Java^{TM}2 Enterprise Edition

J2EE^{TM} Activity Service Specification

JSR095

Specification Lead:
Ian Robinson
IBM Corp.

Technical comments:
jsr-95-comments@jcp.org

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1.0 Introduction

As the J2EE environment matures, increasingly complex business applications are placing greater demands on the container/server middleware to support more sophisticated transactional semantics than the short-lived ACID transactions provided by the Java Transaction Service (JTS)[1]. For example web service applications deployed into a J2EE environment are typically composed of loosely coupled interactions for which it may be necessary to relax the isolation characteristics of a transaction without completely sacrificing atomicity. This requires a different sort of transaction from a JTA transaction, perhaps extending over a more significant period of time and involving participants that require compensation to deliver atomicity. Many strategies are available for dealing with extended transactions, some appropriate for one type of application and some appropriate for another. But there is no single extended transaction model that will satisfy all types of application; what is required is a middleware framework that can be exploited by arbitrary, specific extended transaction models. The OMG Activity service[2]specifies such a framework for CORBA-based middleware. This document describes the system design and interfaces for a J2EE Activity service that is the realization, within the J2EE programming model, of the OMG Activity service.

The purpose of the Activity service is to provide a middleware framework on which extended Unit of Work (UOW) models can be constructed. An extended UOW model might simply provide a means for grouping a related set of tasks that have no transactional properties or it may provide services for a long-running business activity that consists of a number of short-duration ACID transactions. The Activity service is deliberately non-prescriptive in the types of UOW models it supports. The advantage of structuring business processes as activities with looser semantics than ACID transactions, for example by modeling a business process as a series of short-duration ACID transactions within a longer-lived activity, is that the business process may acquire and hold resource locks only for the duration of the ACID transaction rather than the entire duration of the long-running activity. In a widely distributed business process, perhaps involving web-based user interactions and cross-enterprise boundaries, it is neither practical nor scalable to hold resource locks for extended periods of time. A typical problem with extended UOW models is that the failure scenarios may be quite complex, potentially involving the compensation of some or all of the ACID transactions that were committed before a long-running activity failed. The responsibility for providing the appropriate recovery from such a failure may be shared between the application itself, which is the component that understands *what* needs to be compensated, and the extended unit of work service provider, which might provide facilities to register compensating actions.

The Activity service provides a generic middleware framework on which many types of extended transaction and other unit of work, models can be built.

1. Java Transaction Service, V1.0, *Sun Microsystems Inc.*
2. Additional Structuring Mechanisms for the OTS Specification - *OMG document orbos/2001-11-08 (http://www.omg.org/cgi-bin/doc?orbos/2001-11-08.).*

1.1 Scope

This document and related javadoc describes the architecture of the J2EE Activity service and defines the function and interfaces that must be provided by an implementation of the J2EE Activity service in order to support high-level services constructed on top of this. Such high-level services provide the specific extended transaction model behavior required by the application component.

Specific high-level services and extended transaction models that use the Activity service are beyond the scope of this specification and should be introduced into J2EE via separate JSRs.

This specification concerns itself with the rendering of the OMG Activity service[2] into the J2EE architecture. Interoperability of Activities distributed across heterogeneous implementation domains is ensured by requiring the construction of interoperable Activity service contexts, defined in the org.omg.CosActivity package and described in detail in [2]. Specific requirements for interoperability are described in this specification in "Interoperability" on page 50. The basis for such interoperability is an Activity service context defined in IDL which is wholly appropriate for propagation over IIOP. It is envisioned that alternative schema (for example, XML-based) and bindings will be defined for Activity service context appropriate for its propagation over protocols other than IIOP (for example SOAP/HTTP), and work is in progress to this end, but this is beyond the scope of this specification.

Note that the term *extended transaction model* does not necessarily imply the involvement of any ACID transactions, although it may. Throughout the remainder of this specification, the term *transaction*, if unqualified, will be used to refer to a JTS[1] transaction which is typically accessed via JTA[3] in J2EE.

1.2 Target Audience

The target audience of this specification includes:

- providers of high-level services that offer extended transaction behavior.
- implementors of application servers and EJB containers.
- implementors of transaction managers, such as a JTS.

3. Java Transaction API, V1.0.1, *Sun Microsystems Inc.*

1.3 Organization

This document describes the architecture of the Activity service as it relates to the J2EE server environment. The different roles of the components of the service are described, particularly with respect to higher-level services that are built on top of the Activity service. Specific Activity service interfaces are described in general terms in this document and in more detail in the accompanying javadoc packages.

1.4 Document Convention

A regular Times New Roman font is used for describing the Activity service architecture.

A regular Courier font is used when referencing Java interfaces and methods on those interfaces.

1.5 J2EE Activity Service Expert Group

Ian Robinson, IBM (specification lead)
Alex Mulholland, IBM
Orest Halustchak, Autodesk Inc.
Ram Jeyaraman, Sun Microsystems Inc.
Mark Little, Individual member
Priyank Rastogi, Pramati Technologies
Eric Newcomer, IONA Technologies
Pyounguk Cho, IONA Technologies
Phil Quinlan, Bank of America
Satish Viswanathan, iPlanet
Roman Kishchenko, SilverStream Software Inc.
Riad Mohammed , Intalio Inc.

1.6 Acknowledgements

In addition to the members of the expert group, Neil Mallam and Thomas Mikalsen, of IBM, have provided invaluable contributions to this specification.

2.0 Overview

A long-running business transaction may be represented as an application activity, A_0, which is split into many different, coordinated, short-duration activities. This is illustrated below in Figure 1. A_1 and A_2 are Activities (represented by broken ellipses) containing JTA transactions (represented by solid ellipses) T_1 and T_2; A_3 and A_4 do not use JTA transactions at all. In this example A_2 and A_3 are executed concurrently after A_1.

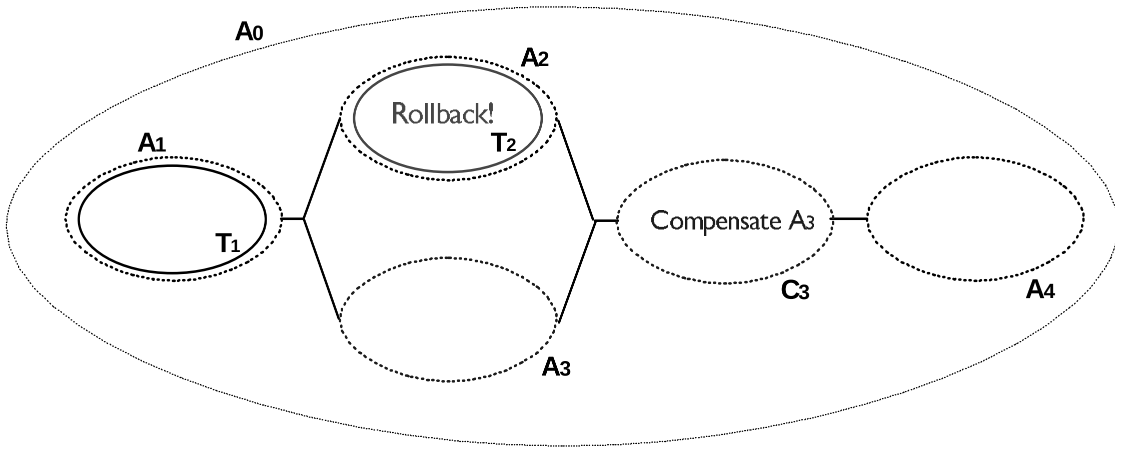

FIGURE 1 **A long-running application activity**

The reason for structuring the application activity as a *logical long-running transaction* rather than as a single top-level transactions is to prevent certain acquired resources from being held for the entire duration of the application. It is assumed that the application's implementors have segmented the transactional activities within the application into smaller transactional and non-transactional activities, each transaction being responsible for acquiring (and releasing) only those resources it requires. However, if failures and concurrent access occur during the lifetime of these activities then the behavior of the entire *logical long-running business transaction* may not possess ACID properties. Therefore, some form of (application specific) compensation may be required to attempt to return the state of the system to (application specific) consistency.

2.1 Scenarios

2.1.1 Fund transfer scenario

This example is a simple money transfer between two accounts, (a source account which is debited and a target account which is credited). It is not desirable to perform the transfer within the scope of a single JTA transaction. (There are many possible reasons for this, including, the accounting systems run on separate, remote legacy systems, the remote systems are high volume transaction processing environments which cannot tolerate the resource locking overhead of a single distributed transaction, one or both accounts are with an external organization which prohibits foreign transactions….).

The customer selects a source account, a target account, and an amount to transfer. The customer submits the request. The first activity is to check for a sufficient account balance in the source account. This is non-transactional. The next activity is a debit from the source account (transactional). It completes successfully. Next, a credit to the target account for the requested amount is attempted. The credit fails and rollback takes place. The prior debit has already been committed so a compensating credit transaction is performed. Forward progress continues with an activity to update the customer history with a summary of the customer interaction.

Note: It could be possible to have the debit and credit activities occur concurrently.

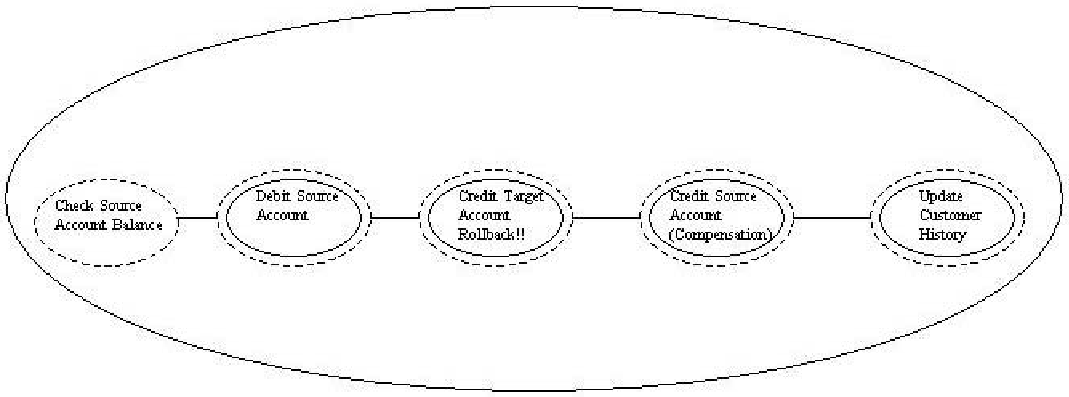
Check Source Account Balance
Debit Source Account
Credit Target Account Rollback!!
Credit Source Account (Compensation)
Update Customer History

FIGURE 2 **Fund transfer activity**

2.1.2 Travel Scenario

A travel agency implements a booking system as a long running application activity. The travel agency provides booking for air, rail, bus, rental car, hotel, etc. In this scenario, a client wants to book travel from Boston to Cambridge, England.

In the first step, the client wants to book a flight from Boston to London Heathrow and then rail from Heathrow to Cambridge. The client is presented with options for departing Boston on July 19, arriving at Heathrow July 20. Rail options are provided for departing July 20 and arriving later that day. The travel agent needs to use two independent systems for booking these two, the airline reservation system for the flight and the separate rail system for the rail trip.

The client chooses options for the airline and rail. The agent's system then starts two parallel reservation activities, one with the rail system and the other with the airline reservation system. The two systems require complete control over their own resources and operational policies of these systems dictate that ownership of their resources cannot be delegated to a foreign transaction. Thus, even though both the flight and rail reservation systems may run within their own JTA transactions, it is not permitted or desirable to scope both systems within a single JTA transaction originated from the agent. Instead, the separate transactions in the two systems are components of a greater reservation activity. In this particular case, the rail reservation system completes first. However, the airline reservation fails because seats cannot be found for the price that the user wanted and the airline transaction is rolled back.

The client then proceeds to pick a different flight that goes to London Gatwick instead. From that location, the client decides to take a bus instead of train.

The first airline reservation transaction was rolled back by the airline reservation system. For the rail reservation, the travel agent applies a compensating activity that cancels the rail reservation. At that point, the agent's system submits two new parallel activities, one to book the new airline reservation (a JTA transaction again) and the other to book the bus tickets. These succeed and the overall reservation activity completes.

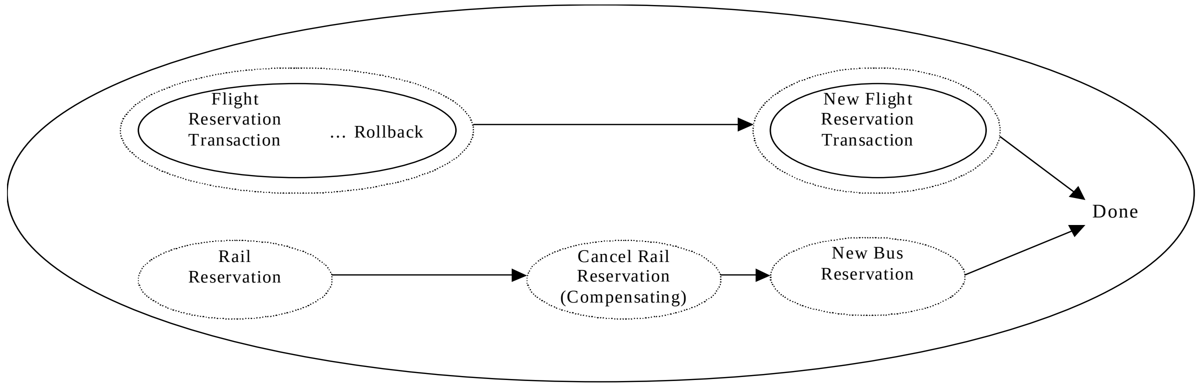
Flight Reservation Transaction
... Rollback
New Flight Reservation Transaction
Done
Rail Reservation
Cancel Rail Reservation (Compensating)
New Bus Reservation

FIGURE 3 **Long-running reservation activity**

2.1.3 Engineering Design Scenario

Collaborative design can involve designers from different disciplines working together on a common design, but each responsible for a different aspect of the design.

This engineering design scenario involves designing a new suburban subdivision in a city. It includes designing land parcels, roads, water/sewer services, and electrical services. This city uses a centralized database system that includes the current infrastructure for all land parcels, roads, and facilities. The single database includes data about the current state of land and facilities in the city as well as all design data. This is accomplished by treating the design changes as long running units of work and implementing the High Level Service using a versioning mechanism (similar to Appendix A.1). The current state is represented with an “as-built” version of the data and each design activity is captured within its own version space. This example shows a “long running” transaction where “long” really is a long period of time – could be months.

First, the project manager begins the long running unit of work in the database as a new project and assigns the design of the land parcels to the land department. The land department designers create the first transaction for the design. A single designer implements the design using a land design product. That design is then inserted into the centralized database as a transaction that captures that change in a new “land design” version space. Then the project manager assigns design of water/sewer to an engineer in the water department and the electrical to an electrical engineer. The water/sewer designer uses a CAD system that runs directly against the database. Their design can view the land design and adds the water/sewer design to the database in a water/sewer version space. Similarly, the electrical engineer adds their design.

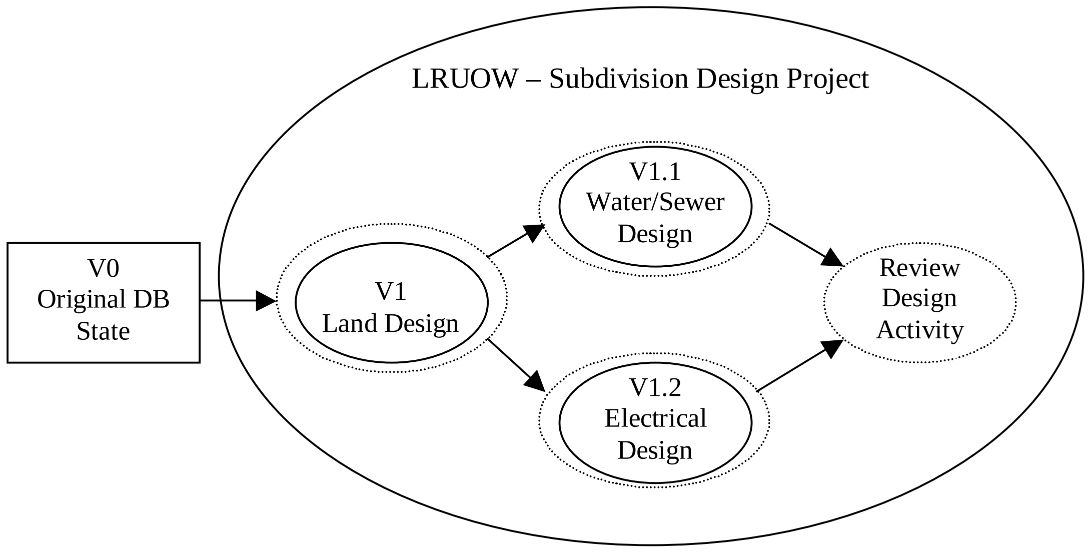

FIGURE 4 Long-Running Unit of Work Scenario

At this point, a separate city engineer reviews the design and determines that a change is needed to the land design. The reviewers were very busy and didn't get around to reviewing the design until a month later at which time the other engineers had produced their designs. At this point the water/sewer and electrical designs need to be removed and a compensating transaction applied to the land design. Then the water/sewer and electrical engineers redo their designs. This is accomplished by first applying compensating transactions against the water/sewer and electrical work by removing those versions of data.

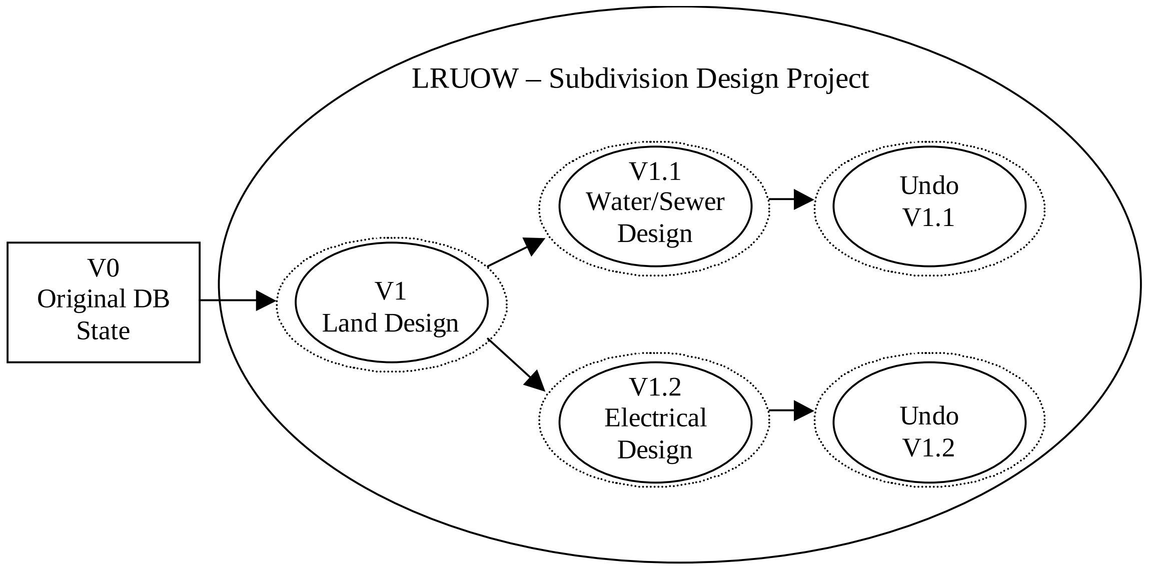

FIGURE 5 LRUOW Scenario - Undo Intermediate Versions

Then, a new transaction makes the change to the land design, which is reviewed immediately.

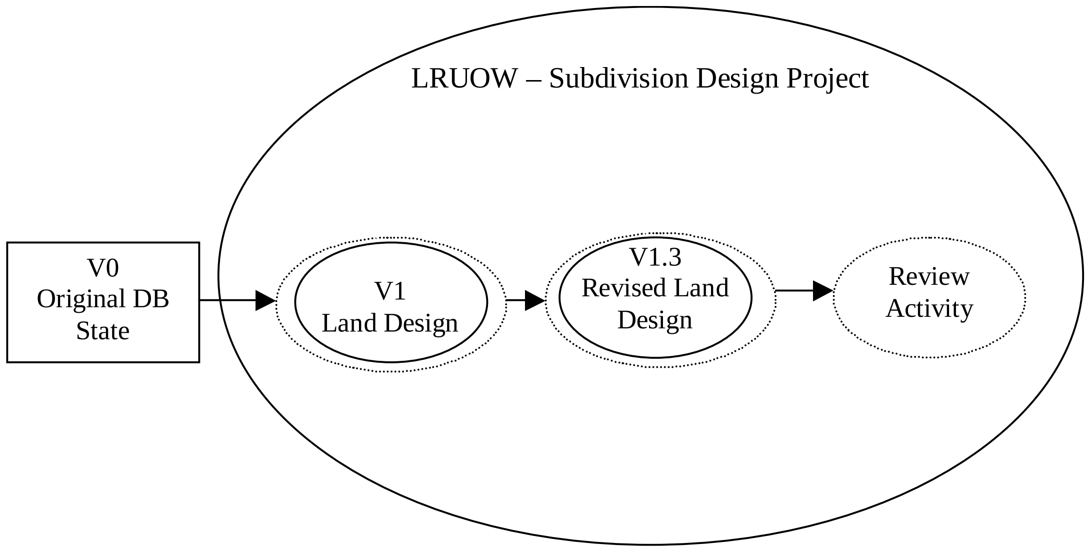

FIGURE 6 LRUOW Scenario - Create New Intermediate Version

Next, the water/sewer and electrical designers redo their design work. Then, the work is carried out in the field where the new subdivision is built.

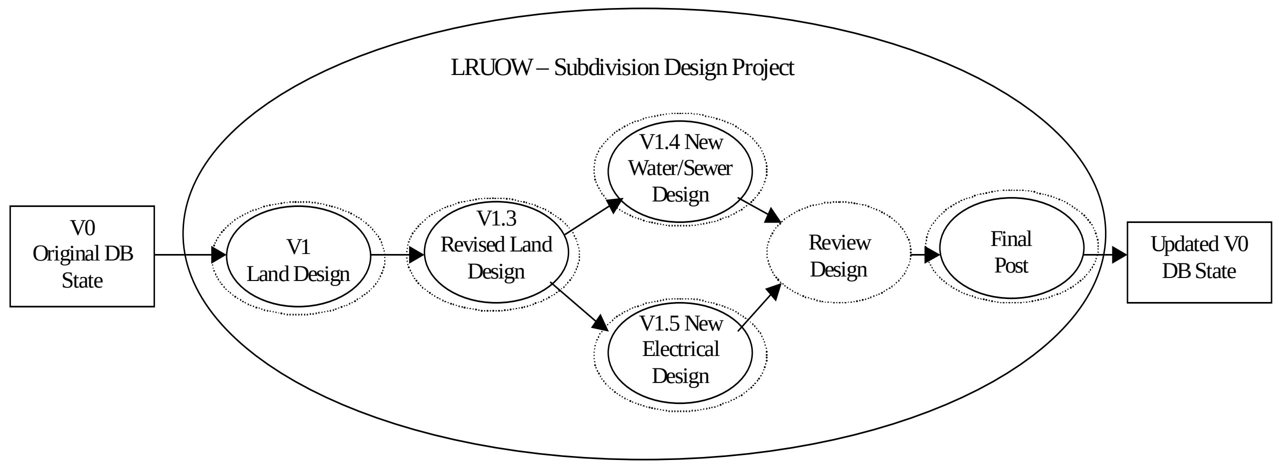

FIGURE 7 **LRUOW Scenario - Further Versions are created**

Finally, this long running unit of work is done and the versions of data in this long running transaction replace the “as-built” versions in the database using a transaction called “final post”. This commits the long running transaction.

