



Resource Management

Draft

77 Pages

Abstract

OSGi applications need hardware and software resources to perform their features. As these resources are limited, they have to be fairly shared between applications in order to preserve the global quality of service. Up to now, OSGi platforms delegate the resource management features to the Java Virtual Machines themselves or took advantage of some external Java Resource Management solution like JVM TI or JMX. Unfortunately, all of these resource management solutions provide features at the Object or Class level. This granularity is too low level to easily monitor resources consumed by OSGi applications.

This specification proposes a Resource Management solution fitting with OSGi model and constraints. Resources (CPU, memory, disk storage space, I/O) are monitored per bundle and can be enabled and disabled at runtime. When a bundle consumes too many resources, the Resource Management solution notifies interested applications and limits resource allocations.

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Feedback

This document can be downloaded from the OSGi Alliance design repository at <https://github.com/osgi/design>. The public can provide feedback about this document by opening a bug at <https://www.osgi.org/bugzilla/>.

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Terminology and Document Conventions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY" and "OPTIONAL" in this document are to be interpreted as described in 1.

Source code is shown in this typeface.

Revision History

The last named individual in this history is currently responsible for this document.

Revision	Date	Comments
Initial	03 06 2013	<i>Initial draft.</i> <i>RINQUIN Arnaud, Orange, arnaud.rinquin@orange.com</i> <i>BOTTARO André, Orange, andre.bottaro@orange.com</i> <i>BONNARDEL Grégory, Orange, gbonnardel.ext@orange.com</i>
v01	04 16 2013	<i>Some modifications after the Cologne meeting:</i> <ul style="list-style-type: none">• <i>Global Resource Context is now named as Platform Resource Context</i>• <i>Bandwidth Monitor → Socket Monitor</i>• <i>Resource Context persistence</i>• <i>Add a table indicating the type of Java object the ResourceMonitor.getUsage() method returns for each type of resource.</i>• <i>New paragraph about the use of the context switching operation (chapter 6.15 Resource Manager)</i>
V02	04 30 2013	<i>Fixes:</i> <ul style="list-style-type: none">• <i>Rewritings</i><ul style="list-style-type: none">◦ <i>Operation Summary</i>◦ <i>CPU Monitor</i>◦ <i>Socket Monitor</i>◦ <i>Framework Resource Context</i>• <i>Actions are taken by authorities</i> <i>Added:</i> <ul style="list-style-type: none">• <i>Resource Thresholds</i>• <i>Resource Event Types</i><ul style="list-style-type: none">• <i>Back To Normal</i>• <i>Back To Warning</i>

Revision	Date	Comments
V03	05 14 2013	<p><i>Fixes:</i></p> <ul style="list-style-type: none">• <i>Rewritings</i><ul style="list-style-type: none">◦ <i>Memory Monitor (OutOfMemoryException)</i>◦ <i>Implementation of all types of Resource Monitor is optional</i>◦ <i>Socket Monitor (existing sockets)</i>◦ <i>BACK_TO_NORMAL Resource Event → NORMAL Resource Event</i>◦ <i>BACK_TO_WARNING Resource Event → WARNING Resource Event</i> <p><i>Added:</i></p> <ul style="list-style-type: none">• <i>A new paragraph about algorithms reducing the number of Resource Event into the Considered Alternatives chapter.</i>• <i>Socket Monitor scope in Considered Alternatives</i>
V04	05 22 2013	<p><i>Fixes:</i></p> <ul style="list-style-type: none">• <i>Socket Monitor</i><ul style="list-style-type: none">◦ <i>only tracks bound or connected socket</i>◦ <i>throw a SocketException when an error threshold is reached</i>• <i>Rewritings</i><ul style="list-style-type: none">◦ <i>Disk Storage Monitor (exception)</i>◦ <i>Thread Monitor (exception)</i>
V05	05 28 2013	<p><i>Modifications:</i></p> <ul style="list-style-type: none">• <i>Add Resource Monitor Factory (new paragraph + entity diagram)</i>• <i>Change resource monitor threshold list to maximum and minimum threshold attributes</i>

