all pending messages. After calling this method, the application cannot send any more messages until it receives a notification of a membership change.
  
  - **Throws**  
    * net.sf.jgcs.NotJoinedException – if the member is not in a group.
    * net.sf.jgcs.JGCSException – if an error occurs.
4.2 Package net.sf.jgcs.membership

- **isBlocked**
  ```java
  boolean isBlocked() throws net.sf.jgcs.NotJoinedException
  ```
  - **Description**
    Verifies if the group is blocked or not.
  - **Returns**
    true if the group is blocked, false otherwise.
  - **Throws**
    * net.sf.jgcs.NotJoinedException – if the member is not in a group.

- **setBlockListener**
  ```java
  void setBlockListener( BlockListener listener) throws net.sf.jgcs.JGCSException
  ```
  - **Description**
    Registers a listener for the block notification.
  - **Parameters**
    * listener – the listener to register.
  - **Throws**
    * net.sf.jgcs.JGCSException – if an error occurs.

### 4.2.3 Interface Membership

This class defines a Membership.

**Declaration**
```java
public interface Membership
```  
**Methods**

- **getCoordinatorRank**
  ```java
  int getCoordinatorRank() 
  ```
  - **Description**
    Gets the rank of the coordinator of this group.
  - **Returns**
    the rank of the coordinator of the group.

- **getFailedMembers**
  ```java
  java.util.List getFailedMembers() 
  ```
  - **Description**
    Gets a list of members that failed since the previous membership.
  - **Returns**
    a list of failed members or null if there are none.

- **getJoinedMembers**
  ```java
  java.util.List getJoinedMembers() 
  ```
4 API DESCRIPTION

4.2 Package net.sf.jgcs.membership

- **Description**
  Gets a list of members that joined the group since the previous membership.

- **Returns**
  - a list of new members or null if there are none.

- **getLeavedMembers**
  java.util.List getLeavedMembers()

  - **Description**
    Gets a list of members that leaved the group since the previous membership.

  - **Returns**
    - a list of old members or null if there are none.

- **getLocalRank**
  int getLocalRank() throws net.sf.jgcs.NotJoinedException

  - **Description**
    Gets the local rank of the member in this membership.

  - **Returns**
    - the local rank of this member.

  - **Throws**
    - net.sf.jgcs.NotJoinedException – if the member is not in a group.

- **getMemberAddress**
  java.net.SocketAddress getMemberAddress( int rank )

  - **Description**
    Gets the socket address of the member that has the given rank.

  - **Parameters**
    - rank – the rank of the member.

  - **Returns**
    - the socket address of the member.

- **getMemberRank**
  int getMemberRank( java.net.SocketAddress peer )

  - **Description**
    Gets the member rank that has the given socket address, or null if there is no matching rank.

  - **Parameters**
    - peer – the socket address of the member.

  - **Returns**
    - the rank of the member.

- **getMembershipID**
  MembershipID getMembershipID()

  - **Description**
    Gets the current membership ID.

  - **Returns**
    - the current membership ID.
• getMembershipList
  java.util.List getMembershipList()

  – Description
  Gets the current view of the membership.
  – Returns – the current view of the membership.

4.2.4 Interface MembershipID

This class defines a MembershipID. It represents an ID of the membership, that must change and grow on every view change, according to the java.lang.Comparable interface.

4.2.5 See also
  – java.lang.Comparable

Declaration  public interface MembershipID
extends java.lang.Comparable

4.2.6 Interface MembershipListener

This class defines a MembershipListener. This listener must be used to receive membership, when the control session used implements the MembershipSession or BlockSession interfaces.

Declaration  public interface MembershipListener

Methods

• onExcluded
  void onExcluded()
  – Description
  Notification from the membership to indicate that the registered member does not belong to the group any more. This should happen when the member lost intermediate views (for instance, when using primary views) and lost some messages. After receiving this notification, the member may try to rejoin again.

• onMembershipChange
  void onMembershipChange()
  – Description
  Notification of a MembershipChange. This should happen due to joining, leaving or failure of group members, but also because of merging or partitioning of memberships. The new membership can be retrieved from the MembershipSession.
4.2.7 Interface MembershipSession

This class defines a MembershipSession. This session should be implemented when the underlying toolkit provides extended view synchrony semantics.

Declaration  public interface MembershipSession
extends net.sf.jgcs.ControlSession

All known subinterfaces  BlockSession (in 4.2.2, page 33)

Methods

- **getMembership**
  Membership  getMembership( )
  throws net.sf.jgcs.NotJoinedException
  
  - Description
    Gets the current Membership.
  