2.1.4 Billing and accounting scenarios

Billing and accounting resource usage typically involve a billing activity being started as a result of a service being undertaken; the billing activity completes when the billable service complete and is logically a nested activity but might need to complete positively regardless of whether the service that started the billing activity completes successfully or not.

2.1.5 Arranging a meeting:

The requirement is to arrange a date for a meeting between a group of people; it is assumed that each user has a personal diary object which records the dates of meetings etc., and each diary entry (slot) can be locked separately. The application starts by informing people of a forthcoming meeting and then receiving from each a set of preferred dates. Once this information has been gathered, it will be analyzed to find the set of acceptable dates for the meeting. This set is then broadcast to the users to get a more definitive idea of the preferred date(s). This process is repeated until a single date is determined. To reduce the amount of work which must be re-performed in the event of failures, and to increase the concurrency within the application, it would be desirable to execute each "round" of this protocol as a separate top-level transaction. However, to prevent concurrent arrangement activities from conflicting with each other, it would be beneficial to allow locks acquired on preferred diary entries to be passed from one transaction to another, i.e., the locks remain acquired on only those entries which are required for the next "round".

2.2 The Need for a Framework

There are several ways in which some or all of the application requirements outlined above could be met. However, it is unrealistic to believe that a single high-level model approach to extended transactions is likely to be sufficient for all (or even the majority of) applications. Therefore, the Activity service provides a low-level infrastructure to support the coordination and control of abstract Activities that are given concrete meaning by the high-level services that are implemented on top of the Activity service. These Activities may be transactional, they may use weaker forms of serializability, or they may not be transactional at all; the important point is that the Activity service itself is only concerned with their control and coordination, leaving the semantics of such Activities to the high-level services.

Examples of the types of unit-of-work (UOW) models that may be provided by high-level services that plug into the J2EE Activity service framework include, but are not restricted to, long-running business processes that are transactional only during a final reconciliation phase, sagas with compensation, open nested transactions, workflows, strict two-phase OTS and nested transactions. Specific examples of high-level services that exploit the Activity service architecture are described in Appendix A, “Specific HLS examples” on page 56, and in the OMG Activity service specification[1]. The qualities of service offered by a specific UOW model, and any application architecture considerations that are implied by that model, are factored in the external description of the high-level service and, as such, are beyond the scope of this specification.

2.3 Components of an Activity

An Activity is a unit of (distributed) work that may or may not be transactional. During its lifetime an Activity may have transactional and non-transactional periods. Every entity including other Activities can be part of an Activity, although an Activity need not be composed of other activities. An Activity is characterized by an application-demarcated context under which a distributed application executes. This context is implicitly propagated with all requests made in the scope of the Activity and defines the unit of work scope under which any part of an application executes.

An Activity is created, made to run, and then completed to produce an `Outcome`. Demarcation notifications of any kind are communicated to any registered Activity participants (`Actions`) through `Signals` which are produced by `SignalSets`. A specific UOW model defines the set of `Signals` that may be produced during the lifetime of an Activity and the set of `Outcomes` that result. It also defines a discrete set of state transitions that may occur as the `Signals` are consumed by the Activity participants. These state transitions are encapsulated and managed by the `SignalSet`. `Actions` allow an Activity to be independent of the specific work it is required to do in response to broadcasting a `Signal`. For example, if a JTS were to be implemented as a high-level service (HLS) on top of the Activity service, the `org.omg.CosTransactions.Resources` would be registered as `Actions` with an interest in a two-phase-commit `SignalSet` which produced *prepare*, *commit*, *rollback*, *commit_one_phase* and *forget* `Signals`.

The purpose of the J2EE Activity service specification is to define the roles and responsibilities of the components of such a service implementation in a J2EE server environment and, where appropriate, the J2EE client environment. In particular this specification defines the interfaces and behavior of an Activity service such that vendors may implement high-level services that use these interfaces to provide the desired extended transaction, or other unit of work, models. The details of specific high-level service behavior and the interfaces between such services and the business applications that use them are beyond the scope of this specification.

3.0 J2EE Activity Service Architecture

The architecture for a high-level service (HLS) providing an extended UOW model and using the facilities of the J2EE Activity service is shown in Figure 8.

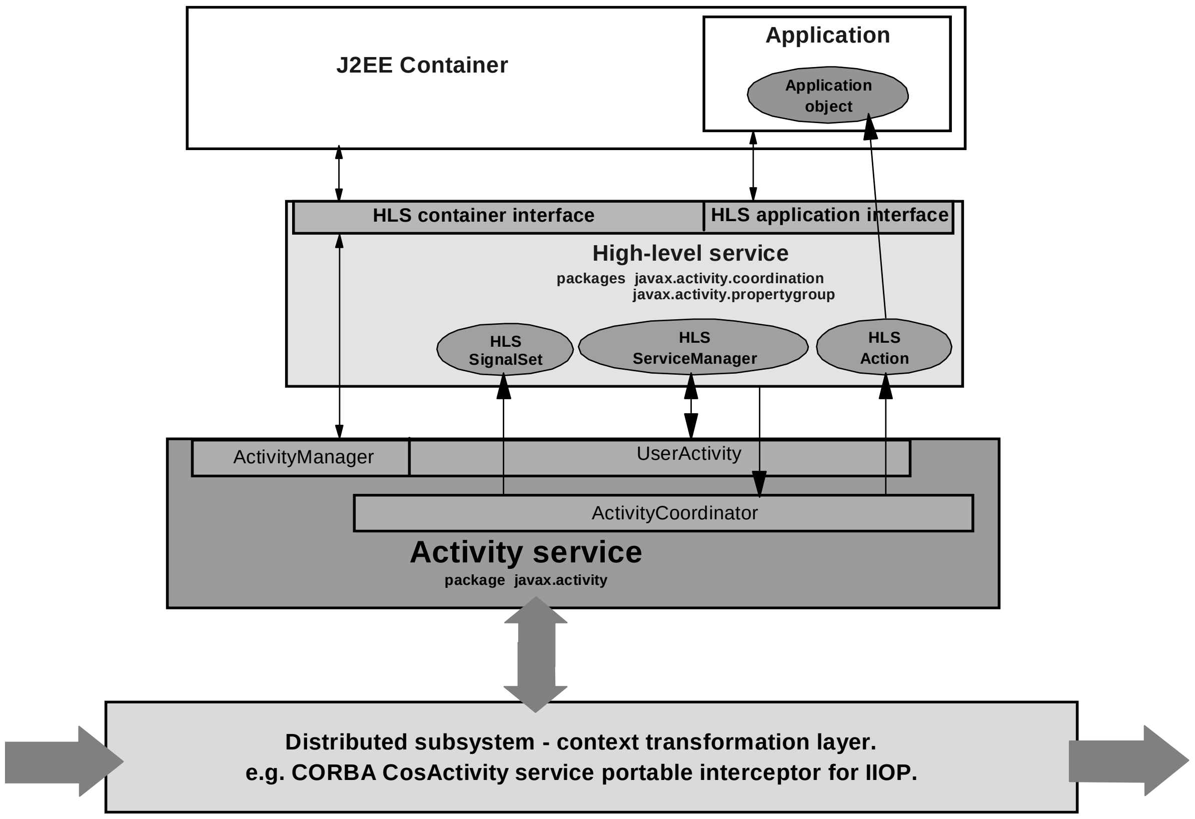

FIGURE 8 **Activity and high-level service architecture**

The architecture is partitioned into the following main components:

Application and container -- the application is designed to participate in a specific type of extended UOW model and uses, either directly or through the container, the facilities provided by the HLS to control the units of activity supported by the HLS. If the HLS provided a compensating extended transaction model, for example, in which a long-running transaction is composed of a sequence of ACID transactions that may need to be compensated following a failure, then the application component would be expected to provide the compensation data that the HLS would drive at the appropriate time. The application component does not call the Activity service directly, but interacts with the Activity service through the HLS. The application component is external to the Activity service and is beyond the scope of this specification.

High-level service (HLS) -- the HLS defines the behavior of a specific extended UOW model and offers interfaces to the application that uses it, as well as the application server and container. The HLS delegates to the Activity service to manage its distributed context and relationships between this context and any JTS context. It uses the Activity service as the means by which signals pertaining to the HLS are distributed to participants in an HLS unit of work. In particular, the HLS provides implementations of the `javax.activity.coordination` interfaces and optionally the `javax.activity.propertygroup` interfaces.
This component is external to the Activity service and is beyond the scope of this specification.

Activity service -- the Activity service manages the HLS's service context, both with respect to other Activity contexts and with respect to JTS context, ensuring its appropriate implicit propagation with remote requests. It provides interfaces to a HLS that support context demarcation and pluggable coordination of HLS-specific objects. The Activity service provides implementations of the classes and interfaces of the `javax.activity` package. This specification is primarily concerned with this component.

Distributed subsystem -- Activity service context may be distributed across execution domains and potentially between different J2EE providers, and indeed application server architectures. The means by which that context is distributed is dependent on the coupling between the domains. For example, the OMG Activity service defines the interoperable distribution of Activity service contexts over IIOP; the context transformation for distribution over IIOP is provided by an OMG Activity service portable interceptor[4].

This component division is intended to be illustrative rather than prescriptive. For example, a container may provide the function of a high-level service.

4. Interceptors Published Draft with CORBA 2.4+ Core Chapters - *OMG document ptc/2001-03-04*

4.0 Elements of the Activity service

4.1 Features

The features provided by the J2EE Activity service to support the implementation of extended transaction models as high-level activity services are described in this section.

4.1.1 Pluggable transaction models

The primary purpose of the Activity service is to provide a means to integrate a wide variety of extended transaction services with the J2EE Application server in such a ways that:

- the extended services can be managed by the application server without the application server needing to understand the details of each service.
- the extended services can be implemented to be portable from one application server to another. The portability of applications that use the extended services will be ensured by the provision of portable extended services.

The embodiment of an extended transaction service in the J2EE Activity service architecture is the *High Level Service (HLS)*. This can be thought of as similar in some respects to a resource adapter in the Java Connector Architecture[5] - it is a service-provider component that plugs into the application server and offers, to applications, service-specific interfaces that are mediated by the application server through specific interactions between the HLS and the application server. An HLS implements the interfaces of the javax.activity.coordination package; it must implement the `ServiceManager` interface and may also implement the `SignalSet` and `Action` interfaces as well as the `javax.activity.propertygroup` interfaces. Where this document describes function as being provided *by an HLS*, it implies that such function is provided by the HLS `SignalSet`, `Action` or `ServiceManager` implementation, or some other HLS-internal object, without being specific about which object.

The pluggable HLS architecture is illustrated in Figure 9.

5. J2EE Connector Architecture, V1.0, *Sun Microsystems Inc*

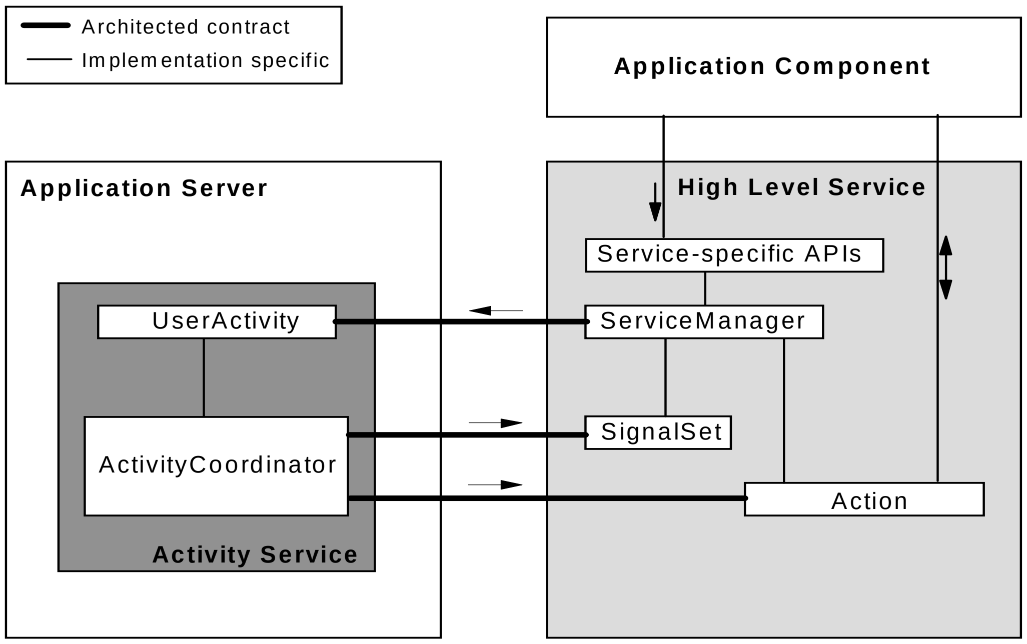

FIGURE 9 **Pluggable HLS architecture**

4.1.2 *Generic coordination*

The coordination of HLS-specific participants by the distribution of HLS-specific messages is a responsibility that is shared between the HLS and the Activity service. The Activity service provides the framework for sending generic `Signals` (messages) to `Actions` (Activity participants), where both `Signals` and `Actions` are given meaning by and implemented by the high-level service that uses the Activity service. The HLS provides a `SignalSet` object that is responsible for producing the `Signals`; the `SignalSet` is obtained from a `ServiceManager`, supplied by the HLS, and is *plugged into* the Activity service `ActivityCoordinator` which drives the `SignalSet`, at the appropriate time, to produce `Signals` and distributes the `Signals` to these `Actions` that have registered an interest. The `ActivityCoordinator` places no semantic meaning on the `Signals` but manages the relationship with registered `Actions` and returns the `Outcomes` received from those `Actions` to the `SignalSet`. The `SignalSet` is a finite state machine that produces `Signals` based on the managed state and accepts `Outcomes` to those `Signals` to influence state transitions. The specific semantics of a HLS are then encapsulated by the `SignalSet` and `Actions` provided by the HLS and the `Signals` and `Outcomes` used by the HLS objects, while the generic management and distribution of the resources of the HLS are provided by the Activity service.

Figure 10 shows the relationship between the `ServiceManager`, `SignalSet`, and `Actions` provided by the HLS, the `Signals` and `Outcomes` used by the HLS objects and the `ActivityCoordinator`.

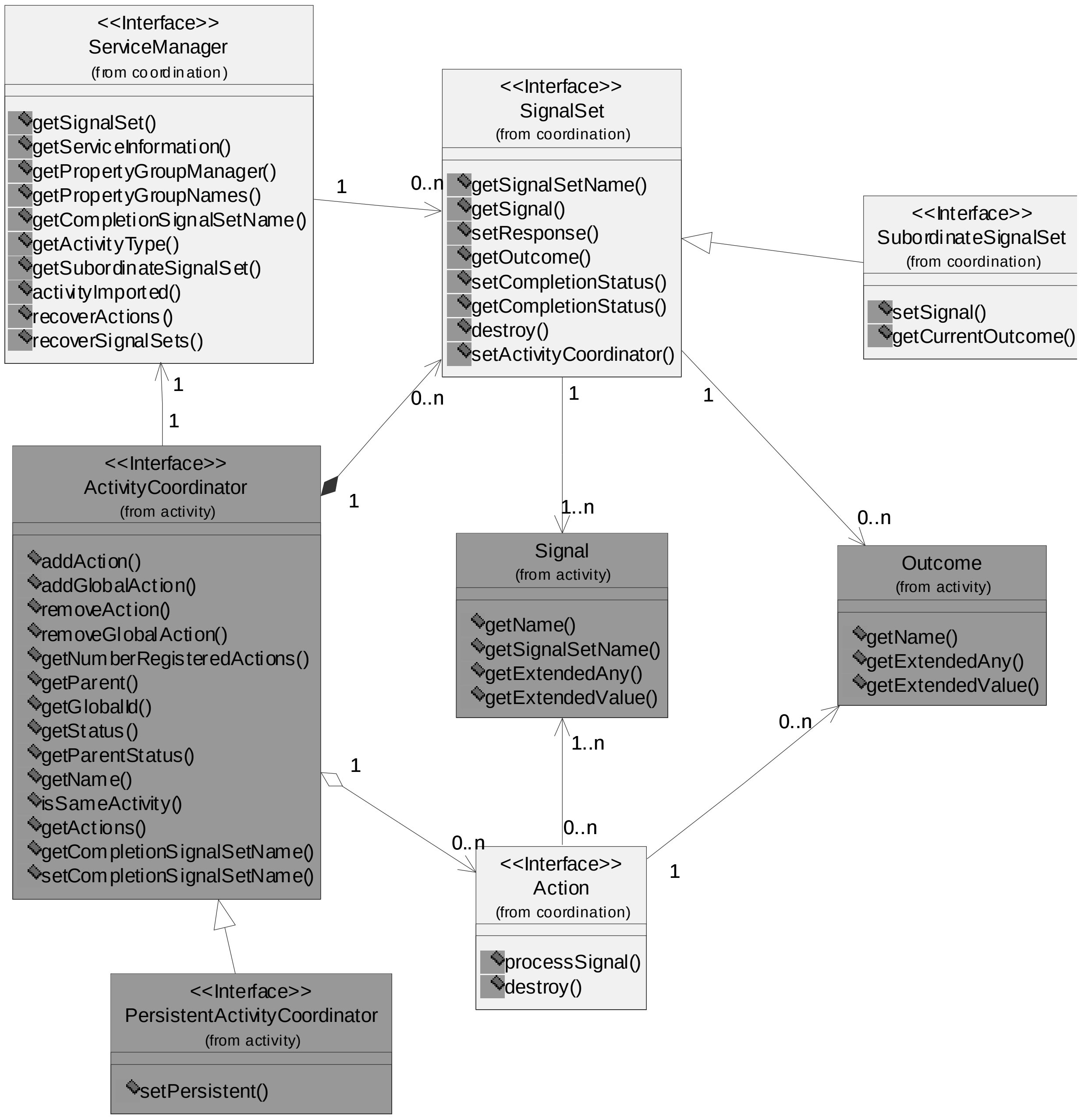

FIGURE 10 **Generic coordination using a pluggable SignalSet provided by the ServiceManager**

4.1.3 Grouping and management of context

Each Activity started by a HLS may be a child of an Activity already running on the thread; such child activities are wholly encapsulated by their parent Activity. An Activity may encapsulate a JTA transaction and may be encapsulated by a JTA transaction. Context hierarchies of Activity and transaction contexts may be created in one execution environment (application server) and propagated via Activity service context to another. The Activity service provides `UserActivity` and `ActivityManager` interfaces to enable a HLS and an EJB container to manage these context hierarchies; the `UserActivity` interface provides simple demarcation methods to begin and complete Activities while the `ActivityManager` interface provides more complex context management functions, such as `suspend` and `resume`. The Activity service hides the complexity of the context hierarchies by enabling the caller of these methods to operate only on the most recent context (the *active* or *current* context) belonging to a particular HLS.

Activities started by different HLS's on the same thread may be wholly unrelated, in which case it would be inappropriate for their contexts to form parent-child relationships and to be cooperatively managed. On the other hand distinct, specific HLS's may wish to have their Activity contexts cooperatively managed with one or more other distinct, specific HLS's and with JTA transaction contexts. *Context groups* are supported by the Activity service for this purpose such that a HLS may specify, through its ServiceManager, which *context group* its Activities participate in.

All Activity contexts within a particular *context group* are strictly nested with respect to one another but are independent of Activity contexts in any other *context group*. A *context group* is identified by a `String` name; an HLS that wishes to have its contexts managed independently of any other HLS can specify the package name of the HLS as the name of the *context group* it wishes to participate in.

A *default* context group is provided, identified by an empty `String`, which must be used by any HLS that wishes to have its Activity contexts managed cooperatively with JTA context. This default context group provides nesting behavior compatible with that described in the OMG Activity service.

Consider, as an example, two high level services, HLS_a and HLS_b. HLS_a offers a unit of work (UOW) scope that consists of an Activity that implicitly starts a JTA transaction. HLS_b offers a UOW scope that is used to control execution parameters determine by context specific to the client instance. An application may consist of components that use either or both of the contexts of HLS_a and HLS_b. While HLS_a contexts must be strictly managed with respect to JTA contexts, HLS_b contexts are wholly independent of HLS_a contexts and are not be affected by them.

If the JTA support is provided by a JTS implementation, then it is JTS contexts that are managed cooperatively with Activity contexts. A JTA provider does not have to use a JTS implementation but is required to represent the transaction context as a JTS context for remote interoperation.

4.1.4 Activity lifecycle

An Activity is started and ended by operations on the UserActivity interface and is represented by an ActivityCoordinator instance (for each application server environment that the Activity is distributed across). Activities may be nested within one another in context groups, as described in “Grouping and management of context” on page 20, with the constraint that a child Activity must be completed before its parent can be completed. The Activity service must ensure checked behaviour and strict nesting within context groups and restricts where and when an Activity can be completed in order to simplify the processing of the participants in that Activity. Specifically:

- Only the component that started an Activity may request its completion. Any attempt by a component to complete an Activity in an environment different from that in which is was started should receive a NotOriginatorException. The exception to this rule is when heuristic completion is requested in a subordinate, as described in “Heuristic Completion and timeout” on page 33.
- Any attempt to complete a parent Activity in a forward direction while there is an outstanding child should result in a ContextPendingException.
- Any attempt to complete an Activity while outstanding work is in progress for that Activity (for example on an asynchronous thread) should result in an ActivityPendingException.

If an application running under an Activity context is not actively performing work for extended periods of time, the application’s container may direct the Activity, through the `ActivityManager` interface, to `hibernate` and then `reactivate` it later when further work is received for that Activity. Hibernating an Activity suspends the Activity from the thread and permits the passivation of Activity resources from active memory to passive storage. Reactivating the Activity resumes the Activity on the thread and returns it to active memory. The hibernation of an Activity does not impact whether or not the Activity is persistent, merely whether or not the Activity is required to be loaded into active memory.

4.1.5 Distributed service context

The behavior of distributed components running under an Activity context is made location independent by use of an Activity service context that is propagated implicitly on all remote calls. For remote calls over IIOP an Activity service implementation should provide a portable interceptor[4] to enable context from a client to be implicitly propagated and established in a target server environment. Response context from the server is returned to the client by the same mechanism.

The format of the interoperable service context is defined in the OMG Activity service specification[2].

4.1.6 *Distributed application property data*

A distributed Activity may consist of a number of components distributed over a variety of remote servers. Different components within the Activity may share application-specific property data that is scoped to the Activity via `PropertyGroup` context that is a subset of the Activity service context, managed by the application and HLS. The relationship in the `PropertyGroup` data between parent and child Activities is defined by the `PropertyGroupManager`, provided by the HLS.

4.2 Activity service packages

The Activity service specification defines three new `javax` packages, described briefly in this section and in further details in the javadoc that accompanies this specification. The `javax.activity` package contains interfaces and classes provided by the Activity service itself. The `javax.activity.coordination` and `javax.activity.propertygroup` packages contain interfaces that may be implemented by a HLS.