Revision	Date	Comments
V06	06 04 2013	<p><i>Modifications:</i></p> <ul style="list-style-type: none"> • <i>Add ResourceContext.addMonitor() and ResourceContext.removeMonitor() methods.</i> • <i>Clarify the Resource Monitor state when a new instance is created by a ResourceMonitorFactory.</i> • <i>ResourceEvent.getResourceThreshold() returns a SNAPSHOT of the Resource Threshold instance at the moment when the event was generated.</i> • <i>Resource Thresholds:</i> <ul style="list-style-type: none"> ◦ <i>A Resource Monitor holds an upper Resource Threshold instance and a lower Resource Threshold.</i> ◦ <i>Add a diagram showing Resource Threshold state transitions. This diagram also shows what kind of Resource Event is generated.</i> • <i>Clarify which threads are monitored by a ThreadMonitor (alive thread = all threads which are in the RUNNABLE, BLOCKED, WAITING, TIMED_WAITING java state).</i>
V07	06 12 2013	<p><i>Modifications:</i></p> <ul style="list-style-type: none"> • <i>Refactoring of the Resource Event interface:</i> <ul style="list-style-type: none"> ◦ <i>Add getResourceType() method</i> ◦ <i>Add getValue() method</i> ◦ <i>Add getThresholdValue() method</i> ◦ <i>Add isUppperThreshold() method</i> ◦ <i>Remove getMonitor() method</i> ◦ <i>Remove getThreshold() method</i> ◦ <i>Remove getMonitor() method</i>
V08	06 19 2013	<p><i>Updates:</i></p> <ul style="list-style-type: none"> • <i>Replace ResourceMonitor.setMonitored(boolean) by ResourceMonitor.enable()/disable()</i> • <i>Replace ResourceMonitor.isMonitored() by ResourceMonitor.isEnabled()</i> • <i>Threshold diagram (new colors + state)</i>

Revision	Date	Comments
V09	06 26 2013	<p><i>Updates:</i></p> <ul style="list-style-type: none"> • <i>Resource Monitor Factory chapter</i> <ul style="list-style-type: none"> ◦ <i>the newly created Resource Monitor instance is disabled by default because it should be configured before activation.</i> ◦ <i>Resource Monitor instance MUST be created only by Resource Monitor Factory instance.</i> • <i>Add ResourceMonitor.isDeleted() method.</i> • <i>Considered Alternatives</i> <ul style="list-style-type: none"> ◦ <i>ResourceMonitor instantiations without ResourceMonitorFactory.</i>
V10	07 04 2013	<p><i>Updates:</i></p> <ul style="list-style-type: none"> • <i>Add a new diagram for upper threshold (cpu example)</i> • <i>The upper and lower threshold diagram has been adapted to the socket resource</i>
V11	07 10 2013	<ul style="list-style-type: none"> • <i>Replaced arrows by circles into diagrams related to Resource Thresholds. Removed the text on arrows/circle. Update diagram titles.</i>
V12	07 18 2013	<ul style="list-style-type: none"> • <i>Remove old references to connected socket → in-use state sockets</i> • <i>Remove old references to active/started threads → alive threads</i> • <i>Remove old reference to Bandwidth Monitor → Socket Monitor</i> • <i>Update Extensibility clause of the Essentials chapter (5 types of resources instead of 4).</i> • <i>New use case for the context switching operation (Event Handler use case)</i>
V13	07 23 2013	<ul style="list-style-type: none"> • <i>A Socket Monitor tracks native socket file descriptors.</i> • <i>Update UML Schema:</i> <ul style="list-style-type: none"> ◦ <i>add Resource Listener Implementer entity</i> ◦ <i>add Resource Monitor Factory Implementer entity</i> • <i>Update Operation Summary</i> • <i>Add new section in Considered Alternatives about compatibility implementation between bundles which handles ResourceManagement api and the other ones.</i>
V14	07 30 2013	<ul style="list-style-type: none"> • <i>Add EventAdmin and HttpService use cases into compatibility section</i> • <i>Describe how a bundle can manage Resource Management features (direct implementation, weaving, service proxy)</i>