  - Returns
    a membership.

  - Throws
    
    * net.sf.jgcs.NotJoinedException – if the member is not joined

- **getMembershipID**
  MembershipID  getMembershipID( )
  throws net.sf.jgcs.NotJoinedException
  
  - Description
    Gets the current membership ID
  
  - Returns
    the current membership ID

  - Throws
    
    * net.sf.jgcs.NotJoinedException – if the member is not joined

- **setMembershipListener**
  void  setMembershipListener( MembershipListener  listener )
  
  - Description
    Registers a listener for the membership changes.
  
  - Parameters
    
    * listener – the listener to register.
5 Samples

5.1 Third party configurator

This sample shows how to setup a group communication toolkit that was previously configured using a Naming and Directory Interface.

The sample uses virtual synchrony and implements all the listeners used to receive messages, exceptions and membership notifications.

```java
public class JNDITest implements MessageListener, ControlListener, MembershipListener, BlockListener, Runnable {
    private static final int NUM_MESSAGES=10;
    private ControlSession control;
    private DataSession data;
    private Context ctx;
    private Service service;

    public JNDITest(Context x) throws JGCSException, NamingException {
        this.ctx=x;
    }

    The first object to lookup is the protocol factory. This object represents the toolkit that will be used by this application.
    ProtocolFactory pf = (ProtocolFactory) x.lookup("myProto");

    A protocol can now be created. This object represents an instance of the toolkit that will be used for group communication.
    Protocol p = pf.createProtocol();

    The application must also lookup a GroupConfiguration object that represents a configuration of the group communication.
    GroupConfiguration g = (GroupConfiguration) x.lookup("myGroup");

    A service object is needed to send messages. The application may use different services for different messages, if it need to send messages with different qualities of service.
    service = (Service) ctx.lookup("myService");

    Using the configuration object provided by the configuration process and the previously created protocol, instances of data and control sessions can now be created. A data session will be used to send and receive messages. The control session will be used to join the group and receive notifications concerning the other elements of the group.
    this.control = p.openControlSession(g);
    this.data = p.openDataSession(g);

    The listeners must be set before the application starts using the group communication toolkit.
    data.setMessageListener(this);
    control.setControlListener(this);
    if (control instanceof MembershipSession)
        ((MembershipSession) control).setMembershipListener(this);
    if (control instanceof BlockSession)
        ((BlockSession) control).setBlockListener(this);
}
```

The first object to lookup is the protocol factory. This object represents the toolkit that will be used by this application.

A protocol can now be created. This object represents an instance of the toolkit that will be used for group communication.

The application must also lookup a GroupConfiguration object that represents a configuration of the group communication.

A service object is needed to send messages. The application may use different services for different messages, if it need to send messages with different qualities of service.

Using the configuration object provided by the configuration process and the previously created protocol, instances of data and control sessions can now be created. A data session will be used to send and receive messages. The control session will be used to join the group and receive notifications concerning the other elements of the group.

The listeners must be set before the application starts using the group communication toolkit.
This method will run after the creation of the class. At this point, all the necessary objects were already retrieved from the lookup service. The application joins the group, sends some messages and finally leaves the group.

```java
public void run() {
    try {
        control.join();
        for (int i = 0; i < NUM_MESSAGES; i++) {
            Thread.sleep(1000);
            Message message = data.createMessage();
            message.setPayload("hello\r\nworld!").getBytes());
            data.multicast(message, service, null);
        }
        Thread.sleep(5000);
        control.leave();
        data.close();
    } catch (Exception e) {
        e.printStackTrace();
    }
}
```

A new message object must be created using the data session.

```java
Message message = data.createMessage();
message.setPayload("hello\r\nworld!").getBytes());
```

The message is sent to the group using the service previously retrieved from the lookup service.

```java
data.multicast(message, service, null);
Thread.sleep(5000);
```

All resources should be freed in the control and data sessions.

```java
control.leave();
data.close();
} catch (Exception e) {
    e.printStackTrace();
}
```

This method represents the message listener. Every time that a message is sent to the group, it is received in this callback by all elements of the group. The application can return an object to identify this particular message in the future, but this feature is not used at the moment. This feature is discussed in other sample.

```java
public Object onMessage(Message msg) {
    System.out.println("Message from " + msg.getSenderAddress() +": " + new String(msg.getPayload()));
    return null;
}
```