4.2.1 javax.activity *package*

The classes and interfaces of the `javax.activity` package are provided by the Activity service itself. These are summarized in this section and described in full in the accompanying javadoc.

4.2.1.1 *UserActivity*

A `javax.activity.UserActivity` instance is used by each HLS to control demarcation of Activities, through the `begin` and `complete` and `completeWithStatus` methods and to provide access to other Activity service interfaces, such as the `ActivityCoordinator`. An instance of `UserActivity` is obtained, by an HLS, via a JNDI lookup of **`java:comp/UserActivity`**. The HLS must register its `javax.activity.coordination.ServiceManager` implementation with the Activity service, through the `UserActivity.registerService` method, before the `UserActivity` instance may be used to start new Activities. The `ServiceManager` is used by the `UserActivity` to determine specific behavior of Activities it creates, such as the `PropertyGroups` and default completion `SignalSet` they use.

Each Activity started by a `UserActivity` instance logically creates an Activity context to represent a unit of work instance specific to the HLS whose `ServiceManager` is registered with the `UserActivity` instance. Methods of the `UserActivity` interface that operate on the active Activity context are operating on the HLS Activity context most recently associated with the calling thread. In practise, the objects that represent an Activity, such as the ActivityContext and the ActivityCoordinator, may be lazily created as required during the lifetime of the Activity.

4.2.1.2 ActivityManager

A `javax.activity.ActivityManager` instance is used by a HLS or EJB container for advanced context management of Activities, such as `suspend` and `resume.` These operations are typically executed as a result of a container policy defined by a HLS. An HLS is responsible for ensuring, through the specification and implementation of its EJB container policies, that the Activity Service context(s) active at the completion of an EJB method are the same as those that were active prior to the method invocation. The ActivityManager interface also supports `hibernate` and `reactivate` operations to support the movement of Activity resources between active and passive storage.

The `ActivityManager` interface is a specialization of `UserActivity,` with which an HLS should register its `ServiceManager`. An instance of `ActivityManager` is obtained via a JNDI lookup of **`services:activity/ActivityManager.`** `ActivityManager` instances are only available in EJB and web container environments, whereas `UserActivity` may be made available through a client container. A container that provide access to the `ActivityManager` may provide a transient binding at the specified **`services:`** URL (which it may re-initialize in-memory each time the container is initialized) but is required to provide access to authorized components, once initialized, regardless of the active J2EE component. For example, a portable interceptor should be able to perform a lookup of this object even in the absence of an active J2EE component.

4.2.1.3 ActivityToken

A `javax.activity.ActivityToken` is used to manipulate hierarchies of Activity and transaction contexts via the `suspend` and `resume` operations of the ActivityManager interface.

ActivityTokens are local to the execution process but may be used on any thread within the execution process.

4.2.1.4 CompletionStatus

The `javax.activity.CompletionStatus` interface defines a finite set of 3 states that an Activity may complete in:

CompletionStatusSuccess -- The Activity has successfully performed its work and can complete accordingly. When in this state, the Activity `CompletionStatus` can be changed.

CompletionStatusFail -- The Activity has not successfully completed its work, either as a result of application failure or simply due to processing that is not yet complete, and should be driven accordingly during completion. When in this state, the Activity

CompletionStatus can be changed. This is the initial CompletionStatus of an Activity.

CompletionStatusFailOnly -- The Activity has not successfully completed its work, as a result of a system or application failure, and should be driven accordingly during completion. When in this state, the Activity CompletionStatus cannot be changed.

4.2.1.5 Status

The javax.activity.Status interface defines a finite set of states that an Activity may progress through during its lifetime.

StatusActive -- There is an active Activity associated with the calling thread.

StatusCompleting -- The Activity associated with the calling thread is completing.

StatusCompleted -- The Activity associated with the calling thread has completed.

StatusNoActivity -- There is no Activity associated with the calling thread.

StatusUnknown -- The Activity service is unable to determine the status of the Activity associated with the calling thread. This is a transient condition.

StatusError -- The Activity service cannot contact the application's signal set to retrieve signals.

StatusCompletingHeuristic -- The Activity associated with the calling thread is completing heuristically.

4.2.1.6 GlobalId

The javax.activity.GlobalId object uniquely identifies an Activity across the namespace.

This object’s equals method returns *true* if the parameter object represents the same Activity as the target object.

4.2.1.7 Signal

Signals are events that are broadcast to interested parties as part of a coordinated SignalSet. Each javax.activity.Signal is uniquely identified by a combination of its SignalName and the name of the containing SignalSet. Signals are produced by javax.activity.coordination.SignalSet objects and consumed by javax.activity.coordination.Action objects.

4.2.1.8 Outcome

A `javax.activity.Outcome` is produced by, and given meaning by, an `Action` which has processed a `Signal` or by a `SignalSet` when it has finished producing `Signals` for a `broadcast` operation or Activity completion. For example, a *completion* `SignalSet` produces the `Outcome` that is returned on the `complete` and `completeWithStatus` methods of the `UserActivity` interface.

4.2.1.9 ActivityCoordinator

The `javax.activity.ActivityCoordinator` is responsible for broadcasting `Signals` to registered `Actions`. The `ActivityCoordinator` obtains the `Signals`, during broadcasting or completion, from `SignalSets` provided by the HLS. It has no logic to understand the `Signals` produced by a `SignalSet` or the meaning of the `Outcomes` produced by `Actions`, it simply mediates between a `SignalSet` and its registered Actions. The only event-processing logic it possesses is to handle `ActionErrorExceptions` or unchecked exceptions from `Actions` by reporting these to the `SignalSet` through the pre-defined `Outcomes` with names "`ActionError`" and "`ActionSystemException`" respectively. The exception is encoded in the specific data of the `Outcome`, retrieved through the `Outcome` object's `getExtendedValue` method.

There is a single logical `ActivityCoordinator` instance per Activity, although in an Activity distributed over several application servers there will be an instance of an `ActivityCoordinator` local to each application server. In such a configuration, the application server on which the Activity is created contains a *root* `ActivityCoordinator` and each application server to which the Activity context is propagated contains an interposed `ActivityCoordinator` which is subordinate to the `ActivityCoordinator` on the server from which the Activity context was propagated. Subordinate `ActivityCoordinators` register an `Action` with their superior `ActivityCoordinator` in order to form a distributed coordination tree. Such an `Action` is registered with an interest in the superior's `SignalSet`(s) for which the local `Actions` on the subordinate have an interest.

This object's `equals` method returns *true* if the parameter object represents the same Activity as the target object.

4.2.1.10 PersistentActivityCoordinator

An Activity service implementation may or may not need to log its own data to support Activity recovery in addition to the requirement that an HLS persist its own recoverable data. This might depend on whether the Activity service creates recoverable, internal objects - for example to support its implementation of interposition - that are not the responsibility of the HLS. For such an Activity service implementation the `ActivityCoordinator` implements the optional `javax.activity.PersistentActivityCoordinator` interface, which provides a `setPersistent` method. When an HLS determines that an Activity needs to be made persistent, it determines whether the

`ActivityCoordinator` is an `instanceof` `PersistentActivityCoordinator` and, if so, calls its `setPersistent` method.

4.2.1.11 ServiceInformation

An instance of a `javax.activity.ServiceInformation` object is associated with each Activity and contains information about the HLS to which the Activity belongs. This information is propagated as part of the `org.omg.CosActivity.ActivityIdentity` structure of the Activity service context, in the `activity_specific_data` field, when the type field of the `ActivityIdentity` indicates a J2EE Activity, as described in “Interoperability” on page 50.

4.2.1.12 ActivityInformation

The `javax.activity.ActivityInformation` class is provided by the Activity service to assist an `Action` that has registered interest with a system `SignalSet` to extract the information from `Signals` produced by that `SignalSet`. `ActivityInformation` objects contain information such as the `GlobalId` of the Activity and are contained in the extended data of system `SignalSets`.

System SignalSets are described in “Predefined Outcomes and SignalSets” on page 29.

4.2.1.13 PropertyGroupContext

The `javax.activity.PropertyGroupContext` utility object is provided by the Activity service to assist a `javax.activity.propertygroup.PropertyGroupManager` read and write `org.omg.CosActivity.PropertyGroupIdentity` context data during marshaling and unmarshaling of the `org.omg.CosActivity.ActivityContext` that incorporates it. Marshaling and unmarshaling occurs at an execution environment boundary when the context needs to be converted to or from the CDR encapsulated form used for remote propagation over IIOP.

4.2.1.14 CoordinationInformation

A `javax.activity.CoordinationInformation` object is produced by a `SignalSet` and used by the `ActivityCoordinator` during signal-processing to determine how to proceed after a response from a particular `Action` has been processed by the `SignalSet`.

4.2.2 javax.activity.coordination *package*

The interfaces of the `javax.activity.coordination` package are implemented by the HLS that uses the Activity service. These are summarized in this section and described in full in the accompanying javadoc.

4.2.2.1 ServiceManager

A `javax.activity.coordination.ServiceManager` is an entity that is provided by a HLS that uses the Activity service; it is a factory for the HLS's objects, such as the `SignalSets` used by the HLS, and also specifies how the HLS's Activities should be managed. In particular, it is used to specify:

- which `PropertyGroups` the HLS uses
- the default *completion* `SignalSet` that is used to complete the HLS's Activities.
- the `ServiceInformation` for the HLS's Activities (which indicates which ContextGroup the HLS participates in). This is propagated as part of the Activity service context.

The Activity service uses the `ServiceManager` when it creates and operates on Activities specific to that service.

A `ServiceManager` implementation must be bound into JNDI by the HLS provider at a location of `services:activity/<service name>` where `<service name>` is the value returned from `ServiceManager.getServiceInformation().getServiceName()`. The Activity service needs to be able to locate a `ServiceManager` implementation from its *ServiceName* when it imports a service context containing a J2EE Activity.

If an imported `ActivityContext` contains Activities of a `type` other than a J2EE Activity, then an administratively configured URL may be obtained by the Activity service and a `ServiceManager` for non-J2EE Activities could be provided, for example to identify appropriate `PropertyGroupManager`(s) for any received `PropertyGroup` contexts. In the absence of such an administratively-configured ServiceManager, an Activity service implementation that receives non-J2EE Activity contexts may either throw an `InvalidActivityException` or may follow the behavior specified in “Behaviour in the case of unknown Activity types, ServiceNames or PropertyGroups” on page 52, using the default context group.

4.2.2.2 SignalSet

A `javax.activity.coordination.SignalSet` is an entity that is provided by a HLS built on top of the Activity service that produces `Signals` and understands the responses to those `Signals`. The `SignalSet` abstracts from the `ActivityCoordinator` the knowledge of which `Signal` should be distributed to the registered `Actions` based on the state of the Activity and responses to previous `Signals`. The Activity service itself then needs to provide only a very generic `ActivityCoordinator` to drive any specific `SignalSet`. The `ActivityCoordinator` simply asks a

`SignalSet` for the next `Signal` and then broadcasts it to each interested `Action` in turn. The response from each `Action` is fed back to the `SignalSet` which has the knowledge of what that result means, which `Signal` should be sent next and whether the `Action` that returned a particular `Outcome` expects to receive further `Signals`.

4.2.2.3 SubordinateSignalSet

If an Activity is distributed across execution domains then each domain will contain a local `ActivityCoordinator`/`SignalSet` pair. The domain in which the Activity is started is the *root*, or *superior*, and the domains to which the Activity is propagated are *subordinate* to the root. The root `SignalSet` produces signals whereas the subordinate `SignalSet` merely redistributes received signals to local `Actions` and reconciles the responses. The `javax.activity.coordination.SubordinateSignalSet` interface extends `SignalSet` by adding a `setSignal` method which the Activity service implementation calls when signals are received from a superior. Although the `SubordinateSignalSet` has no role to produce signals, it may do so as an optimization if it can predict the next signal from its superior - for example a JTS `SignalSet` can be confident of receiving a *rollback* signal after a *VoteRollback* response.

4.2.2.4 Action

A `javax.activity.coordination.Action` is an entity that is provided by the HLS and registered with an interest in one or more `SignalSets`. An `Action` may only be registered with a single `ActivityCoordinator`.

An `Action` is the target object to which a `Signal`, produced by a `SignalSet`, is sent during the `broadcast`, `complete` and `completeWithStatus` operations initiated via `UserActivity`.

4.2.2.5 RecoverableAction

A `javax.activity.coordination.RecoverableAction` encapsulates an Action and the priority it was registered with. This entity is persisted by a HLS once it has performed recoverable work.

4.2.3 javax.activity.propertygroup *package*

The interfaces of the `javax.activity.propertygroup` package may be provided by an HLS that uses the Activity service, although they are all optional. These are summarized in this section and described in full in the accompanying javadoc.

4.2.3.1 PropertyGroup

A `javax.activity.propertygroup.PropertyGroup` is used to provide distributed context, scoped to an Activity, that may be set by an application or a HLS built on top of the Activity service. The format of the distributed context is specific to the `PropertyGroup` implementation and is neither examined nor understood by the Activity service.

The semantics of the behavioral relationship between `PropertyGroups` in nested Activities is defined by the specification of each type of `PropertyGroup` and not by the Activity service. Any number of named `PropertyGroup` types may be configured in a `ServiceManager` and used within an Activity. When an Activity is started, an instance of each type of `PropertyGroup` used by the Activity is created and associated with the Activity.

4.2.3.2 PropertyGroupManager

A `javax.activity.propertygroup.PropertyGroupManager` is an entity that may be provided by a HLS and understands how to create and manipulate a specific type of `PropertyGroup`. It is registered with the Activity service and is used by the Activity service to create `PropertyGroup` instances and to manipulate the `PropertyGroupContext` that is implicitly propagated as part of an Activity context.

For a particular type of `PropertyGroup`, there must be a `PropertyGroupManager` available (from the `ServiceManager`) in each client and server execution environment for which the `PropertyGroup` will be accessed. If `PropertyGroupContext` is propagated, as part of an Activity context, to an environment in which there is no appropriate `PropertyGroupManager` registered, then the `PropertyGroupContext` is not available within that environment although it may be cached by the Activity service and propagated on to any downstream environment to which the Activity context is further distributed.

4.3 Predefined Outcomes and SignalSets

The Activity service provides implementations of the following predefined `Outcomes` and `SignalSets`.

4.3.1 Outcomes

4.3.1.1 ActionError

This pre-defined `Outcome` is created by the `ActivityCoordinator` and returned to a `SignalSet` if the ActivityCoordinator receives an `ActionErrorException` on an `Action.processSignal()` request.

4.3.1.2 ActionSystemException

This pre-defined `Outcome` is created by the `ActivityCoordinator` and returned to a `SignalSet` if the `ActivityCoordinator` receives a system exception on an `Action.processSignal()` request. The received exception is passed back to the `SignalSet` in the extended data of the `Outcome` and can be retrieved via the `getExtendedValue` method. A `SignalSet` may handle this in any way it deems appropriate.

4.3.1.3 preCompletionSuccess, preCompletionFailed

These predefined `Outcomes` may be produced by the predefined *Synchronization* `SignalSet`, as described in 4.3.2.1 “Synchronization”.

4.3.2 SignalSets

4.3.2.1 Synchronization

The *org.omg.CosActivity.Synchronization* `SignalSet` contains the Signals `preCompletion` and `postCompletion`, which are sent to interested `Actions` under the following circumstances:

preCompletion -- sent prior to distributing `Signals` from a completion `SignalSet` if the `CompletionStatus` is *CompletionStatusSuccess.* `Actions` must respond to this signal with a pre-defined Outcome of `preCompletionSuccess` or `preCompletionFailed`.

postCompletion -- sent after all Signals produced by a completion `SignalSet` have been distributed. A `null` Outcome is expected in response to this signal.

No `Outcome` is produced by this `SignalSet`. This `SignalSet` changes the Activity `CompletionStatus` to *CompletionStatusFailOnly* in the event that any `preCompletion` signal receives an Outcome of `preCompletionFailed`, `ActionError` or `ActionSystemException`.

4.3.2.2 ChildLifetime

The *org.omg.CosActivity.ChildLifetime* `SignalSet` contains the signal `childBegin`, which is sent to interested `Actions` under the following circumstances:

childBegin -- sent when a child Activity context is started. This `Signal` is sent after the child Activity and all its `PropertyGroups` have been created, when the child Activity context is the active context on the thread.

No `Outcome` is produced by this `SignalSet`. In the event of any failures being reported back to the `SignalSet` during the processing of the `childBegin` signal, for example as a result of an `ActionErrorException` being raised by any of the registered `Actions`, then the child Activity's `CompletionStatus` is changed to *CompletionStatusFailOnly*. The parent Activity's `CompletionStatus` may or may not be changed as a result of such a failure.

Note: The OMG Activity service specification has an open Issue (#4711), at the time of writing of this draft of the J2EE Activity service specification, regarding the means by which a `childBegin` signal can be distributed in the case where a child Activity is started on a node (JVM) that is not the root node of the parent Activity. A suggested resolution to this issue is that the `childBegin` signal be distributed from the node in which the child Activity is started. Actions registered with the parent's upstream superior ActivityCoordinator are not then informed of these events.

4.3.2.3 Failure

The *org.omg.CosActivity.Failure* `SignalSet` contains the signals `initialFailure` and `finalFailure`, which are sent to `Actions` in the event that a remote `SignalSet`, in which the `Actions` have an interest, cannot be reached during signaling. All `Action` implementations must be prepared to handle these signals and respond appropriately.

initialFailure -- indicates that the application `SignalSet` could not be contacted but that the problem may be transient. An `Action` that receives the `initialFailure` signal should respond with one of two pre-defined Outcomes `org.omg.CosActivity.Failed` or `org.omg.CosActivity.FailureRetry`. Any `Action` that responds with `Failed` will not receive any further signals. Any `Action` that responds with `FailureRetry` is indicating that it wishes the `ActivityCoordinator` to continue to retry contacting the application `SignalSet`. If contact is subsequently made, signaling with the application `SignalSet` may continue.
The Activity service changes the Activity Status to `StatusUnknown` prior to distributing this signal.
The Signal object's getSignalSetName method returns the name of the failed SignalSet rather than "*org.omg.CosActivity.Failure*".

finalFailure -- indicates that the `ActivityCoordinator` has exhausted its attempts to contact the `SignalSet`. The point at which this happens is a detail of the Activity service implementation and may be configured administratively. This signal indicates to the `Action` that it should perform whatever processing is appropriate to it in this situation. The `Failure` SignalSet ignores any `Outcome` produced for this signal.

The Activity service changes the Activity Status to `StatusError` prior to distributing this signal.
The Signal object's getSignalSetName method returns the name of the failed SignalSet rather than "*org.omg.CosActivity.Failure*".

If the application `SignalSet` does not complete its signaling, the `ActivityCoordinator` raises the ActivityNotProcessed exception and this is returned on the UserActivity `complete`, `completeWithStatus` or `broadcast` method that triggered the signaling.

4.4 Recovery

Recovering applications after failures, such as machine crashes or network failures, is an inherently complex problem: the states of objects in use prior to the failure may be corrupt, and the references to objects held by remote clients may be invalid. At a minimum, restoring an application after a failure may require making object states consistent. The advantage of using transactions to control operations on persistent objects is that the transactions ensure the consistency of the objects, regardless of whether or not failures occur. ACID JTA transactions, for example, will guarantee that in the event of failures any transactions that were in flight will either be committed or rolled back, making permanent or undoing any changes to objects that had occurred within the transaction. Rather than mandate a particular means by which objects should make themselves persistent, many transaction systems simply state the requirements they place on such objects if they are to be made recoverable, and leave it up to the object implementors to determine the best strategy for their object's persistence. The transaction system itself will have to make sufficient information persistent such that, in the event of a failure and subsequent recovery, it can tell these objects whether to commit any state changes or roll them back. However, it is typically not responsible for the application object's persistence.

This section does not mandate a specific persistence and recovery mechanism for an Activity service implementations but states the requirements on such a service in the event of a failure. It is left to individual implementors to determine their own recovery mechanisms. In a distributed application, an individual Activity may run on different implementations of a HLS and different implementations of the Activity service during its lifetime. Recovery is the shared responsibility of the Activity service, HLS and application in each domain. The implementations in each domain may perform recovery in a completely different manner but must allow the services that consume them to be portable between domains. The definition of what it means to *recover* an Activity is largely dependent on the extended transaction model and the external behavior of each model must be defined by each type of HLS. Some may offer to complete an Activity in a state where object data is left consistent, some may offer lower forms of guarantee and some may offer to return an Activity to an intermediate state of consistency and allow the activity to continue making forward progress. It is not possible for the Activity service to perform such complete recovery on its own; it requires the co-operation of the HLS that uses it and potentially the application that uses the HLS. Since it is the HLS logic that imposes meaning on `Actions`, `Signals`, and `SignalSets` in order to drive the activities to completion during normal (non-failure) execution, it is predominately this logic that is required to drive recovery and ensure activity components become consistent.

The HLS is responsible for deciding at which point, if any, during an Activity the participants need to be made persistent. An Activity service implementation itself may or may not need to log its own data to support Activity recovery. This might depend on whether the Activity service creates recoverable, internal objects - for example to support its implementation of interposition - that are not the responsibility of the HLS. For such an Activity service implementation the `ActivityCoordinator` must implement the optional `PersistentActivityCoordinator` interface, which provides a `setPersistent` method. When an HLS determines that an Activity needs to be made persistent, it determines whether the `ActivityCoordinator` is an `instanceof PersistentActivityCoordinator` and, if so, calls its `setPersistent` method. The HLS itself is responsible for persistently recording the essential state of its `Actions, SignalSets` and `PropertyGroups` that are registered with the `ActivityCoordinator` during the Activity. The recovery of an Activity, following any failure and subsequent re-initialization of its environment, is initiated by the HLS (perhaps with the cooperation of the application that uses the HLS) by calling the `UserActivity recreate` method. The Activity service uses the HLS `ServiceManager`, during recreation of an Activity, to obtain recovered `SignalSets, Actions` and `PropertyGroups`. The HLS and/or application is then responsible for completing the Activity once it has been recreated, although it may perform forward processing (as though the interruption to the environment had not occurred) if this behavior is desired by the HLS. The association of the recreated Activity's context with the thread may be controlled by appropriate use of flags on the `UserActivity recreate` call. It is the responsibility of the HLS to re-establish hierarchies of contexts by recovering them in the appropriate order. An HLS may use the `UserActivity recover` method to determine whether the Activity service implementation has recorded its own information about persistent Activities. The HLS should drive the `UserActivity forget` method for any Activities returned on the recover call for which the HLS has no information. The HLS can assume that it must have previously completed and forgotten about such Activities or may assume they never performed any recoverable work.

If Activities and transactions co-operate within a given application, then the respective recovery mechanisms will also be required to co-operate. Obviously it is not necessary for a user of the Activity service implementation to use transactions at all, in which case only Activity recovery will be required in the event of a failure (i.e., it is possible to have recovery domains that do not require a transaction service implementation at all).