Revision	Date	Comments
V15	08 06 2013	<ul style="list-style-type: none"> <i>ResourceManager entity registered as a service and accessible through the adapt method.</i>
V16	08 14 2013	<ul style="list-style-type: none"> <i>Introduce Resource Context Listener and Resource Context Event</i> <i>All Resource Context are retrieved through the Resource Manager service (Bundle.adapt() approach is deprecated)</i> <i>Thresholds are now hosted by Resource Listener</i> <i>Resource Threshold entities have been removed.</i>
V17	09 26 2013	<ul style="list-style-type: none"> <i>Exceptions thrown when a threshold is reached are now optional.</i> <i>Use of MemoryException instead of OutOfMemoryException</i>
V18	11 06 2013	<ul style="list-style-type: none"> <i>Introduce new methods in ResourceMonitor reporting resource context operations.</i>
V19	July 24, 2014	Antonin CHAZALET, Orange <ul style="list-style-type: none"> <i>Fix typos.</i> <i>Add several comments.</i>
v20	July 25 th , 2014	André Bottaro, Orange <ul style="list-style-type: none"> <i>Removed context switching feature in the specification chapter part. Put the main context switching feature descriptions into 'considered alternatives' section.</i> <i>Partially removed the link between resource context and threads. To be continued.</i>
V21	July 30 th , 2014	Antonin CHAZALET, Orange <ul style="list-style-type: none"> <i>Add javadoc.</i>
<u>V22</u>	<u>August 1st, 2014</u>	<u>Antonin CHAZALET, Orange</u> <u>André BOTTARO, Orange</u> <ul style="list-style-type: none"> <u><i>Remove "links" amongst Resource Context, and Thread.</i></u>

1 Introduction

Applications, executed on an OSGi platform, need hardware resources (CPU, memory, disk, storage space) and software resources (sockets, threads). As these resources are limited, applications have to share them in order to preserve system quality of service. This is a general fact in the Enterprise and Residential markets.

Providing fair resource management features is crucial for the Smart Home to emerge as Residential players are opening their gateway (or box) execution environment to third party applications. In this perspective, the framework administrator has to fairly offer the same guarantees to every actor sharing the platform.

Resource Monitoring is also vital to Cloud Computing scenarios where a management agent needs to ensure that SLAs agreed around the cloud offering are met. When a cloud node gets overloaded or fails this can affect the pre-agreed SLA and action needs to be taken. In a Cloud Computing scenario this may imply starting additional nodes, adjusting the provisioning state of the system by moving or adding deployments or indeed shutting down some nodes if the system become quiet. To be able to handle such scenarios the management agent will need to have visibility of the resource utilization of the cloud system as a whole, which encompasses a multiplicity of nodes and runtimes.

For the moment, existing OSGi specifications do not provide monitoring resource mechanism ensuring a fair resource sharing between bundles and applications. The underlying JVM provides only some standard mechanisms at a level that is too fine-grained, e.g., classes, objects, methods. The bundle being the smallest deployment unit of interest for platform administrator and application provides, this RFC defines an API compliant with the RFP [3].

Introduce the RFC. Discuss the origins and status of the RFC and list any open items to do.

2 Application Domain

Resources of environments are always limited and entities that share such environments should be aware of that. This is not different in OSGi environments. Each bundle consumes resources of different types. Some of them are required for the very basic operations, some others are nice to have, but all of them can run out and lead to situations where the bundle, a set of bundles that form an application, or even the framework as a whole is not operational anymore.

Problematic situations arise when a software unit binds a lot of resources but does not release them after normal operation. This can be caused by wrong implementations, wrong error handling or by intention in case of malware. Especially in environments with very limited resources and/or with a huge number of bundles/vendors it is crucial to monitor the state of bundles and their resource consumption and also to provide mechanisms to react on detected failures.

What are resources?