These call backs are used to notify the application that some member has joined, left or failed. This is not necessary if the application is using a Membership or Block sessions.

```java
public void onJoin(SocketAddress peer) {
    System.out.println("--JOIN: " + peer);
}
public void onLeave(SocketAddress peer) {
    System.out.println("--LEAVE: " + peer);
}
public void onFailed(SocketAddress peer) {
    System.out.println("--FAILED: " + peer);
}
```

This notification is issued every time that the group membership changes. It is only used if the membership extensions were implemented and may be used instead of the previous call backs. The new membership may be retrieved from the membership session.
public void onMembershipChange()
{
  try
  {
    System.out.println("-- NEW MEMBERSHIP: " +
    ((MembershipSession) control).getMembership());
  } catch (NotJoinedException e) {
    e.printStackTrace();
    data.close();
  }
}

This call back notifies the application that the group will block and a new membership will be received. The application must flush any pending messages at this time and call the blockOk method from the control session. The membership will not be received if the application do not call this method.

public void onBlock()
{
  try
  {
    ((BlockSession) control).blockOk();
  } catch (JGCSException e) {
    e.printStackTrace();
  }
}

This call back is used to notify the application that it was removed from the group.

public void onExcluded()
{
  System.out.println("-- REMOVED from group.");
}

public static void main(String[] args) {
  try
  {
    Context x = new InitialContext();
    Runnable test = new JNDITest(x);
    test.run();
  } catch (Exception e) {
    e.printStackTrace();
  }
}

5.2 Early deliveries

This sample shows how to send and receive messages using a toolkit that was configured to make early deliveries and service notifications.

The sample uses extended virtual synchrony and implements all the listeners used to receive messages, exceptions and membership notifications.

```java
public class EarlyDeliveryTest implements MembershipListener, ServiceListener, Runnable {
    private static final int NUM_MESSAGES=10;
    private ControlSession control;
    private DataSession data;
    private Context ctx;
    private Service uniformService;

    public EarlyDeliveryTest(Context x) throws JGCSException, NamingException {
        this.ctx=x;
        ProtocolFactory pf = (ProtocolFactory) x.lookup("myProto");
        Protocol p = pf.createProtocol();
        GroupConfiguration g = (GroupConfiguration) x.lookup("myGroup");
        uniformService = (Service) ctx.lookup("myService");
        this.control = p.openControlSession(g);
        this.data = p.openDataSession(g);
        data.setMessageListener(this);
        data.setServiceListener(this);
        if (control instanceof MembershipSession)
            ((MembershipSession) control).setMembershipListener(this);
    }

    public void run() {
        try {
            control.join();
            for (int i = 0; i < NUM_MESSAGES; i++) {
                Thread.sleep(1000);
                Message message = data.createMessage();
                message.setPayload("hello world!").getBytes();
                data.multicast(message, uniformService, null);
            }
            Thread.sleep(5000);
            control.leave();
            data.close();
        } catch (Exception e) {
            e.printStackTrace();
        }
    }
}
```

This method represents the message listener. Every time that a message is sent to the group, it is received in this callback by all elements of the group. In this example, the application assumes that the group communication was configured to make early deliveries of messages. This means that the message payload is delivered before the requested service is ensured. In this example, the application may process the message but will not show that message until the required service is received.
Note that the processing of these messages is not complex (in this example) but some applications can have complex processing based on the message contents, that can be done before printing results to the user or writing results to physical storage.

```java
public Object onMessage(Message msg) {
    String messageToPrint = "Message from " + msg.getSenderAddress() + "=" + new String(msg.getPayload());
    return messageToPrint;
}
```

This method represents the service listener. For each message, several services can be provided. These services have an order relation. This example only prints the messages that have already the uniform property.

```java
public void onServiceEnsured(Object context, Service service) { 
    try {
        if (service.compare(uniformService) >= 0) {
            String messageToPrint = (String) context;
            System.out.println(messageToPrint);
        }
    } catch (UnsupportedServiceException e) {
        e.printStackTrace();
    }
}
```

```java
public void onMembershipChange() { 
    try {
        System.out.println("-- NEW MEMBERSHIP: " + ((MembershipSession) control).getMembership());
    } catch (NotJoinedException e) {
        e.printStackTrace();
        data.close();
    }
}
```

```java
public void onExcluded() {
    System.out.println("-- REMOVED from group.");
}
```

```java
public static void main(String[] args) { 
    try {
        Context x = new InitialContext();
        Runnable test = new EarlyDeliveryTest(x);
        test.run();
    } catch (Exception e) {
        e.printStackTrace();
    }
}
```
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