4.5 Heuristic Completion and timeout

In a distributed environment, network failures may occur and distributed Activities may not be able to complete in a coordinated fashion. Communication may be lost with either a subordinate Action or a superior `ActivityCoordinator`. Operational policy will often determine whether and for how long this is acceptable. Timeout is one mechanism that can be used to ensure timely cleanup of resources in the event that contact with the controlling superior is lost. So long as an Activity has not reached a stage where it is persistent and requires `Signals` from the superior to make progress, a subordinate environment may timeout an Activity, causing the target Activity and any child Activities to complete with failure. A timeout period is specified on each Activity that starts and a default timeout may be set through the `UserActivity` interface. The timeout for an Activity is propagated with the `ActivityContext` to remote environments so that it may be established independently in each environment.

If an Activity fails and has to be recovered by the HLS that started it, then the HLS can direct completion so long as the failure and recovery is of a root Activity. If the recovery is for a subordinate Activity, for example in an application server to which an Activity context was distributed, then the subordinate should be reconnected to its superior to restore the situation prior to failure. If, in the meantime, the superior has been administratively completed, or remains unavailable for an extended period, then the HLS recovering the subordinate Activity may chose to complete the subordinate heuristically by driving the `ActivityCoordinator heuristicComplete` method. Heuristic completion differs from normal completion in two ways:

1. heuristic completion can be initiated on subordinate `ActivityCoordinator` whereas normal completion may only be initiated on the root `ActivityCoordinator`.
2. the Activity service sets the `Status` to *StatusCompletingHeuristic* rather than *StatusCompleting* when heuristic completion is requested. This gives a completion `SignalSet` the opportunity to produce different `Signals` or to set different data in `Signals` for heuristic completion if desired.

5.0 Component Interactions

This section describes some typical Activity service object interaction sequence diagrams. These interactions are intended to be illustrative rather than prescriptive.

5.1 HLS initialization

An HLS `ServiceManager` is registered with a `UserActivity` object before that `UserActivity` object begins any Activities. This need happen only once, during HLS initialization.

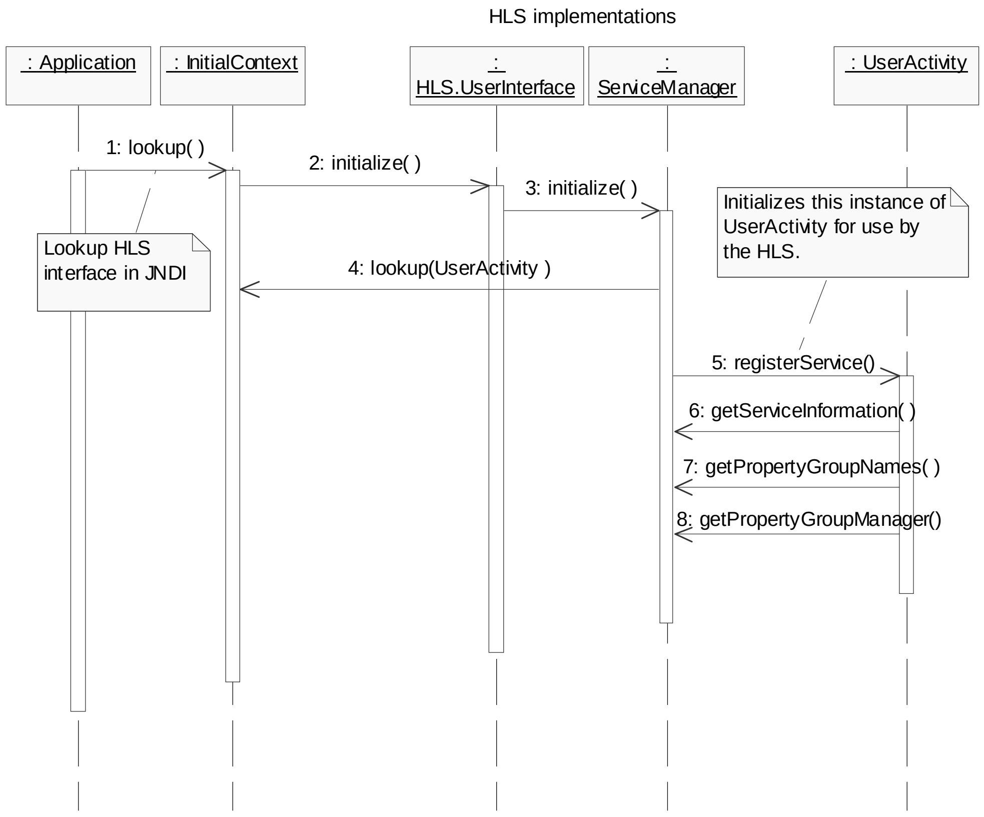

FIGURE 11 **HLS initialization sequence diagram.**

1. An application performs a JNDI lookup of the application interface provided by a HLS it uses.
2. An instance of the HLS user interface object bound in JNDI is created and initialized.
3. The HLS user interface object initialization obtains a reference to its `javax.activity.coordination.ServiceManager` interface.
4. The `ServiceManager` obtains the `UserActivity` reference from JNDI.
5. The `ServiceManager` initializes the `UserActivity` instance by registering itself via `registerService`.
6. The `UserActivity` instance completes its initialization by obtaining further information from the HLS `ServiceManager` - specifically the `ServiceInformation`...
7. ...list of `PropertyGroup` names used by the HLS...
8. ...and a `PropertyGroupManager` reference for each of these `PropertyGroups` from which instances of the `PropertyGroups` may be managed (created, related to parent and so on).

5.2 Begin an Activity

An application performs an operation that causes the HLS to begin an Activity.

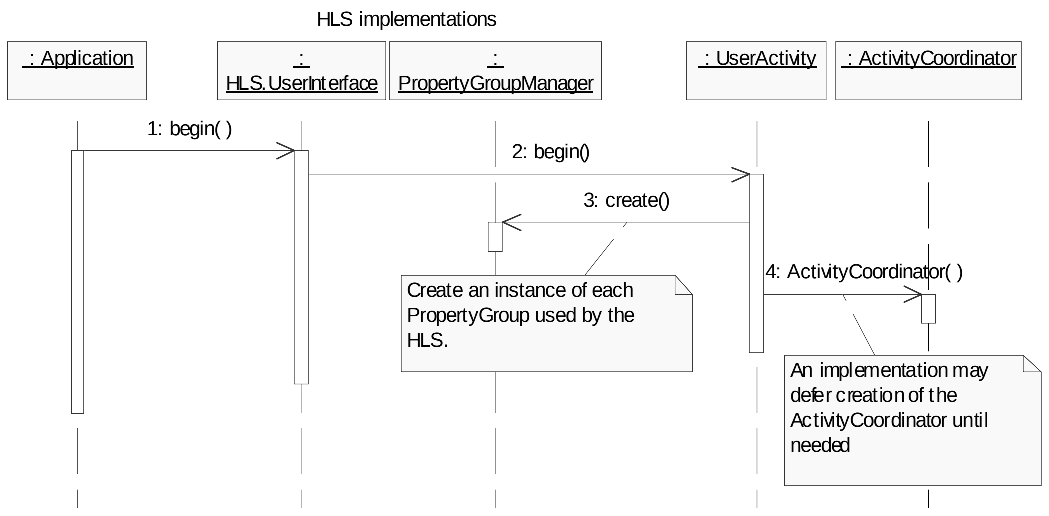
HLS implementations
: Application
: HLS.UserInterface
: PropertyGroupManager
: UserActivity
: ActivityCoordinator
1: begin( )
2: begin()
3: create()
4: ActivityCoordinator( )
Create an instance of each PropertyGroup used by the HLS.
An implementation may defer creation of the ActivityCoordinator until needed

FIGURE 12 **Activity begin - sequence diagram**

1. An application starts a new HLS activity.
2. The HLS begins a new `UserActivity`.
3. The Activity service requests creates an instance of each `PropertyGroup`, used by the HLS, through its `PropertyGroupManager.`

4. An `ActivityCoordinator` instance is created for the new Activity. The `ActivityCoordinator` may not be needed until an Action is registered with the Activity, so this step may be deferred or eliminated in some Activities.

5.3 Add an Action

An application performs an operation that causes the HLS to register an Action with the Activity, with an interest in the specific SignalSet. Although this example doesn't show it, an Action may have an interest in more than one SignalSet.

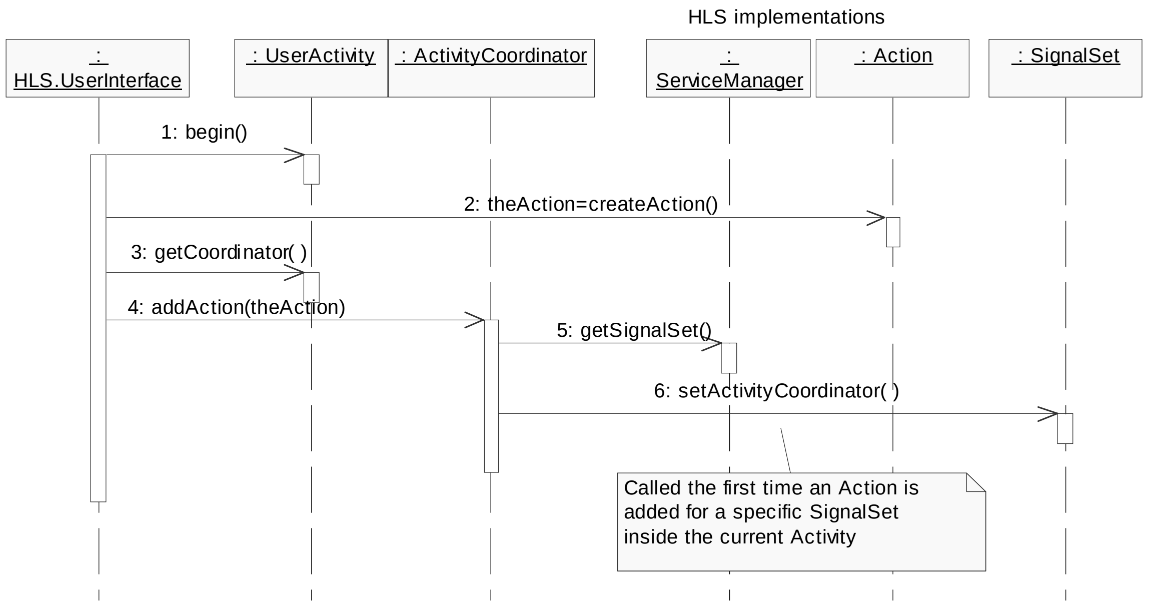

FIGURE 13 **Add an Action - sequence diagram**

1. The HLS begins an Activity.
2. The HLS creates an HLS Action using an mechanism specific to the HLS.
3. The HLS obtains the `ActivityCoordinator` from the `UserActivity` object.
4. The HLS registers the `Action` with the Activity service by passing it as a parameter on an `addAction` call, indicating which `SignalSet` the `Action` is interested in.
5. The `ActivityCoordinator` obtains a `SignalSet` instance from the `ServiceManager` if it isn't already using that `SignalSet` within the Activity.
6. The `ActivityCoordinator` passes a reference to itself to the `SignalSet` instance; this may be required by the `SignalSet` if it needs to make the Activity recoverable. At that time the `SignalSet` must call the `ActivityCoordinator setPersistent` method `ActivityCoordinator` is an `instanceof PersistentActivityCoordinator.`

5.4 Complete an Activity

An application performs an operation that causes the HLS to complete the current Activity.

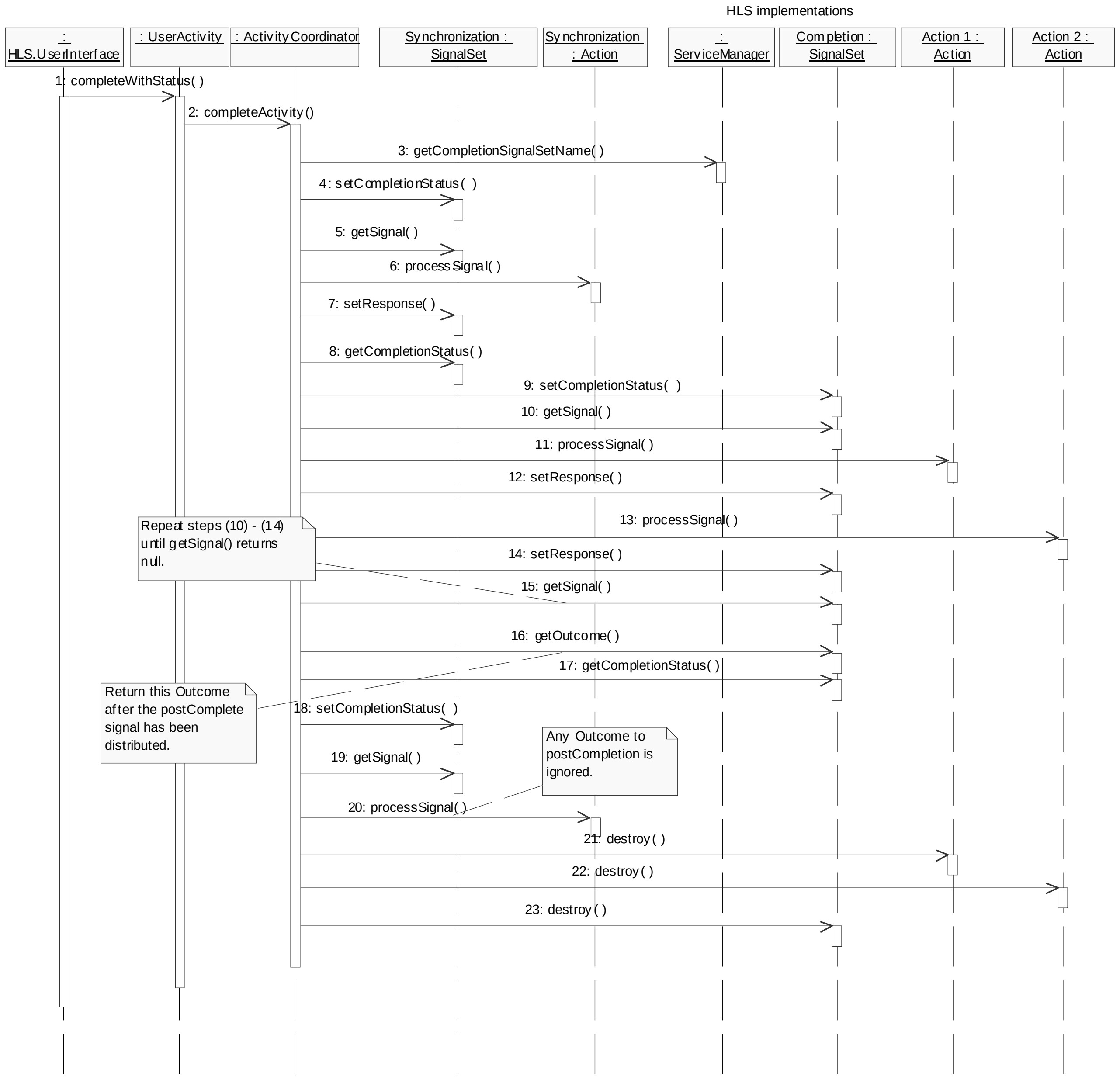

FIGURE 14 Activity completion - sequence diagram

1. An HLS performs `completeWithStatus`, passing a `CompletionStatus`, for example `CompletionStatusSuccess`.

2. The `UserActivity` object instructs the `ActivityCoordinator` to complete the Activity. The specific `ActivityCoordinator` method to achieve this is internal to Activity service implementation - `completeActivity` is used in the figure for illustrative purposes.
3. If no specific completion `SignalSet` has been specified to the `ActivityCoordinator,` then the name of the default completion `SignalSet` can be obtained from the HLS `ServiceManager.` Alternatively, the completion `SignalSet` name could be obtained from the `ActivityCoordinator`. The `SignalSet` itself will already be in-use by the Activity if any `Actions` have been registered with an interest in it.
4. Processing of the predefined *Synchronization* `SignalSet` now begins; the Activity `CompletionStatus` is passed to the *Synchronization* `SignalSet`.
5. The first signal (`preCompletion`) is obtained from the *Synchronization* `SignalSet` if the `CompletionStatus` is `CompletionStatusSuccess`.
6. The `Signal` is sent to the highest priority `Action` that registered an interest in *Synchronization*, which returns an `Outcome` response. The Activity context is available on the thread during the processing of the signal.
7. This response is passed to the `SignalSet`; the `SignalSet` decides what to do next based on this response and returns a `CoordinationInformation` object. The `CoordinationInformation` object indicates whether the `preCompletion` signal should continue to be distributed to any remaining `Actions`.
8. Once `preCompletion` signaling is complete, the `ActivityCoordinator` obtains the updated `CompletionStatus` from the *Synchronization* `SignalSet`.
9. It sets this `CompletionStatus` into the completion `SignalSet`, to influence the completion `Signals` produced.
10. The first `Signal` is requested from the completion `SignalSet`.
11. The `ActivityCoordinator` sends this signal to the highest-priority `Action` interested in completion and obtains an `Outcome` from that `Action`. The Activity context is available on the thread during the processing of the completion signals.
12. The `ActivityCoordinator` passes this `Outcome` to the `SignalSet` which factors this `Outcome` into its state table and returns a `CoordinationInformation` object that indicates whether to continue sending the current `Signal` and whether to continue involving the current `Action`.
13. Assuming the `CoordinationInformation` object does not indicate that the current `Signal` should be abandoned, the `Signal` is sent to the next `Action`.
14. Again, the Action’s `Outcome` is fed into the `SignalSet` and a `CoordinationInformation` object returned.
15. If the `CoordinationInformation` object indicates that the next `Signal` should be retrieved or if the previous `Signal` has been sent to all the interested `Actions`, then the `ActivityCoordinator` retrieves the next `Signal` from the `SignalSet`.
16. If the returned `Signal` reference is null, then the `SignalSet` has completed processing and the Activity service retrieves the final `Outcome` from the `SignalSet`. This `Outcome` will be returned on the `UserActivity` complete method that ultimately triggered the completion.
17. The `ActivityCoordinator` updates its view of the `CompletionStatus` from the `SignalSet`.
   (Not shown in the sequence diagram). Any `PropertyGroups` used by the HLS are called with `suspended` and then `completed`. The Activity context of the completing Activity is logically suspended prior to these calls on the `PropertyGroups`.

18. The final `CompletionStatus` is passed to the *Synchronization* `SignalSet`.
19. The `ActivityCoordinator` retrieves the `postCompletion` signal from the *Synchronization* `SignalSet`.
20. It sends this to all `Actions` registered with an interest in *Synchronization*. Any `Outcomes` from these `Actions` are ignored and cannot influence the `Outcome` of the Activity. The `postCompletion` `Signal` indicates that no further `Signal` will be sent to the `Action`, so it should destroy itself on completion of processing this `Signal`.
21. Actions that are not registered with the *Synchronization* `SignalSet` get explicitly told to `destroy` themselves at the end of the Activity. In this case, *Action 1* is destroyed.
22. *Action 2* is destroyed.
23. Finally, the completion `SignalSet` is told to `destroy` itself. After this, the `Outcome` produced in (16) is returned to the caller.

5.5 Broadcast Signals from a SignalSet

An application performs an operation that causes the HLS to broadcast a `Signal` to all interested `Actions` in the middle of an Activity. An HLS may support any number of `SignalSets` and may broadcast `Signals` from zero, one or more of those `SignalSets` during the course of the Activity.

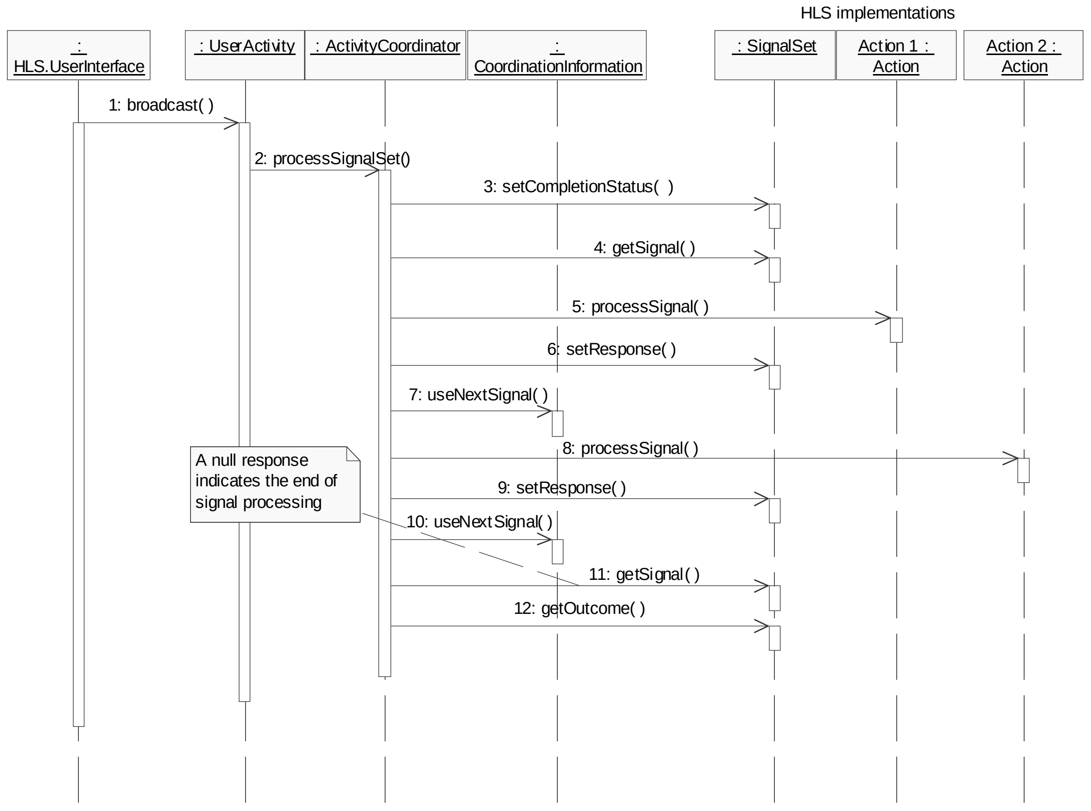

FIGURE 15 **Broadcast - sequence diagram**

1. An HLS wishes to broadcast `Signals` from a particular `SignalSet` to `Actions` with an interest in that `SignalSet` prior to completion, and does so by calling the `UserActivity` `broadcast` method.
2. The `UserActivity` object instructs the `ActivityCoordinator` to distribute the Signals of the specific `SignalSet`. The specific `ActivityCoordinator` method to achieve this is internal to Activity service implementation - `process-SignalSet` is used in the figure for illustrative purposes.
3. The `ActivityCoordinator` indicates to the `SignalSet`, through the `set-CompletionStatus` call, that the Activity is still active and is not completing.
4. The first `Signal` is requested from the `SignalSet`.
5. The `ActivityCoordinator` sends this signal to the highest-priority `Action` interested in the `SignalSet` and obtains an `Outcome` from that `Action`.
6. The `ActivityCoordinator` passes this `Outcome` to the `SignalSet` which factors this `Outcome` into its state table and returns a `CoordinationInforma-tion` object
7. The `ActivityCoordinator` enquires of the `CoordinationInformation` object whether to continue sending the current `Signal` and whether to continue involving the current `Action`.