There are some obvious, basic resources like CPU, memory, disk-space, bandwidth. But new applications might introduce the need for new, different types of resources that are required for their normal operation (e.g., the

presence of certain external services and devices, room temperature etc.). Because of that it is impossible to provide a complete list of potential resources here. The following figure tries to illustrate that:

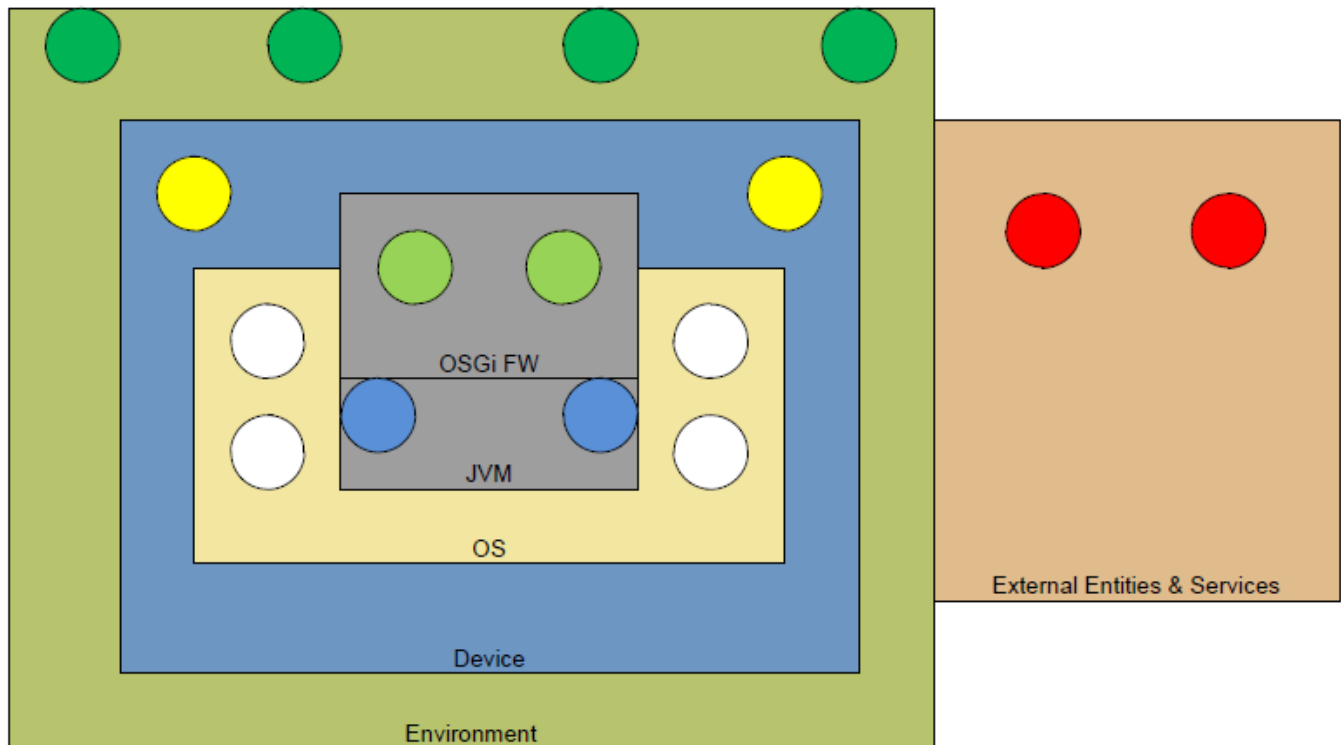


Figure 1: Origins of resources

Every circle in this picture stands for a certain resource. As illustrated these resources can come from:

- the same OSGi Framework (e.g., service instances, exported packages ...),
- the same Java VM (e.g., threads, memory ...),
- the device (e.g., USB-Ports,, network interfaces/ports ...),
- the local environment (e.g., room temperature, power consumption of the device, geo-location...),
- or from completely external locations (e.g., special external services like maps, dictionary ...).

Most common and crucial resources

Applications use hardware and operating system resources. Targeted resources are:

- CPU
- Memory
- Disk storage space
- Bandwidth on connected networks

JVMs allocate these resources when applications call Java standard APIs. They may provide resource monitoring mechanisms such as:

- Java Management Extension (JMX), now provided by all J2SE-v5-compliant JVM
- JVM Tool Interface (JVMTI) and JVM Profiler Interface (JVMPI)
- Proprietary resource management API (e.g., IBM J9, Oracle Java Embedded Client, /K/ Embedded Mika Max, Myriad Jbed)

The latter provide strict algorithms that charge bundles with consumed resources. There are two known algorithms [4].:

- Direct accounting: the resources consumed during bundle interaction are accounted to the code provider. In other words, the CPU used by a code that belongs to bundle A will be accounted to A, even if it is the bundle B that called this code through a public interface.
- Indirect accounting: all the resources consumed by the threads belonging to a bundle are accounted to this same bundle. Therefore in service interaction there is no resource consumption accounted to service providers.