8. Assuming the `CoordinationInformation` object does not indicate that the current `Signal` should be abandoned, the `Signal` is sent to the next `Action`.
9. Again, the Action's `Outcome` is fed into the `SignalSet` and a `CoordinationInformation` object returned.
10. The `ActivityCoordinator` enquires of the `CoordinationInformation` object whether to continue sending the current `Signal` and whether to continue involving the current `Action`.
11. If the `CoordinationInformation` object indicates that the next `Signal` should be retrieved or if the previous `Signal` has been sent to all the interested `Actions`, then the `ActivityCoordinator` retrieves the next `Signal` from the `SignalSet`.
12. If the returned `Signal` reference is null, then the `SignalSet` has completed processing and the Activity service retrieves the final `Outcome` from the `SignalSet`. This `Outcome` is returned on the `UserActivity broadcast` method.

5.6 Import an ActivityContext

The following sequence illustrates the processing of an inbound IIOP Activity service context. In the case of a received IIOP service context the service context filter is a Portable Interceptor, as defined by the CORBA specification[4]. An Activity service implementation must provide a Portable Interceptor implementation in order to be able to process Activity-related work distributed over IIOP.

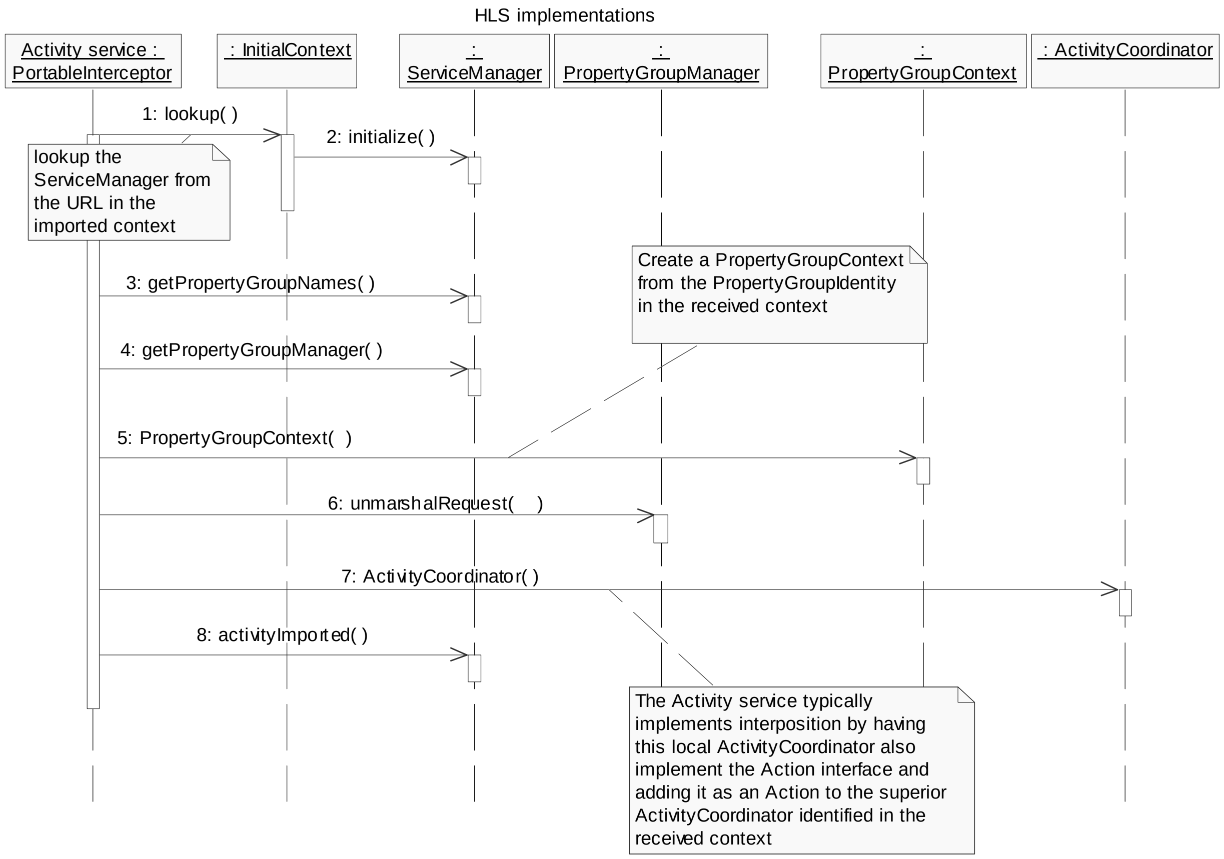
HLS implementations
Activity service : PortableInterceptor
: InitialContext
: ServiceManager
: PropertyGroupManager
: PropertyGroupContext
: ActivityCoordinator
1: lookup( )
2: initialize( )
lookup the ServiceManager from the URL in the imported context
Create a PropertyGroupContext from the PropertyGroupIdentity in the received context
3: getPropertyGroupNames( )
4: getPropertyGroupManager( )
5: PropertyGroupContext( )
6: unmarshalRequest( )
7: ActivityCoordinator( )
8: activityImported( )
The Activity service typically implements interposition by having this local ActivityCoordinator also implement the Action interface and adding it as an Action to the superior ActivityCoordinator identified in the received context

FIGURE 16 **Import an Activity service context - sequence diagram**

1. An inbound IIOP request is processed by an ORB and the registered Activity service portable interceptor's `receive_request` method is driven. If the request contains an Activity service context, the interceptor unmarshals it and examines the `activity_specific_data` of each `ActivityIdentity` to determine the lookup name of the `ServiceManager` for that `ActivityIdentity`. It performs a JNDI lookup of the `ServiceManager` name to obtain a `ServiceManager` object.
2. A `ServiceManager` instance is returned.
3. The interceptor retrieves the list of `PropertyGroup` names supported by the `ServiceManager`.
4. The interceptor requests an instance of a `PropertyGroupManager`, from the `ServiceManager`, for each type of `PropertyGroup` supported.
5. The interceptor creates a `PropertyGroupContext` object from each `PropertyGroupIdentity` structure contained within each `ActivityIdentity`.
6. The interceptor passes the `PropertyGroupContext` for each `PropertyGroup` to the appropriate `PropertyGroupManager` to unmarshal the `PropertyGroup` data.

7. The interceptor determines whether the received Activity context is already active within the receiving server and, if so, associates that context with the current thread. If it is not already active, the interceptor may create a new `ActivityCoordinator` and register it back as an `Action` with the superior (i.e. calling) node's `ActivityCoordinator` (i.e. it may interpose a local, subordinate ActivityCoordinator). As a standard performance optimization, the creation of an interposed `ActivityCoordinator` may be deferred until an `Action` is registered locally or an `ActivityContext` needs to be marshaled for an outbound request.
8. If a new context has been received from another domain then the `ServiceManager` is informed of this. This gives the HLS an *interception* point when a new context for the target `ServiceManager` is imported into the server. Any `ServiceInformation` retrieved from the `activity_specific_data` is passed to the `ServiceManager`.

5.7 Subordinate completion of an Activity

A subordinate `ActivityCoordinator` is registered as an `Action` with its superior `ActivityCoordinator`. The `Action` is registered with an interest in the pre-defined *Synchronization* `SignalSet` as well as any `SignalSets` that locally-registered `Actions` have an interest in.

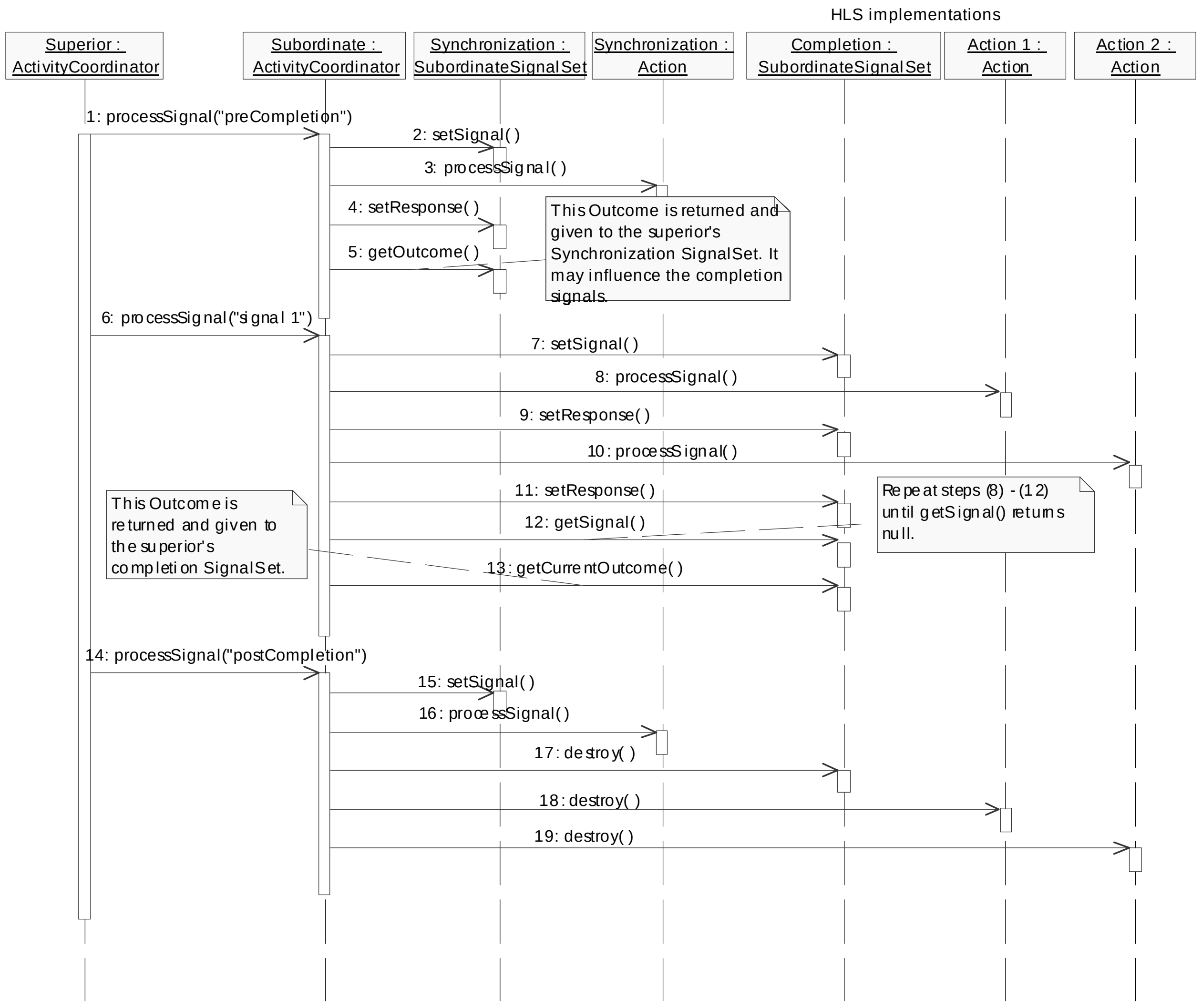
HLS implementations
Superior : ActivityCoordinator
Subordinate : ActivityCoordinator
Synchronization : SubordinateSignalSet
Synchronization : Action
Completion : SubordinateSignalSet
Action 1 : Action
Action 2 : Action
1: processSignal("preCompletion")
2: setSignal( )
3: processSignal( )
4: setResponse( )
5: getOutcome( )
This Outcome is returned and given to the superior's Synchronization SignalSet. It may influence the completion signals.
6: processSignal("signal 1")
7: setSignal( )
8: processSignal( )
9: setResponse( )
10: processSignal( )
11: setResponse( )
Repeat steps (8) - (12) until getSignal() returns null.
This Outcome is returned and given to the superior's completion SignalSet.
12: getSignal( )
13: getCurrentOutcome( )
14: processSignal("postCompletion")
15: setSignal( )
16: processSignal( )
17: destroy( )
18: destroy( )
19: destroy( )

FIGURE 17 **Subordinate completion - sequence diagram**

1. The subordinate `ActivityCoordinator-Action` receives a `preCompletion` signal from its superior.
2. It calls `setSignal` on its local *Synchronization* `SubordinateSignalSet` to indicate that a superior has produced this `Signal`.
3. The subordinate `ActivityCoordinator` then sends this `Signal` to the highest-priority `Action` that registered an interest in *Synchronization*, which returns an `Outcome` response.

4. This response is passed to the SignalSet; the SignalSet decides what to do next based on this response and returns a CoordinationInformation object. The CoordinationInformation object indicates whether the preCompletion signal should continue to be distributed to any remaining Actions.
5. Once preCompletion signaling is complete, the subordinate ActivityCoordinator obtains a correlated Outcome from the *Synchronization* SignalSet and returns it to its superior. This Outcome may affect the final CompletionStatus reached by the root *Synchronization* SignalSet and therefore the completion Signals produced by the root completion SignalSet.
6. The subordinate ActivityCoordinator-Action receives a completion Signal from its superior.
7. It calls setSignal on its local completion SubordinateSignalSet to indicate that a superior has produced this Signal.
8. The subordinate ActivityCoordinator then sends this Signal to the highest-priority Action that registered an interest in the completion SignalSet, which returns an Outcome response.
9. This response is passed to the SignalSet; the SignalSet decides what to do next based on this response and returns a CoordinationInformation object. The CoordinationInformation object indicates whether the Signal should continue to be distributed to any remaining Actions and whether the called Action should receive any further Signals.
10. Assuming the CoordinationInformation object does not indicate that the current Signal should be abandoned, the Signal is sent to the next Action.
11. Again, the Action's Outcome is fed into the SignalSet and a CoordinationInformation object returned.
12. If the CoordinationInformation object indicates that the next Signal should be retrieved or if the previous Signal has been sent to all the interested Actions, then the ActivityCoordinator retrieves the next Signal from the SignalSet.
13. If the returned Signal reference is null, then the SignalSet has completed processing of the received Signal and requires the next Signal to be produced by the superior SignalSet. The ActivityCoordinator-Action retrieves the current Outcome from the SignalSet and returns this to its superior, which processes the Outcome as it would an Outcome from any other Action.
14. After all the completion Signals have been produced, the root ActivityCoordinator drives the postCompletion Signal, which the subordinate ActivityCoordinator-Action has an interest in.
15. It calls setSignal on its local *Synchronization* SubordinateSignalSet to indicate that a superior has produced this Signal.
16. The subordinate ActivityCoordinator then sends this to all Actions registered with an interest in *Synchronization*. Any Outcomes from these Actions is ignored and cannot influence the Outcome of the Activity. The postCompletion Signal indicates that no further Signal will be sent to the Action, so it should destroy itself on completion of processing this Signal.
17. The local completion SignalSet is told to destroy itself.
18. Actions that are not registered with the *Synchronization* SignalSet get explicitly told to destroy themselves at the end of the Activity.
19. Action 2 is destroyed.

5.8 Beginning a child Activity

An application performs an operation that causes the HLS to begin an Activity as a child of an existing Activity. Actions registered with the parent Activity's *ChildLifetime* `SignalSet` are informed of this event.

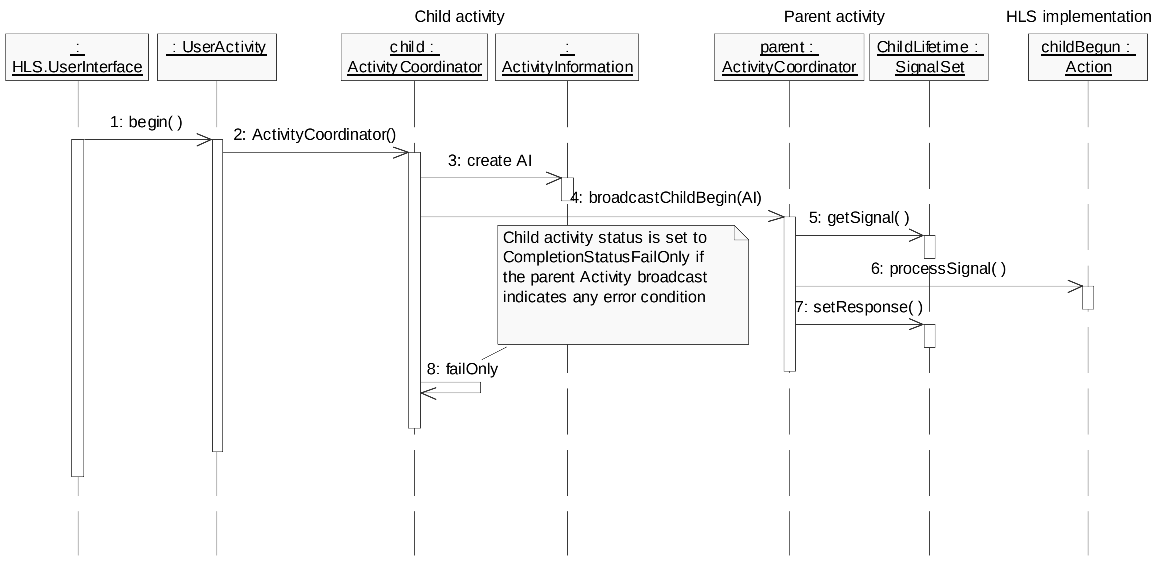

FIGURE 18 **Beginning a child Activity - sequence diagram**

1. The HLS begins an Activity, while an Activity is already active on the thread, by calling `UserActivity` in the usual way. This Activity is the child of the existing Activity.
2. The Activity service creates its internal objects, including the `ActivityCoordinator`, as described in "Begin an Activity" on page 36.
3. The Activity service creates an `ActivityInformation` object describing the child Activity.
4. The `UserActivity` object notifies the parent's `ActivityCoordinator` that the child Activity has begun, passing the child Activity's `ActivityInformation`. The specific `ActivityCoordinator` method to achieve this is internal to the Activity service implementation - broadcastChildBegun is used for illustrative purposes.
5. In the parent Activity, processing of the predefined *ChildLifetime* `SignalSet` begins if any Actions have been registered with the parent `ActivityCoordinator` with an interest in *ChildLifetime* signals. The `ActivityCoordinator` retrieves the first (and only) signal (*childBegin*) from the *ChildLifetime* `SignalSet`.
6. The `Signal` is distributed to each registered `Action`.
7. There are no predefined `Outcomes` for the *ChildLifetime* `SignalSet` so the only response that would be set would be following an exception during signal processing.

8. Any failure in the parent processing the *ChildLifetime* `SignalSet` results in the child Activity `CompletionStatus` being set to `CompletionStatus-FailOnly`.

5.9 Recovering after failure

An HLS recreates an Activity that was previously made persistent. Any recovery of the HLS itself is outside the scope of the Activity service specification. The HLS is responsible for initiating the recreation of the persistent Activity following a failure. The HLS must also complete the Activity at some stage after recreating it.

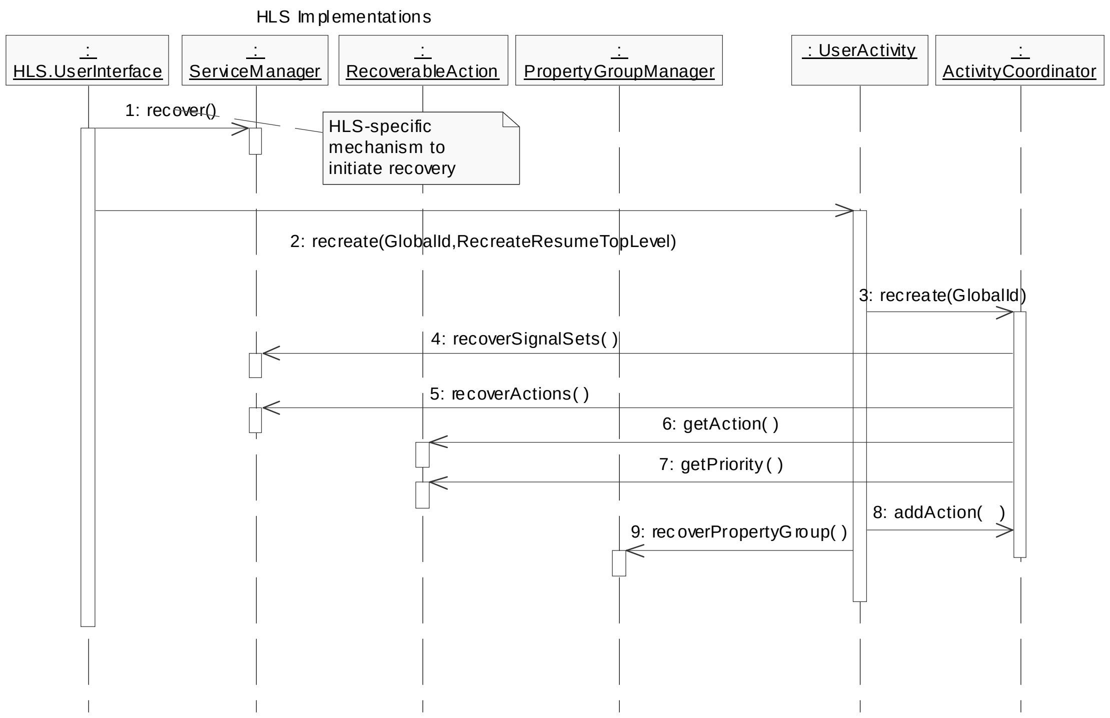

FIGURE 19 **Recovery after failure - sequence diagram**

1. After performing any required initialization (for example, as described in “HLS initialization” on page 35) the HLS performs a service-specific recovery of its own data, including all incomplete and persistent `GlobalIds`.

2. For each recovered `GlobalId`, the HLS calls `recreate` on the `UserActivity` object. On return from this call the distributed Activity context will have been recreated, associated with the thread (depending on the `recreate` flag specified) and ready for the HLS to complete it or make forward progress.
3. The Activity service creates an `ActivityCoordinator` object for the Activity being recreated. The specific mechanism for doing this is internal to the Activity service implementation - the recreate call on the `ActivityCoordinator` is used here for illustrative purposes.
4. The Activity service retrieves the list of HLS `SignalSets` used in the Activity from the HLS `ServiceManager`.
5. For each recovered `SignalSet` the Activity service retrieves the list of `RecoverableActions` registered for that `SignalSet.`
6. Each `RecoverableAction` encapsulates an `Action` and the priority is was previously registered with. Selectivity service retrieves the Action...
7. then retrieves the priority...
8. then re-registers the Action with the ActivityCoordinator.
9. The Activity service retrieves any PropertyGroup, causing such recovered PropertyGroup to become associated with the Activity.

6.0 Interoperability

6.1 Requirements on an Activity service implementation

A J2EE Activity service implementation is required to be interoperable across different vendors' ORB boundaries. The format of the interoperable service context is defined by the `org.omg.CosActivity.ActivityContext` structure in the OMG Activity service specification. The IOR for any object that supports the receipt of Activity service context must have an `org.omg.CosActivity.ActivityPolicy` value of REQUIRES or ADAPTS encoded in the TAG_ACTIVITY_POLICY of the IOR.

A J2EE Activity service implementation is required to be interoperable with a CORBA Activity service implementation so long as the latter implements interposition; that is, the CORBA Activity service must create a local `org.omg.CosActivity.ActivityCoordinator` when inbound Activity context is received from an upstream (superior) node and register an `org.omg.CosActivity.Action` back to the superior's ActivityCoordinator (whose reference is passed in the `ActivityContext` service context).

A J2EE Activity service must implement interposition by creating a local `javax.activity ActivityCoordinator` when inbound Activity context is received from an upstream (superior) node and registering an `org.omg.CosActivity.Action` back to the superior's `org.omg.CosActivity.ActivityCoordinator`.

A J2EE Activity needs to propagate information, in the Activity service context, to identify the type of HLS that created the Activity in order that the appropriate `ServiceManager` be located in the target system. The `org.omg.CosActivity.ActivityIdentity` structure in the Activity service context contains an unsigned long `type` field, which for J2EE Activities must be set to `0x4A324545` by the domain that creates the service context. For such Activities, the `activity_specific_data` field of the `ActivityIdentity` is architected to encode information specific to J2EE HLS's. The `activity_specific_data` field is of type `org.omg.CORBA.Any` and, for a J2EE Activity type, contains a `TypeCode` with a `TCKind` of `_tk_struct` and a value of a `j2ee_activity_specific_data` structure which is defined in IDL as follows:

```
module javax
  {
    module activity
    {
      struct j2ee_activity_specific_data
      {
        string service_name;
        string context_group;
        any service_specific_data;
        any extended_data;
      };
    };
  };
```

The `j2ee_activity_specific_data` structure is referenced, within the J2EE domain, through a `javax.activity.ServiceInformation` object. `ServiceInformation` data for an Activity is populated by the HLS `ServiceManager`. The data is consumed, in the target domain of a remote request, in part by the Activity service (to determine the `ServiceManager` to use) and in part by the `ServiceManager` implementation in that domain.

6.2 CORBA interfaces

A J2EE Activity service provider must provide implementations of the `org.omg.CosActivity.ActivityCoordinator` and `org.omg.CosActivity.Action` interfaces that satisfies the requirements for interoperability stated in 6.1 “Requirements on an Activity service implementation”, on page 50. These are internal to the implementation of the Activity service and need not be exposed to any J2EE Activity service HLS.

A J2EE Activity service provider may optionally support a configuration in which HLS-provided SignalSets are remote from the ActivityCoordinator. This may be desirable for some J2EE platforms in which *application* code (and an HLS-provider can be considered to be *application* code, although some HLS’s may become part of the *application server/container*) is deployed in a separate JVM from the *system* code (*e.g.* the Activity service implementation itself, which is part of the *application server/container*). Such a configuration would require the `ActivityCoordinator` implementation to be able to make calls to a (remote) `org.omg.CosActivity.SignalSet` and would require an implementation of an `org.omg.CosActivity.SignalSet` in the remote domain that passed these requests onto the local `javax.activity.coordination.SignalSet`.

6.3 CORBA Exceptions

The following CORBA System Exceptions have been added to CORBA 3.0 for use by the CORBA Activity service. Each of these requires an equivalent J2EE Activity service `java.rmi.RemoteExeption`:

INVALID_ACTIVITY -- maps to `javax.activity.InvalidActivityException`. This system exception may be thrown on any method for which Activity context is accessed and indicates that the attempted invocation or the Activity context associated with the attempted invocation is incompatible with the Activity's current state. It may also be thrown by a container if Activity context is received on a method for which Activity context is forbidden. This exception will be propagated across

ORB boundaries via an `org.omg.CORBA.INVALID_ACTIVITY` system exception. An application should handle this error by attempting to complete the Activity.

ACTIVITY_COMPLETED -- maps to `javax.activity.ActivityCompletedException`. This system exception may be thrown on any method for which Activity context is accessed and indicates that ongoing work within the Activity is not possible. This may be because the Activity has been instructed to complete with `CompletionStatusFailOnly` or has ended as a result of a timeout. This exception will be propagated across ORB boundaries via an `org.omg.CORBA.ACTIVITY_COMPLETED` system exception. An application should handle this error by attempting to complete the Activity.

ACTIVITY_REQUIRED -- maps to `javax.activity.ActivityRequiredException`. This system exception is thrown by a container if Activity context is not received on a method for which Activity context is mandatory. This exception indicates a deployment or application configuration error. This exception will be propagated across ORB boundaries via an `org.omg.CORBA.ACTIVITY_REQUIRED` system exception.

6.4 Behaviour in the case of unknown Activity types, ServiceNames or PropertyGroups

When an `ActivityContext` is received by a domain on which no Activity service is configured, the `ActivityContext` is ignored.

When an `ActivityContext` is received by a domain on which the Activity service is configured, the `ActivityContext` is processed according to the following rules:

- If the `org.omg.CosActivity.ActivityIdentity.type` or `activity_specific_data` are not recognized, an `InvalidActivityException` is thrown.
- If the `service_name` in the `activity_specific_data` is not recognized, then Activity context is resumed into the `context_group` defined within the `activity_specific_data` in order that the context nesting hierarchy is preserved on flows to downstream domains. The Activity context is otherwise not available to an HLS in the importing domain.
- If a `PropertyGroupIdentity` structure is received for which no local `PropertyGroupManager` is available, the `PropertyGroupIdentity` data is cached with the Activity in its marshalled form and will be propagated on flows to downstream domains. The `PropertyGroupIdentity` data is otherwise not available to an HLS in the importing domain.

7.0 Impact on other specifications

The following specifications will need to be modified to accommodate the J2EE Activity service.

EJB specification -- Under "Support for Distribution and Interoperability", the table of mapped System Exceptions needs to be extended to include the following CORBA standard exceptions, introduced by the OMG Activity service specification.

J2EE exception	Mapped CORBA exception
javax.activity.InvalidActivityException	INVALID_ACTIVITY
javax.activity.ActivityCompletedException	ACTIVITY_COMPLETED
javax.activity.ActivityRequiredException	ACTIVITY_REQUIRED

TABLE 1 **New standard exception mappings**

--

Under "Exception handling", 3 new EJBExceptions need to be defined with equivalent meanings to the 3 javax.activity RemoteExceptions. These are:

- javax.ejb.InvalidActivityLocalException
- javax.ejb.ActivityCompletedLocalException
- javax.ejb.ActivityRequiredLocalException

An EJB container may raise these exceptions in the event of a method dispatch to a EJB local interface failing for reasons of improper Activity context.

Java-to-IDL specification -- support the new exception mappings.

J2SE -- CORBA Activity service system exceptions (which are defined in CORBA 3.0) need to be supported by J2SE. These are part of a larger list of new CORBA 2.6 and CORBA 3.0 system exceptions that J2SE 1.4 does not currently know about. The inclusion of the new CORBA exceptions in J2SE will be pursued through JSR 176 (J2SE 1.5)

OMG standard tags -- An `org.omg.CosActivity.ActivityIdentity.type` needs to be allocated for J2EE Activities. A value of `0x4A324545` has been requested. The format of the `ActivityIdentity.type` is described in 6.0 "Interoperability", on page 50.

8.0 Glossary

Action -- An activity participant. `Actions` are provided by a HLS and are registered with an `ActivityCoordinator` for specific `SignalSets`. `Actions` consume the signals produced by a `SignalSet`.

Activity -- A unit of (distributed) work that has a well-defined boundary, within which participants may register interest for `Signals` produced during the execution of the unit of work. An activity is uniquely identified by its `GlobalId`.

Activity context -- a set of data that represents a specific Activity that includes the activity `GlobalId` and a reference to the `ActivityCoordinator`. An Activity context may be thought of as being associated with the thread of execution of any application or middleware performing work within the Activity. The context is implicitly propagated, by the Activity service, with any remote requests such that it can be established in the execution domain of a remote target process.

ActivityCoordinator -- An Activity-specific object that participants register with in order to receive `Signals` from the Activity. The `ActivityCoordinator` has no understanding of specific `Signals` and `Outcomes` but understands how to distribute signals to participants and feed back the responses.

child/parent relationship -- A parent-child relationship is established when an Activity (the *child*) is started when another Activity (the *parent*) is already active (associated with the thread of execution). This should not be confused with the superior/subordinate relationship.

context group -- A related set of high level services whose Activities may form parent-child relationships with one another. Activities in different context groups are independent of one-another and do not form parent-child relationships.

high level service (HLS) -- a provider of a specific unit of work (UOW) model. An HLS is the specific embodiment of a UOW service that implements the `javax.activity.coordination` interfaces and provides HLS-specific interfaces to the applications that use it. It consists of a `ServiceManager` and one or more `SignalSets` and `Action` implementations, together with a set of defined `Signals` and `Outcomes`.

Outcome -- A result produced by an individual `Action` or the collective result of an Activity, produced by a `SignalSet`. The meaning of individual `Outcomes` is HLS-specific.

PropertyGroup -- HLS-specific data within the Activity context that can be made available, by the HLS, to the application using the HLS. The Activity service does not interpret this data.

Signal -- An item of data produced by a `SignalSet` for consumption by `Actions`. The meaning of individual `Signals` is HLS-specific.

SignalSet -- The intelligent processing engine (state machine), provided by an HLS, that produces a set of `Signals` in a progression that may be influenced by the responses to earlier `Signals`. The `SignalSet` is plugged into the `ActivityCoordinator` to enable the `Signals` it produces to be distributed to the registered participants (`Actions`).

superior/subordinate relationship -- If an Activity becomes distributed from Server1 to Server2, Server1 is said to be the *superior* server and Server2 the *subordinate*, from the perspective of the Activity service. The superior distributes `Signals` to subordinates, treating them as Activity participants.

Appendix A Specific HLS examples

This section contains examples of high-level services that use the Activity service. Other examples may also be found in the OMG Activity service specification[2]. None of these examples are intended to be prescriptive - they merely show ways in which a HLS may be employed to exploit the facilities of the Activity service.

A.1 Long-running Unit of Work (LRUOW)

A.1.1 The Problem

As business processes execute concurrently over extended periods, it is increasingly likely that these processes will attempt to access the same data. To ensure data integrity and consistency, a concurrency control mechanism is needed, and transactions are often employed for this purpose.

A.1.2 A simple example

Figure 20 illustrates a simple business process.

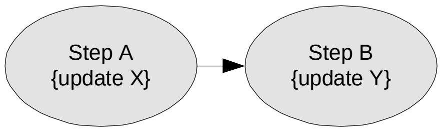

FIGURE 20 Simple business process

This process has two steps. *Step A* might involve, for example, updating some object *X*, and *step B* might be involve updating some object *Y.* In this case, we would like to execute the entire process as a single atomic action: either both X and Y are updated by the process, or neither.

We could execute both steps within a single global transaction, as illustrated in below in Figure 21.

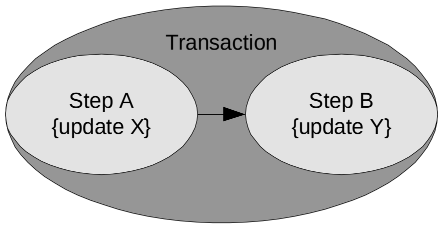

FIGURE 21 **Business process in global transaction**

For long-lived processes, however, there are some problems with this approach. First, if the process is long-lived, it introduces a temporal dependency between the two steps. In our example, it requires that object X and object Y be available at the same time. Such a dependency might not be desirable, or even possible, depending on the system. Furthermore, such temporal dependencies can potentially reduce concurrency; for example, locks acquired in step A must be held until after step B completes. A consequence of considering this process as a global transaction is that the entire process is a unit of failure: that is, if one step fails, all steps fail. If step A is costly, we might like to avoid re-doing it once it executes successfully.

Consider splitting each step into a separate transaction as illustrated below in Figure 22.

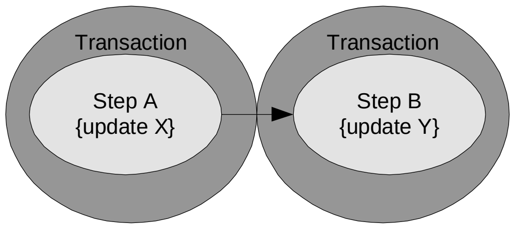

FIGURE 22 **Transactional steps**

If, after executing step A, step B cannot be executed straight away (because object Y is not available, for example), the step can be rescheduled for a later time. In doing so, the process becomes forward recoverable: if step B fails, we need not redo step A.

The problem with this approach is that the process is no longer atomic. For example, what if we update object X (in step A) but cannot reach object Y (in step B)? We can no longer simply abort a global transaction to reverse the effect of step A. Another problem is that the process no longer executes in isolation; that is, partial effects are visible before the entire process completes (e.g., there is a point where the update to object X is visible but not the update to object Y.).

To ensure process atomicity, we could use *compensation steps*, as proposed in the Sagas, transactional workflows and Open-nested Transaction models. A compensation step is used to reverse the effect of some previously executed step (or steps) within a partially completed process. In Figure 23, for example, step B cannot be executed, and the overall process must be aborted. Having successfully executed step A, compensation step *A'* is used to reverse its effect, returning the system to semantically equivalent initial state.

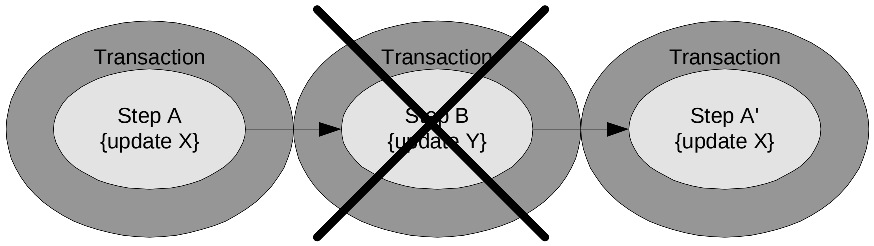

FIGURE 23 **Compensation steps**

One consideration with this approach is that compensation logic can become complex, and difficult to get right. Further, there is limited support for compensation in existing commercial systems.

A.1.3 The LRUOW Approach

The Long-running Unit of Work (LRUOW) approach[6] addresses these problems by allowing a long-running business process to execute as multiple, transactional steps, while providing isolation and atomicity for the process as a whole.

Figure 24 shows business process executing within the context of an LRUOW. Process steps execute as transactions within the LRUOW context. Prior to completion of the process, the effects of its steps are visible only to other steps executing within that same process (i.e., the same LRUOW context). Steps executing concurrently within the same process execute as concurrent transactions, and interact according to the semantics of the underlying transaction model.

6. B. Bennett, B. Hahm, A. Leff, T. Mikalsen, K. Rasmus, J. Rayfield, and I. Rouvellou. "A Distributed Object Oriented Framework to Offer Transactional Support for Long Running Business Processes" in J. Sventek and G. Coulson, editors, *Proceedings IFIP/ACM International Conference on Distributed Systems Platforms*, New York , NY, USA April 2000 (Middleware 2000); Lecture Notes in Computer Science 1795, Springer-Verlag, Berlin, pp. 331-348, April 2000.

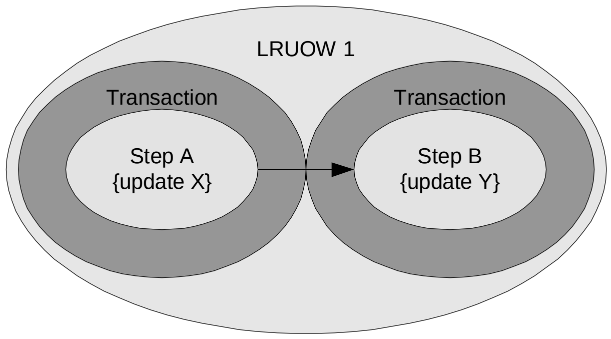

FIGURE 24 **LRUOW business process**

A.1.3.1 Version spaces

Each LRUOW context creates a *version space*, which provides isolation for the LRUOW: the effects of steps executing in one LRUOW are independent of a steps executing in other LRUOWs.

Steps executing within a LRUOW context represent transactions that transform a version space between consistent states. The initial state of a version space is the state of the *global version space* at the time that the LRUOW context is created. When a LRUOW completes successfully, its version space must be *reconciled* with the current state of the global version space.

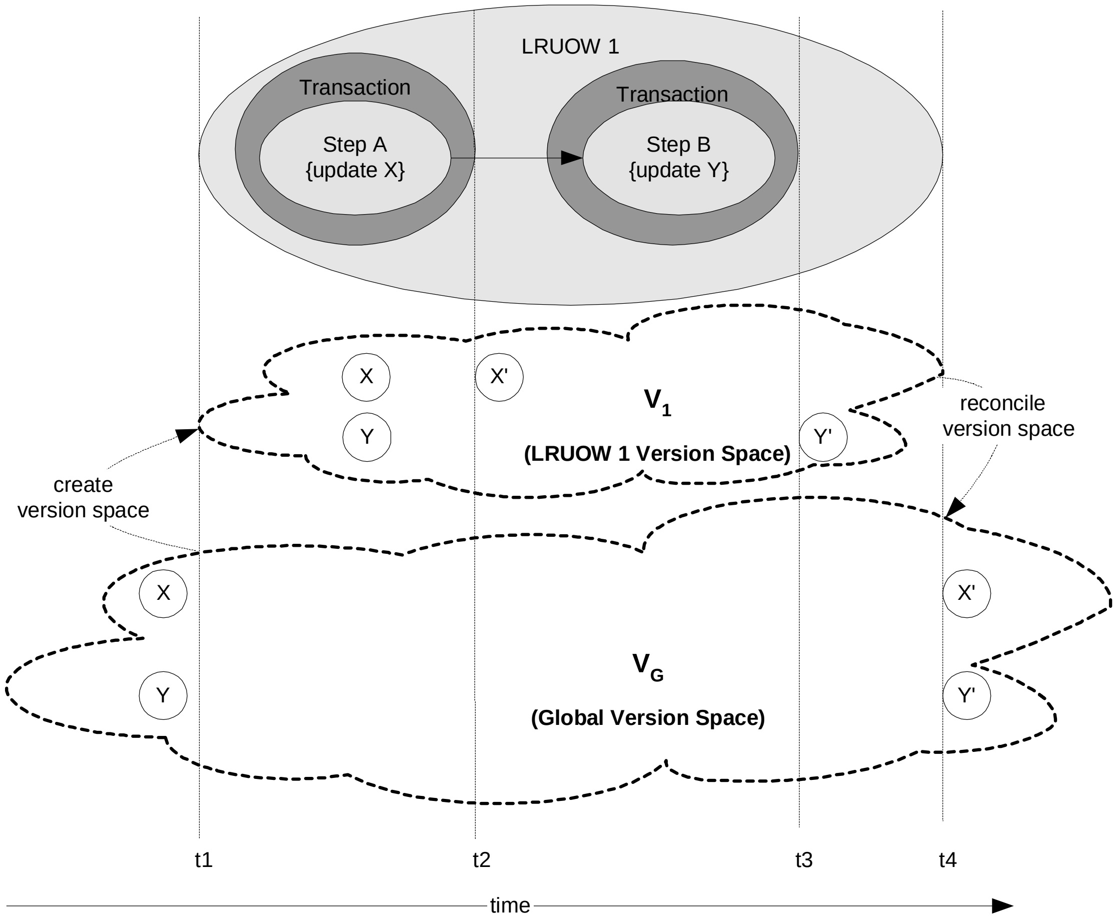

FIGURE 25 **Version spaces**

Figure 25 shows an LRUOW, its associated version space, and the global version space:

- At time *t1*, context LRUOW 1 and associated version space V_1 are created. The initial state of V_1 is the state of the global version space, V_G, at time *t1*: $V_1 = V_G = \{ X , Y \}$.
- At time *t2*, step A's update to object X is committed: $V_1 = \{ X', Y \}$.
- At time *t3*, step B's update to object Y is committed: $V_1 = \{ X' ,Y' \}$.
- At time *t4*, the LRUOW completes, and changes to version space V_1 are reconciled with the global version space: $V_G = \{ X' , Y' \}$.

In this example, the global version space did not change during LRUOW 1's execution, so the reconciled state of V_G is simply V_1's final state. If, however, another LRUOW had completed before LRUOW 1 (but after LRUOW 1 begun), the reconciliation process would not have been so simple. We will return to this subject later in Section A.1.3.3, "Version Space Reconciliation".

A.1.3.2 Nesting

LRUOW contexts, and associated version spaces, can be nested, as is illustrated in Figure 26.

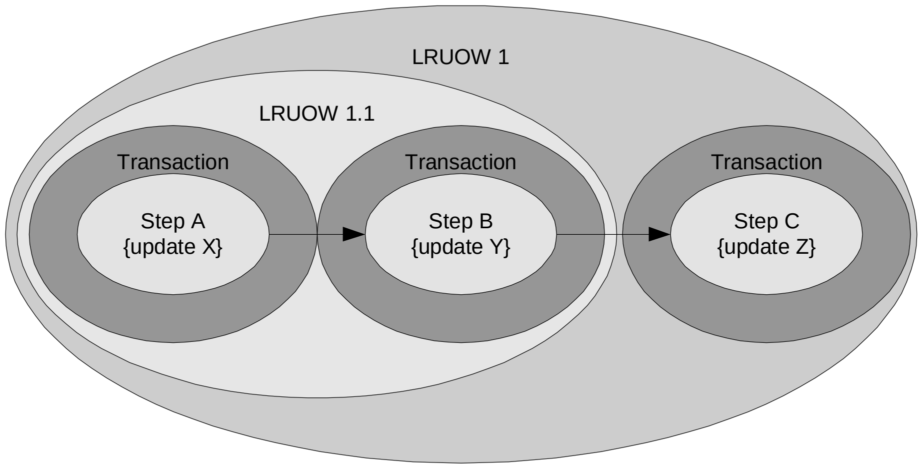

FIGURE 26 **Nested LRUOWs**

A.1.3.3 Version Space Reconciliation

The technique used to reconcile a version space (or subset of a version space) is an implementation detail of the *versioned resource managers* implementing the version space, as described later. As examples of existing techniques, two general methods have been proposed [6]: *Predicate Transform* (*P/T*) and *Conflict Detection and Resolution* (*CDR*).

Predicate/Transform (P/T):

This method associates a predicate with each transform to be applied to a version space. Before applying the transform, the associated predicate is evaluated within the context of the version space. If the predicate holds, the transform is applied to the version space, and the predicate/transform pair is logged. To reconcile this version space with the global version space, each logged predicate/transform pair is examined, in order. If the predicate still holds when evaluated within the context of the global version space (or parent version space, if nested), the transform is applied to the global version space. Otherwise, if the predicate no longer holds, version reconciliation fails, and the associated LRUOW can attempt to fix the problem.

Conflict detection / Resolution (CD/R)

This method proposes a structured mechanism for detecting conflicts between version space objects and applying algorithms that resolve such conflicts when they occur.

A.1.3.4 Transactional reconcile step

In some cases, version space reconciliation can fail. When this occurs, the business process can detect the failure and initiate additional steps and attempt to correct the problem. To avoid version space inconsistencies that could arise as part of such a failure, reconciliation is itself executed transactionally.

As shown in Figure 27, an implicit *reconcile step* is used to transactionally transform the global version space between consistent states.