Java and OSGi enables CPU management per bundle on any VM (without any VM customization) [4].[5].

However, memory management require that standard VMs either implement JVMTI Java standard [8]. or implement custom APIs. [6].[7]. These features are not available on standard VMs, with the following definition: a standard Java platform implements the JVM Specification [9]., Java Language Specification [10]. and base class libraries (<http://docs.oracle.com/javase/7/docs/api>). It does not include tools like javac, javadoc, JVMTI, tools.jar which are outside the Java platform specification.

What is Healthiness?

Healthiness of an entity (service, bundle, set of bundles, or the whole framework) is meant as the state where the entity is operational as it was specified and will be for the foreseeable future. The correct operation of such an entity is often strongly related to the availability, and perhaps a certain quality, of resources that the entity needs to work. That means an entity that doesn't have or get the required resources is not healthy. There might also be intermediate states where mandatory resources are there, but some optional ones are not available.

Other reasons for non-healthy entities are potential failure situations either inside the entity itself or in their environment. Sometimes such conditions cause shortage of other resources, which at the end affects other entities as well.

So, in order to ensure the healthiness of entities the first step that should be done is to ask themselves, "how do you feel?", and the second step is to know the entities resources requirements, and to monitor their availability.

Terminology and abbreviations

Application

A set of bundles needed to render a full application to the user.

Observable

An entity that is subject of Health monitoring. In the scope of this document this can be a framework, a bundle or a set of bundles.

Health

The state of an observable that describes its ability to work as specified.

Resource

A limited source or supply of physical or virtual goods that are used by bundles in order to provide their service(s).

Fault

The term fault is usually used to name a defect at the lowest level of abstraction, e.g., a memory cell that always returns the value 0.

Error

A fault may cause an error, which is a category of the system state.

Failure

An error, in effect, may lead to a failure, meaning that the system deviates from its correctness specification.

This section should be copied from the appropriate RFP(s). It is repeated here so it can be extended while the RFC authors learn more subtle details.

3 Problem Description

OSGi platforms host several applications which are executed concurrently. These applications have to share limited resources between them.

Cooperative applications

These mechanisms should also allow to estimate the severity of the situation and to decide for required actions to recover the intended state. Ideally, this should be done in cooperation with the bundle that causes the failure. If a failure situation is detected and can be assigned to a certain bundle, then first this bundle should have the chance to take actions to come back to a healthy state. If this is not successful, then appropriate actions must be taken by another entity.

Due to the wide range of potential failures and the definition of resources as very generic and application specific, this can not be achieved by a fixed and inflexible mechanism that handles a fixed set of predefined problems.

What is needed is a flexible framework that allows dynamic provisioning of modules to:

- collect information about resource requirements, and further, the normal, intended states of the monitored entities,
- monitor those resources (as defined above) and ask services for their health status,
- warn interested and legitimate applications when monitored consumptions are above thresholds,
- evaluate the severity of deviations of the currently monitored state from the intended state,
- take decisions and perform actions to recover the intended state,

- control/monitor the success of the actions taken.

Less cooperative or legacy applications

In case of an application consumes too much resources, it may affect the quality of service of the other applications installed on the platform. Those situations have to be prevented by OSGi platforms.

As described in the previous chapter, JVMs may provide resource management mechanisms. However, all these solutions are designed to monitor low granularity elements: e.g., threads, classes, objects or methods.

As such, these data are of limited interest and there is a need to raise the abstraction to the primitive deployment unit in OSGi, bundles and applications (or sets of bundles). This encourages the specification of a standard unified OSGi-level API managing resources of bundles and sets of bundles installed on the platform.

This section should be copied from the appropriate RFP(s). It is repeated here so it can be extended while the RFC authors learn more subtle details.

4 Requirements

R1: The solution MUST provide at least one resource accounting algorithm (e.g., direct accounting algorithm).

R2: The solution MUST monitor resources per bundle or per bundle set.