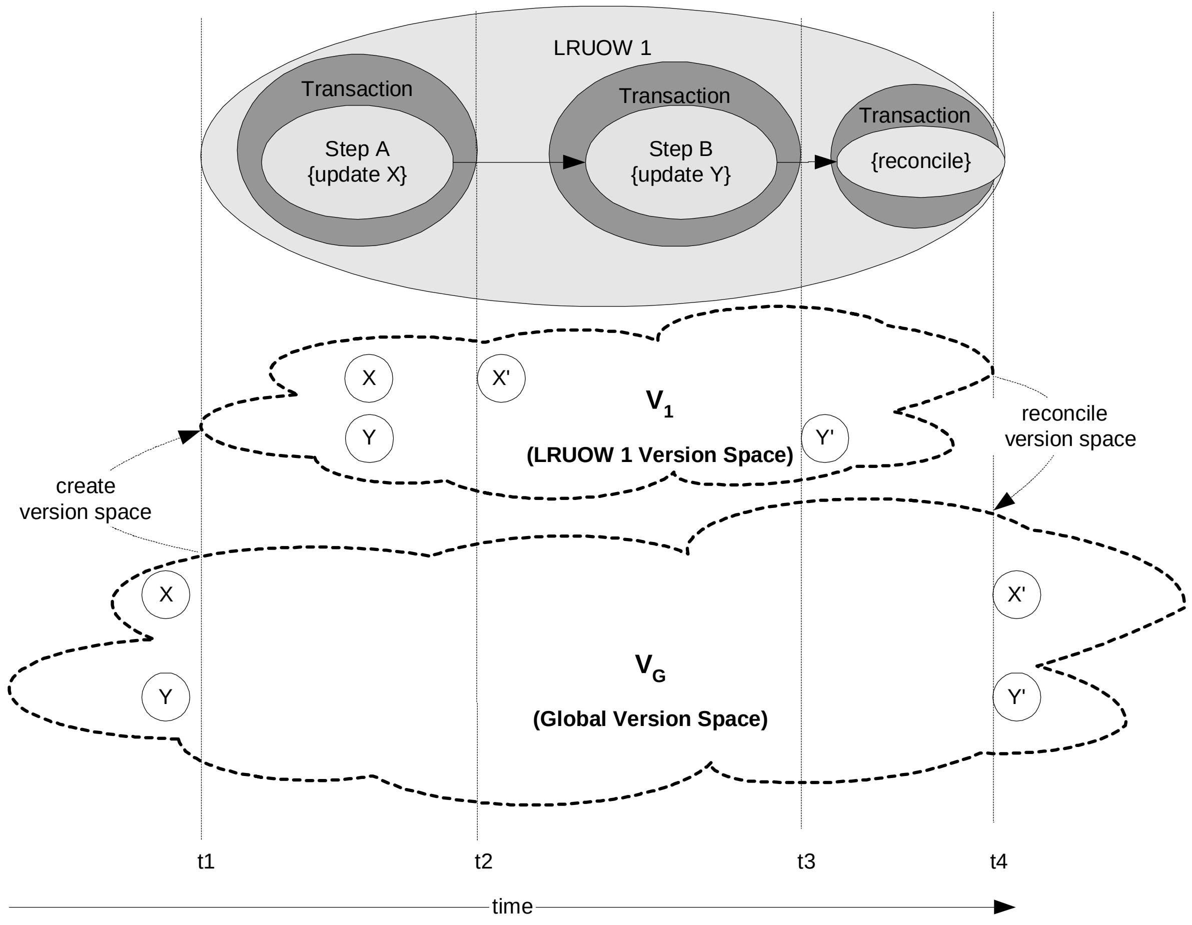

FIGURE 27 **Transactional reconcile step**

At time *t4*, the effects of the reconcile step are committed. Though the reconcile step updates the global version space (or parent version space, if nested), it is still considered to be part of the child LRUOW context.

A.1.4 LRUOW as a High-level Service

LRUOW contexts are modeled as *activities*, and each business process step executes as a *JTA transaction* subordinate to such an activity. This is illustrated in Figure 28.

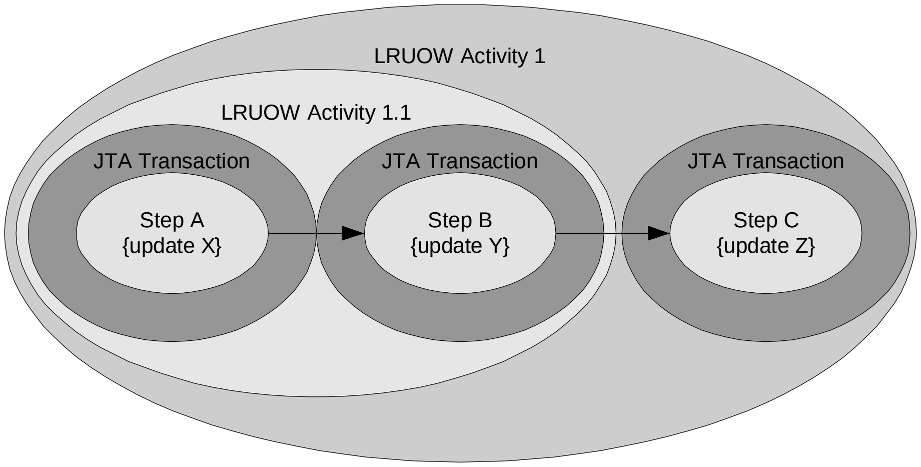

FIGURE 28 **LRUOW activities and transactions**

The completion processing of a LRUOW activity involves an implicit *reconcile step* which is used to reconcile changes in the LRUOW's version space with any changes in the global (or parent) version space. This is embodied in the LRUOW HLS by a `ReconcileSignalSet` producing signals for registered `ReconcileActions`. Like business process steps, the reconcile step executes as a JTA transaction subordinate to the LRUOW activity.

A.1.4.1 Versioned resource managers

Version spaces are modeled using *version resource managers* (VRMs). A VRM supports three interfaces: the *version space interface* (VSI), the *JTA XAResource interface* [JTA spec], and an application programming interface (API) (such as SQL).

Version space interface (VSI)

The LRUOW HLS service manager uses this interface to create and reconcile version spaces, and to associate application threads with version spaces. Below, we briefly present this interface:

vsi_start(vsid) - Start (or resume) work within a version space, given by *vsid*, associating the calling thread with the version space. Subsequent invocations (by the same thread) on the VRMs API execute within the context of the given version space.

vsi_end(vsid) - End (or suspend) work within a version space, given by vsid, removing the calling thread's association with the version space.

vsi_reconcile(vsid) - Reconcile work performed within a version space.

vsi_abandon(vsid) - Abandon work performed within a version space.

JTA XAResource interface

The LRUOW HLS service manager and transaction manager use this interface to associate application threads with transaction contexts, and to coordinate distributed transactions.

Application Program Interface (API)

Application steps use this interface to manipulate objects within version spaces.

When multiple VRMs are accessed as part of an LRUOW, each VRM represents a subset of the LRUOW's associated version space. Executing the reconcile step as a transaction ensures that the version space is reconciled as an atomic action. This is illustrated below in Figure 29.

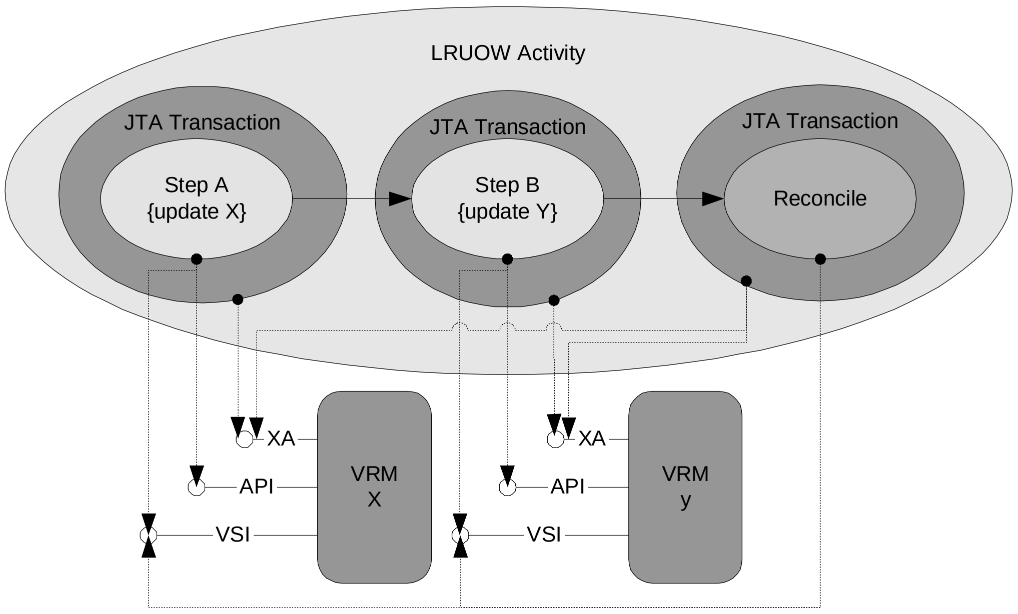

FIGURE 29 **Atomic version space reconciliation**

A.1.4.2 Reconcile SignalSet

The LRUOW HLS implements the `javax.action.coordination` package's `SignalSet` and `Action` interfaces through `ReconcileSignalSet` and `ReconcileAction` objects.

When first accessed, a VRM becomes a participant in the LRUOW activity by adding a `ReconcileAction` to the `ReconcileSignalSet` associated with the LRUOW's activity. To successfully complete the LRUOW, the ReconcileSignalSet produces `ReconcileSignals` for distribution to all registered `ReconcileActions` during completion processing.

A `ReconcileAction` is simply a proxy to an associated VRM. When a ReconcileAction receives the `ReconcileSignal`, it invokes the vsi_reconcile() method on its associated VRM. If successful (i.e., the version space was reconciled), the `ReconcileAction` returns an outcome of `ReconciledOutcome`; otherwise, an outcome of `ReconcileFailedOutcome` is returned.

The reconcile step is triggered by a request, on the part of the application, to complete an LRUOW. As mentioned above, the reconcile step executes transactionally; that is, the broadcast of `ReconcileSignals` to `ReconcileActions` occurs within a transaction. If any `ReconcileAction` fails (i.e., produces an outcome of `ReconciledFailedOutcome`) this transaction is rolled back, reverting the version space to its previously committed state. Otherwise, if all ReconcileActions succeed (i.e., produce an outcome of `ReconciledOutcome`), the transaction is committed.

A.1.4.3 VRM adapters

In a J2EE application server environment, application steps access VRMs indirectly through a *VRM adapters*. A VRM adapter is analogous to a JCA Resource Adapter[5] (and can be implemented as such).

When the application requests a connection, the VRM adapter first enlists the VRM in the appropriate version space and transaction (using the VSI and XAResource interfaces described above); this may involve adding `ReconcileAction's` as described above. Then, subsequent application requests through the connection execute within the correct context. When the application closes the connection, the VRM adapter delists the VRM from the LRUOW and transaction.

A.2 Open Nested Transactions

The Open Nested Transaction (ONT) model is an example of an extended transaction model that can be implemented as a High Level Service on top of the J2EE Activity service. This appendix describes an ONT model and how an ONT implementation (the *Open-*

Nested service) makes use of the Activity service framework to provide the desired function. This example is intended merely to illustrate the use of the Activity service; it is not required that an Activity service implementation provides an OpenNested service.

A.2.1 The ONT Model

In the ONT model an activity may contain any number of nested activities, which may recursively contain other nested activities organized into a hierarchical tree. Each activity represents an atomic unit of work to be done; that is, a JTA transaction. The creation of an activity implies the creation of an associated top-level transaction (which may possibly contain nested transactions, if the provided Transaction Service supports nested transactions). This combined activity and transaction is referred to as an ONT Activity, and from the application point of view, an ONT Activity is implicitly transactional.

The ONT model respects the following rules:

- ONT Activities are strictly nested. An ONT Activity cannot complete with success unless all of its children have completed. Since an ONT Activity is implicitly transactional, completing with success means that the associated transaction is committed.
- When an ONT Activity completes with failure, all of its children that are still in an active state are completed with failure. Completing with failure means that the associated transaction is rolled back.
- When an ONT Activity completes with failure, all of its children that previously completed with success shall be compensated if compensating actions have been defined for them. The behavior of the compensation action is defined by the application since it is only the application that possesses sufficient information to perform compensation.

ONT provides the *UserOpenNested* interface, which allows end-users to control ONT Activities. Propagation of an ONT Activity to a different execution environment is achieved through an Activity Context, to represent the activity, and an OTS transaction context to represent the current transaction.

A.2.1.1 External interfaces

UserOpenNested

The `UserOpenNested` interface defines operations that allow the client to begin and end ONT Activities and to obtain information about the current Activity and associated transaction. The methods on this interface will generally make calls to the underlying JTA and Activity service interfaces. Since this `UserOpenNested` interface is intended to be layered on both JTA and the Activity Service, exceptions raised by those services are caught by this interface and re-raised to the end-user application.

The UserOpenNested implementation needs to be made accessible to applications; in this example it is bound into JNDI at “java:comp/UserOpenNested” and obtained by a lookup on the InitialContext.

ONTActivityStatus

The ONTActivityStatus interface defines Status values that are specific to the ONT model, rather than using the more general Activity service Status values. The diagram below shows these states and indicates the transitions an ONT Activity can undergo.

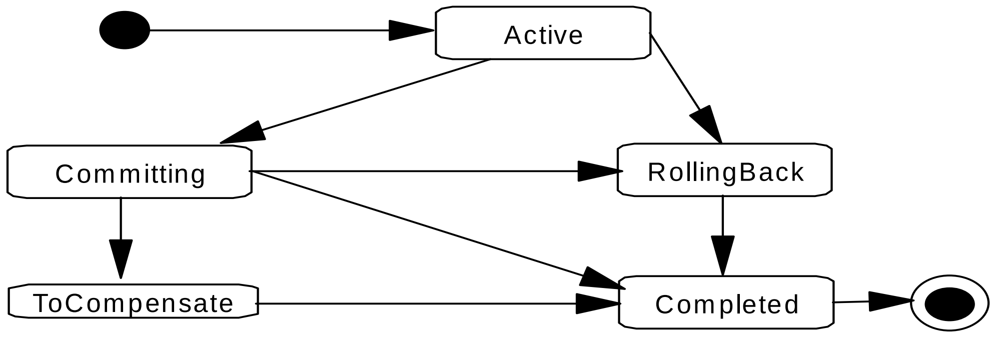

FIGURE 30 **ONT Activity state diagram.**

Compensator interface

The `Compensator` interface provides a generic mechanism to compensate for an ONT Activity in which the transactional work has been committed, but subsequently needs to be undone. Compensation for committed work will be performed either if an enclosing ONT Activity rolls back, or if the Compensator cannot be registered with the enclosing scope after its transaction commits.

This interface is implemented by the user of ONT, and performs the application-specific actions required to compensate for a previously committed transaction.

A.2.1.2 ONT Behavior

An ONT implementation can be used to produce a consistent outcome across a group of transactions; either all the transactions will be committed or they will all be rolled back, compensated or not attempted.

Figure 31 shows a nest of ONT Activities, with their associated JTA transactions and Compensations. This has been achieved by use of the UserOpenNested interfaces as follows:

```
UserOpenNested uon = ic.lookup("java:comp/UserOpenNested");

uon.activityBegin(0);  // starts ONTActivity1/txn1
uon.activityBegin(0); // starts ONTActivity2/txn2
uon.activityCommit(compensator2) // commits txn2
uon.activityBegin(0); // starts ONTActivity3/txn3
uon.activityBegin(0); // starts ONTActivity4/txn4
uon.activityCommit(compensator4) // commits txn4
uon.activityCommit(compensator3) // commits txn3
uon.activityBegin(0); // starts ONTActivity5/txn5
uon.activityCommit(compensator5) // commits txn5
uon.activityCommit(); // commits txn1 and ends nest
```

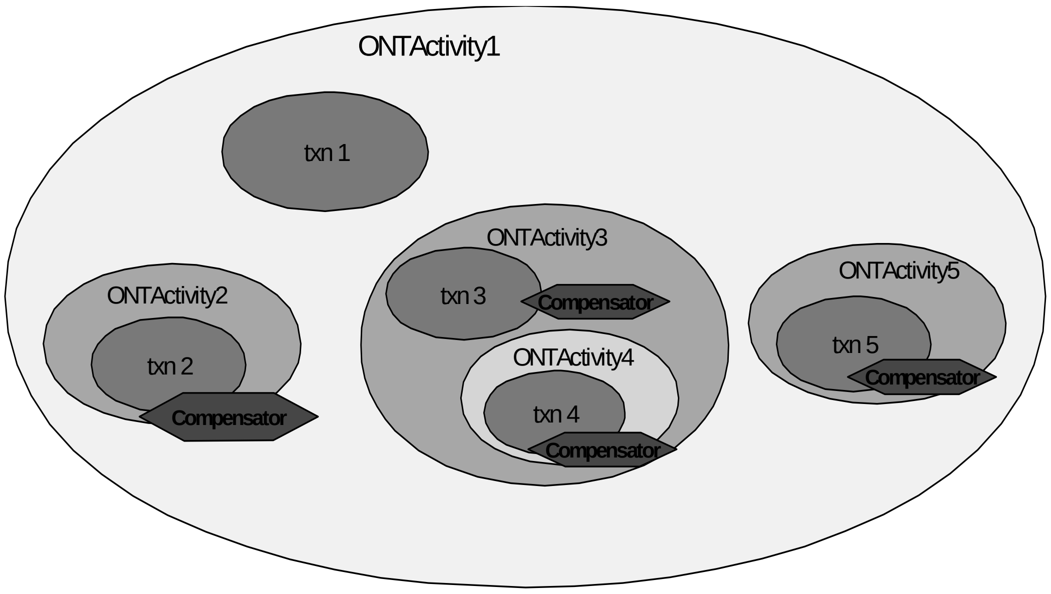

FIGURE 31 Nested ONT Activities with associated JTA transactions and Compensators

If transaction 3 rolls back then compensator4 is automatically invoked to compensate for the previously committed transaction 4, which was nested within ONTActivity3. If transaction 1 rolls back then all four compensators are driven, to compensate for all the committed transactions nested within ONT Activity1. If transactions 2, 4 or 5 fail there is no automatic compensation performed by the ONT service as they are all bottom-level transactions; they have no committed transactions nested within them; however, the application could choose to rollback ONT Activity 1 in such a situation, in which case compensators will be driven for any transactions than have committed up to that point.

A.2.2 Implementation of the OpenNested Service as an HLS

The Activity Service defined in the earlier part of this specification enables the development of an advanced transaction model through implementations of ServiceManager, SignalSet, Signals and Actions appropriate for the transaction model. This section describes how these entities are defined to implement the ONT Model in the *OpenNested* Service.

Figure 32 illustrates the relationship between an application which may define a compensating action and the provider of the ONT model. Within the OpenNested Service, a Compensator object is wrapped in an Action; the Action will receive signals from the ActivityCoordinator and will respond by calling appropriate methods on the Compensator implementation.

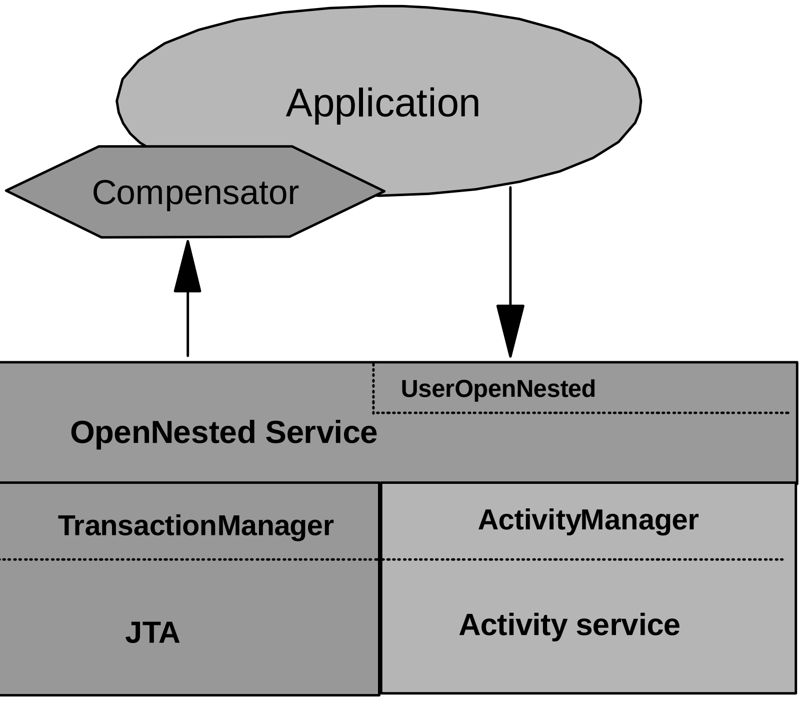

FIGURE 32 **Activity and ONT relationship.**

Since the OpenNested Service provider is responsible for coordinating nested activities according to their final outcomes, it must have the knowledge of the outcomes of their associated transactions in the case of failure. If the ONT provider chooses to provide a recoverable service, it will need to register as a *javax.transaction.xa.XAResource* object with the transaction. Registering a resource is a way for the ONT Service to determine if the reference of the Compensator object must be logged to be retrieved in case of failure, as well as ensuring that it will be notified of the transaction outcome after recovery.

Once a Sub-activity has committed, its `Compensator` object must be reachable in case an enclosing Activity rolls back. The ONT provider and the underlying Activity Service Provider are responsible for maintaining access to `Compensator` objects.

A.2.2.1 Activity service classes used by ONT

Signal

The OpenNested service creates signals with the following names:

- activity_rolledback
- activity_committed

Outcome

The following identifiers define the Outcome objects used by the OpenNested service:

- parent_add_successful
- parent_has_completed
- parent_add_failed
- compensate_successful
- compensate_failed
- heuristic_compensate_decision
- heuristic_cannot_compensate

A.2.2.2 UserOpenNested implementation

When `activityBegin` is called on `UserOpenNested`, it:

- invokes the Activity Service to create an activity
- invokes JTA to create a transaction; any existing transaction on the current thread is suspended before the new activity and transaction are begun.

When `activityCommit` is called on `UserOpenNested`, it:

- invokes the JTA to commit the associated transaction

If the transaction commits:

- if a Compensator object was provided in the `activityCommit`, and the commit is related to a nested activity, the Open Nested Service adds an Action object, responsible for compensation, to the **parent** activity; this Action specifies interest in the ONT SignalSet.
  - If the adding operation fails, the Open Nested Service invokes the Compensator object to compensate the committed transaction, and invokes the Activity Service to complete the activity with the completion status `CompletionStatus-Fail`. Ultimately it throws `ActivityRolledBackException` to the end-user.

  - If the adding operation succeeds, the Open Nested Service invokes the Activity Service to complete the current activity with the completion status `CompletionStatusSuccess`.
    - -- If the Open Nested Service receives the *heuristic_compensate_decision* Outcome on the `UserActivity.complete` operation, it throws `HeuristicCompensateException` to the end-user.
    - -- A null Outcome returned by the `complete` operation on the UserActivity interface is interpreted as an acknowledgment of the completion with success decision.
- if the commit is related to a top-level activity, the Open Nested Service invokes the Activity Service to complete the activity with the completion status `CompletionStatusSuccess` using the ONT SignalSet. If a compensator object is provided in the commit request, an Action object that wrappers the compensator is added to the current activity; during activity completion the compensator will be invoked to *forget*.

If the transaction rolls back

- the Open Nested Service invokes the Activity Service to complete the activity with the completion status `CompletionStatusFail`.
  - If the Open Nested Service receives the *heuristic_cannot_compensate* Outcome, it throws `HeuristicNoCompensateException` to the end-user application.
  - A null Outcome returned by the `complete` operation on the UserActivity interface is interpreted as an acknowledgment of the completion with failure decision. The Open Nested Service throws the `ActivityRolledBackException` to the end-user.

When `UserOpenNested.activityRollback` is called, the Open Nested Service:

- invokes the JTA to rollback the associated transaction,
- invokes the Activity Service to complete the activity with the completion status `CompletionStatusFail`.
  - If the Open Nested Service receives the *heuristic_cannot_compensate* Outcome, it throws `HeuristicNoCompensateException` to the end-user application.
  - A null Outcome returned by the `complete` operation on the UserActivity interface is interpreted as an acknowledgment of the completion with failure decision.

If a transaction was suspended when the committing ONT Activity was begun, that transaction is resumed onto the current thread.

A.2.2.3 Service Manager Implementation

The OpenNested Service implements the `javax.activity.ServiceManager` interface with an object that provides the following information to the Activity service:

`getServiceInformation` returns a ServiceInformation class that has been constructed with a serviceName of “javax.activity.opennested” and a null contextGroup.

`getPropertyGroupNames` returns null as PropertyGroups are not used by this service.

`getCompletionSignalSetName` returns the name “javax.activity.opennested.ONT”, and `getSignalSet` is capable of providing an instance of that SignalSet.

A.2.2.4 SignalSet Implementation

The OpenNested service implements the javax.activity.coordination.SignalSet interface with a signal set called “javax.activity.opennested.ONT”. This signal set provides the activity_committed and activity_rolledback signals, and responds appropriately to the outcomes that are generated in response to those signals.

The Activity service provides the ONT SignalSet with a reference to the ActivityCoordinator through the operation `setActivityCoordinator`, and with the CompletionStatus of the Activity using the `setCompletionStatus` operation, before any signals are requested. The ONT SignalSet obtains a reference to its *parent* ActivityCoordinator, if any, by calling `getParent` on the ActivityCoordinator. Figure 33 shows the states that the ONT SignalSet passes through as the ActivityCoordinator invokes methods on it.

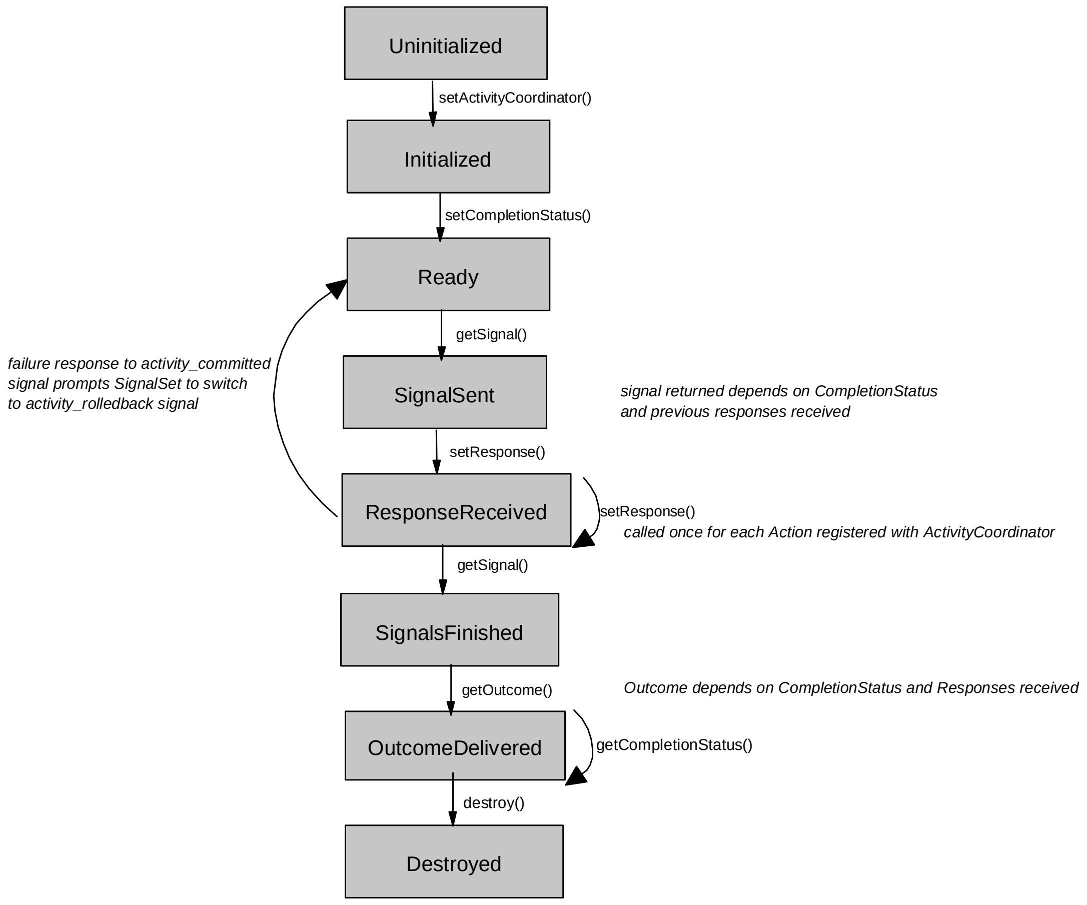
Uninitialized
setActivityCoordinator()
Initialized
setCompletionStatus()
Ready
getSignal()
SignalSent
signal returned depends on CompletionStatus and previous responses received
failure response to activity_committed signal prompts SignalSet to switch to activity_rolledback signal
setResponse()
ResponseReceived
setResponse() called once for each Action registered with ActivityCoordinator
getSignal()
SignalsFinished
getOutcome()
Outcome depends on CompletionStatus and Responses received
OutcomeDelivered
getCompletionStatus()
destroy()
Destroyed

FIGURE 33 **Lifecycle of the ONT SignalSet**

Depending on the activity `CompletionStatus`, and on any responses already received by the SignalSet, an ONT SignalSet object returns to the ActivityCoordinator when requested with `getSignal`, either

- the *activity_committed* Signal (with the parent ActivityCoordinator in the signal's extended data), if the completion status is `CompletionStatusSuccess`, or
- the *activity_rolledback* Signal (with null in the signal's extended data) if the completion status is `CompletionStatusFail` or if a previous response to the *activity_committed* Signal indicated a failure.

So the getSignal method could be coded as follows:

```
public Signal getSignal()
{
        Signal signal = null;
        _started = true;

        if (!_finished)
        {
           if (_completionStatus ==
                 CompletionStatus.CompletionStatusSuccess )
           {
              try
              {
                 signal = new Signal("activity_committed",null,
             (java.io.Serializable)_activityCoordinator.getParent());
              }
              catch (SystemException e)
              {
                 signal = new Signal("activity_committed",null,
                                            (java.io.Serializable)null);
              }
           }
           else if (_completionStatus ==
                              CompletionStatus.CompletionStatusFail)
           {
              signal = new Signal("activity_rolledback",null,
                                            (java.io.Serializable)null);
           }
        }
        return signal;
     }
```

After providing the signal *activity_committed*, if the ONT SignalSet related to a nested activity receives an outcome on `SetResponse` of:

- *parent_has_completed* (indicating that the Action failed to be registered with the parent `ActivityCoordinator` because it has completed), the SignalSet indicates to the `ActivityCoordinator` through the CoordinationInformation (*useNextSignal* = true) that a subsequent signal shall be distributed. This next signal is *activity_rolledback*. The SignalSet will subsequently return the outcome *parent_has_completed*.

- *parent_add_failed* (indicating that the Action failed to be registered with the parent `ActivityCoordinator` due to any other error), the SignalSet indicates to the `ActivityCoordinator` through the CoordinationInformation (*useNextSignal* = true) that a subsequent signal shall be distributed. This next signal is *activity_rolledback*. The SignalSet will subsequently return the outcome *parent_add_failed*.

```
        if ( resName.equals("parent_has_completed") ||
                 resName.equals("parent_add_failed"))
        {
           _outcome = new Outcome(resName,(java.io.Serializable)null);
           _completionStatus = CompletionStatus.CompletionStatusFail;
           coordInfo = new CoordinationInformation(true,true);
        }

```

After providing the signal *activity_rolledback*, if the ONT SignalSet receives

- the Outcome response *compensate_failed* indicating that an Action fails to invoke *compensate* on the Compensator object the ONT SignalSet will return the outcome *heuristic_cannot_compensate*. The same signal is sent to any remaining actions, but no further signals are distributed.

```
      else if ( resName.equals("compensate_failed"))
      {
         _outcome = new Outcome("heuristic_cannot_compensate",
                                          (java.io.Serializable)null);
         coordInfo = new CoordinationInformation(false, false);
      }
```

A.2.2.5 Action Implementation

The OpenNested service implements the javax.activity.coordination.Action interface with an object that wraps the Compensator objects supplied by the application, and converts received signals to appropriate calls on those objects.

If the Open Nested service Action receives the *activity_committed* signal it then looks for a parent coordinator reference in the extended data of the signal:

```
public Outcome processSignal(Signal signal) throws ActionErrorException
{
    Outcome result = null;
    if (signal.getName().equals("activity_committed"))
    {
      ActivityCoordinator acp =
               (ActivityCoordinator)signal.getExtendedValue();
```

If a parent coordinator reference is found, the Action wraps its Compensator object in a new Action, and registers it with the parent coordinator. The activity_committed signal indicates to the Action that it is participating in an Activity that has, nominally, completed successfully, but which may need to be compensated later, which is why it needs to ‘promote’ its Compensator to the parent activity. The Action then returns the Outcome *parent_add_successful*. If the registration with the parent fails because the parent has completed (for example because of a timeout), it returns the Outcome *parent_has_completed*. If the registration with the parent fails due to any other failure, it returns the Outcome *parent_add_failed*.

```
      if (acp!=null)
      {
        try
        {
            int priority = _priority +
                    acp.getNumberRegisteredActions(“ONTSignalSet”);
            acp.addAction(new CompensateAction(_compensator,
                               priority),  “ONTSignalSet”, priority);
            result = new Outcome("parent_add_successful",
                                          (java.io.Serializable)null);
         } catch (IllegalStateException ie)
         {
            result = new Outcome("parent_has_completed",
                                      (java.io.Serializable)null);
         } catch (Exception e)
         {
            result = new Outcome("parent_add_failed",
                                          (java.io.Serializable)null);
         }
```

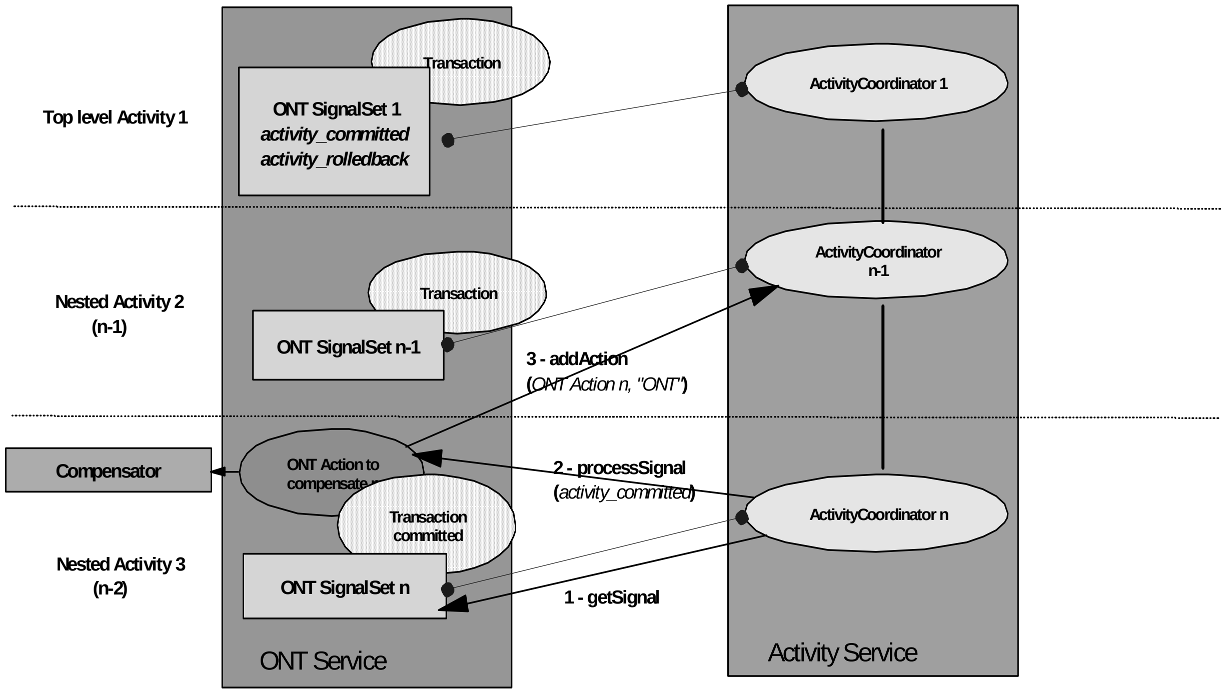

FIGURE 34 **Transactional Activity commitment and Compensation registrations**

If the parent scope commits successfully, the Action will then register with the next scope up; this recursively ends up in having all Compensator objects listed in the ONT Actions and having the ONT Actions registered to the top-level ONT SignalSet as illustrated in Figure 35.

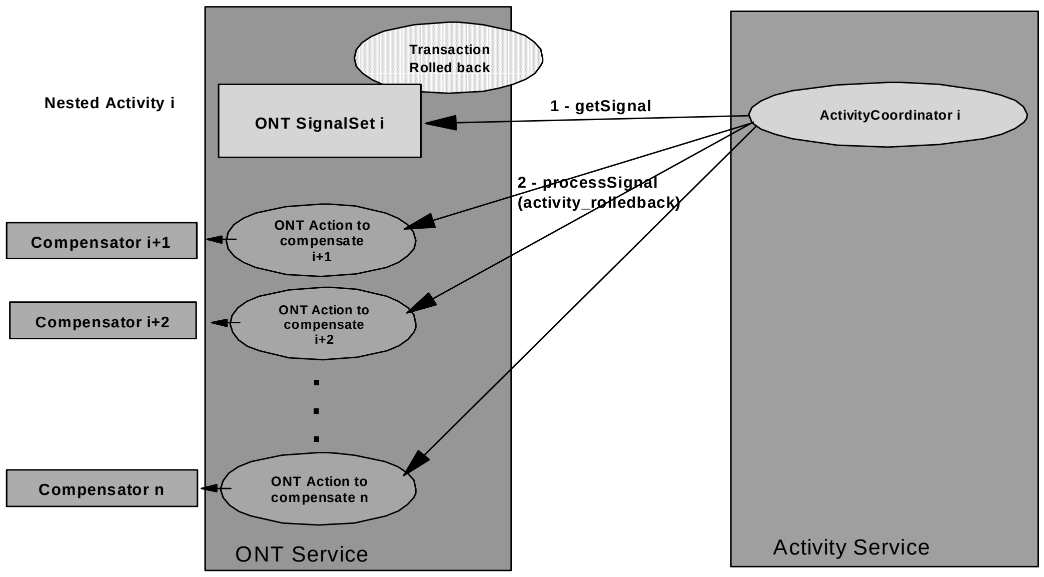

FIGURE 35 **Compensation on Activity rollback**

If the Action receives the *activity_committed* signal with a null parent `ActivityCoordinator`, it invokes a `forget` operation on the Compensator object to inform it about the final completion.

```
_compensator.forget();
result = new Outcome("compensate_successful",
                               (java.io.Serializable)null);
```

If the Action receives the *activity_rollback* signal, it invokes the `compensate` operation on the Compensator object. If the Action fails to invoke the Compensator object it returns the outcome *compensation_failed*.

```
try
{
    _compensator.compensate(null);
    result = new Outcome("compensate_successful",
                                       (java.io.Serializable)null);
}
catch (Exception e)
{
    result = new Outcome("compensate_failed",
                                       (java.io.Serializable)null);
}
```

After a timeout or once restarted, the OpenNested Service has the responsibility to inquire of its associated activity using the `getStatus` operation on the `ActivityCoordinator`. If the `ActivityCoordinator` has completed, the Open Nested Service invokes `compensate` on the Compensator object. It has the responsibility to retry the `compensate` method in case of failure.

An application programmer may invoke the creation of a transaction or an activity within the `compensate` operation. However if that transaction rolls back or the activity completes with failure, it is up to application to retry. The Open Nested Service which invokes `compensate` is not responsible for its behavior, but only responsible to reach the Compensator object.

A.2.3 Example Flow Sequence

The OpenNested Service is shown in Figure 36 to begin two ONT Activities. The inner activity and its associated transaction complete successfully, so the Compensator for this committed transaction is registered with the outer (parent) activity. In this example, when the parent activity is completed the associated transaction rolls back, so compensation of the first transaction is performed.

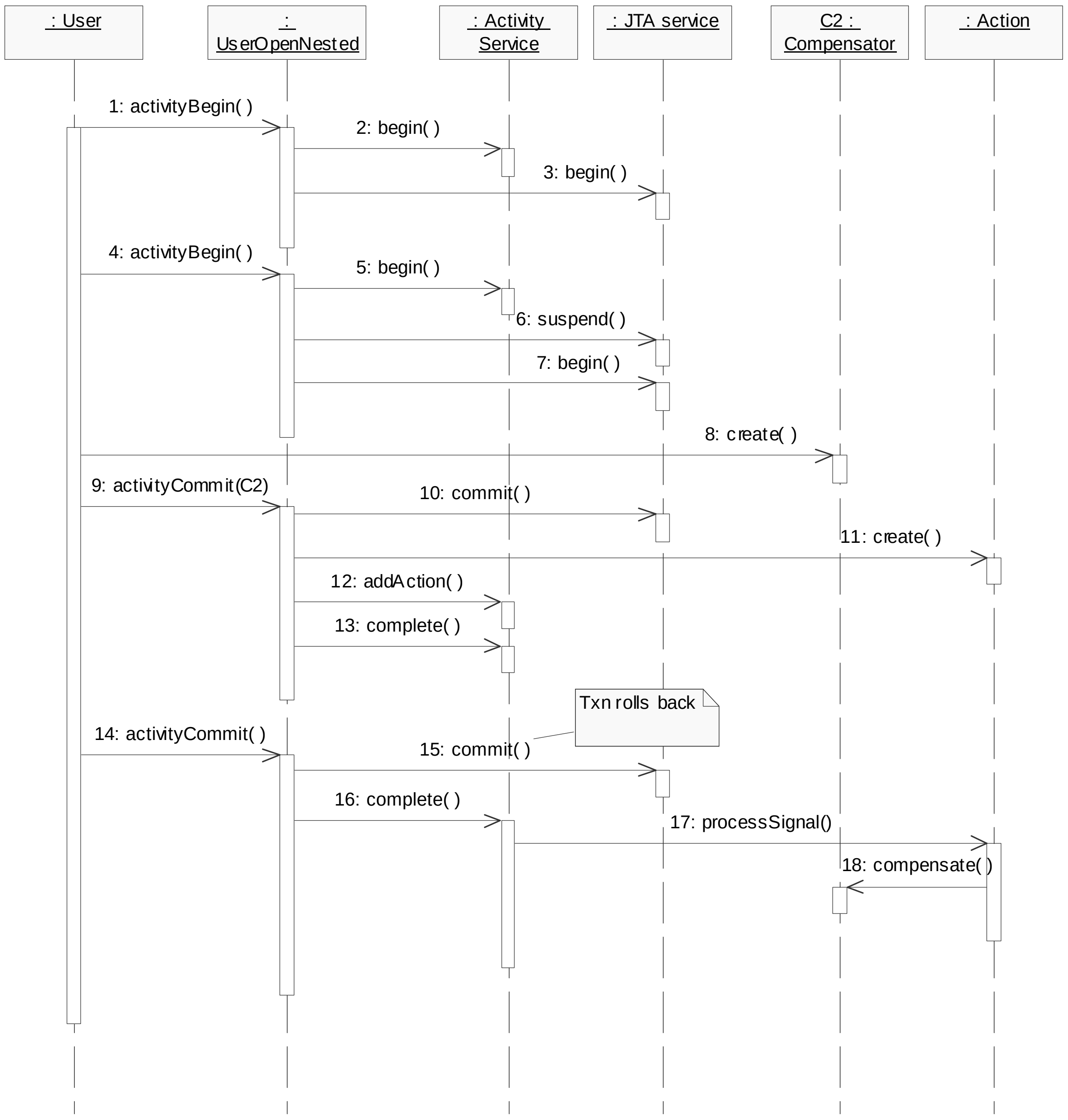

FIGURE 36 **Use of Open Nested Service: sequence diagram**

10. The user requests that the first (outer) ONT Activity is begun
11. The Open Nested service calls the Activity service to begin an activity.
12. The Open Nested service calls the transaction service to begin a JTA transaction.
13. The user requests that the second (inner) ONT Activity is begun.

14. The Open Nested Service calls the Activity service to begin a second activity, which is nested by the Activity service within the first activity.
15. The Open Nested Service calls the transaction service to suspend the first JTA transaction and to
16. begin a second JTA transaction.
17. The user performs some transactional work, and creates a Compensator object which can compensate that transactional work if necessary.
18. The user requests that the inner ONT Activity be committed.
19. The Open Nested Service commits the inner transaction successfully.
20. The Open Nested Service creates an Action to represent the Compensator for the committed transaction, and
21. adds it to the parent activity.
22. The inner activity is completed with CompletionStatusSuccess; there are no Actions registered with this activity so no signals are sent.
23. The user requests that the outer ONT Activity be committed.
24. The Open Nested Service tries to commit the associated transaction, but in this example, this transaction rolls back.
25. The Open Nested Service completes the outer activity with CompletionStatusFail, so
26. the *activity_rolledback* signal is sent to the Action which
27. calls `compensate` on the Compensator, thus compensating for the transactional work that was committed in step 10.

Appendix B Change History

B.3 Public draft 0.1, April 12 2003

B.3.1 Javadoc

- Added `RecoverableAction` class. Return this on `ServiceManager.getActions()`.
- Added a `recreateFlag` to `UserActivity.recreate()`.
- Added `recover` and `forget` methods to `UserActivity`.
- Added `ActivityCompletedException` to `ServiceManager` `recoverActions` and `recoverSignalSets` methods
- Added `completeActivity` and `heuristicComplete` methods to `ActivityCoordinator`
- Added `StatusCompletingHeuristic` to `Status`
- Added `hibernate` and `reactiviate` methods to `ActivityManager`
- Added `recoverPropertyGroup` to `PropertyGroupManager`
- Make `GlobalId` extend `Serializable`.

B.3.2 Specification

- “Introduction” on page 3 - tidied up language relating to web services.
- “Activity lifecycle” on page 21 - created this section. Introduced `hibernate` and `reactivate` function.
- “ActivityManager” on page 23 - associate `hibernate` and `reactivate` methods with `ActivityManager` interface.
- “PersistentActivityCoordinator” on page 25 - added this description of existing interface.
- “ServiceManager” on page 27 - specify JNDI location of ServiceManager implementation.
- “RecoverableAction” on page 28 - added description of this interface.
- “Recovery” on page 32 - updated section to describe the new option on `recreate` to control context association with thread after recovery and also the new `recover` and `forget` methods.
- “Heuristic Completion and timeout” on page 33 - created this section.
- “Recovering after failure” on page 48 - updated sequence diagram and description.