R3: The resource monitoring solution MUST be configurable, enabled and disabled at runtime per bundle or per bundle set.

R4: The solution MUST monitor the following resources, if relevant on the underlying (hardware and software) platform:

- CPU
- Memory
- Disk storage space
- Bandwidth on any connected network

R5: The solution MUST provide a mechanism to list the resource types that can be monitored on the underlying (hardware and software) platform.

R6: The solution MUST allow the setting of a warning threshold and an error threshold per bundle or set of bundles.

R7: The solution MUST send events while a bundle or a bundle set is exceeding one of the two thresholds defined by R6.

R8: The solution MUST define CPU thresholds as a percentage of use over a configurable period.

R9: The solution MUST define memory thresholds as bytes.

R10: The solution MUST define disk storage space thresholds as bytes.

R11: The solution **MUST** define thread thresholds as a number of threads.

R12: The solution **MUST** define socket thresholds as a number of opened sockets.

R13: The solution **MUST** be able to lower bundle thread priorities while CPU error threshold is reached.

R14: The solution **MUST** raise an error (e.g., `OutOfMemoryError`) and **MUST** prevent further memory allocation while memory error threshold is reached.

R15: The solution **MUST** raise an error (e.g., `IOException`) and **MUST** prevent further disk storage space allocation while disk storage space error threshold is reached.

R16: The solution **MUST** raise an error (e.g., `InternalError`) and **MUST** prevent further thread activation while thread error threshold is reached.

R17: The solution **MUST** raise an error (e.g., `IOException`) and **MUST** prevent further connected-state socket while socket error threshold is reached.

R18: The solution **MUST** define means for bundles to define their intend resource usage.

R19: The solution **MUST** allow OSGi applications to monitor bundles, evaluate their states and take decisions to react gracefully.

R20: The solution **MAY** define optional means for a bundle to resolve its own conflicts based on the decisions of the entity introduced in R19.

R21: Thanks to notification from R6, an application able to monitor the success of R20 **MAY** take actions, if the conflicts are not resolved after a period of time. Default action **MAY** be that the framework mechanism resolve this conflict.

R22: The solution **MUST** provide a mechanism that allows to plug application specific components to evaluate application specific resources.

R23: Special (non standard, see standard Java Runtime definition in section 2) Java platform implementations **MAY** be necessary to support management of certain resource types.

5 Initial Specification Chapter

Essentials

Monitoring – Bundle execution resource usage is monitored.

Granular activation – The resource manager can be activated and deactivated per bundle or per bundle set.

Extensibility – five resource types are specified (CPU, memory, disk storage, alive thread and in-use sockets). The list of monitored resource types is extensible and query-able.

Eventing – the resource manager notifies interested entities of exceeded limits.

Entities

Resource Context – A logical entity for resource accounting. A context may be related to a single bundle or a set of bundles.

System Resource Context – Resource context of the core framework.

Platform Resource Context – A Resource context monitoring the resource usage of the platform as a whole.

Resource Monitor – Monitors the usage of a specific resource type for a specific Resource Context. Resource Monitors track resource usage. They hold Resource Thresholds instances. Resource Monitor object implementation may depend on standard or proprietary JVM APIs, and on operating system features.

Resource Monitor Factory – a factory creating Resource Monitor instances for every Resource Context.

CPU Monitor – Resource Monitor used to monitor CPU.

Memory Monitor – Resource Monitor used to monitor memory.

Socket Monitor – Resource Monitor used to monitor socket resource.

Disk Storage Monitor – Resource Monitor for disk storage usage.

Thread Monitor – Resource Monitor used to monitor alive Java Thread objects.

Resource Listener – A Resource Listener receives resource threshold notifications.

Resource Event – A Resource Event defines a notification to be sent to Resource Listener instances.

Resource Context Listener – A Resource Context Listener receives notifications about resource context creation and configuration.

Resource Context Event – A Resource Context Event defines a notification to be sent to Resource Context Listeners instances.

Resource Manager – This is a singleton entity which manages Resource Context instances. It is used to create new Resource Context instances and to enumerate existing contexts.

Resource Management Authority – Makes any decision to ensure the quality of the service of the system. They use the Resource Manager to create Resource Context instances. It configures them by adding bundles and Resource Monitors.

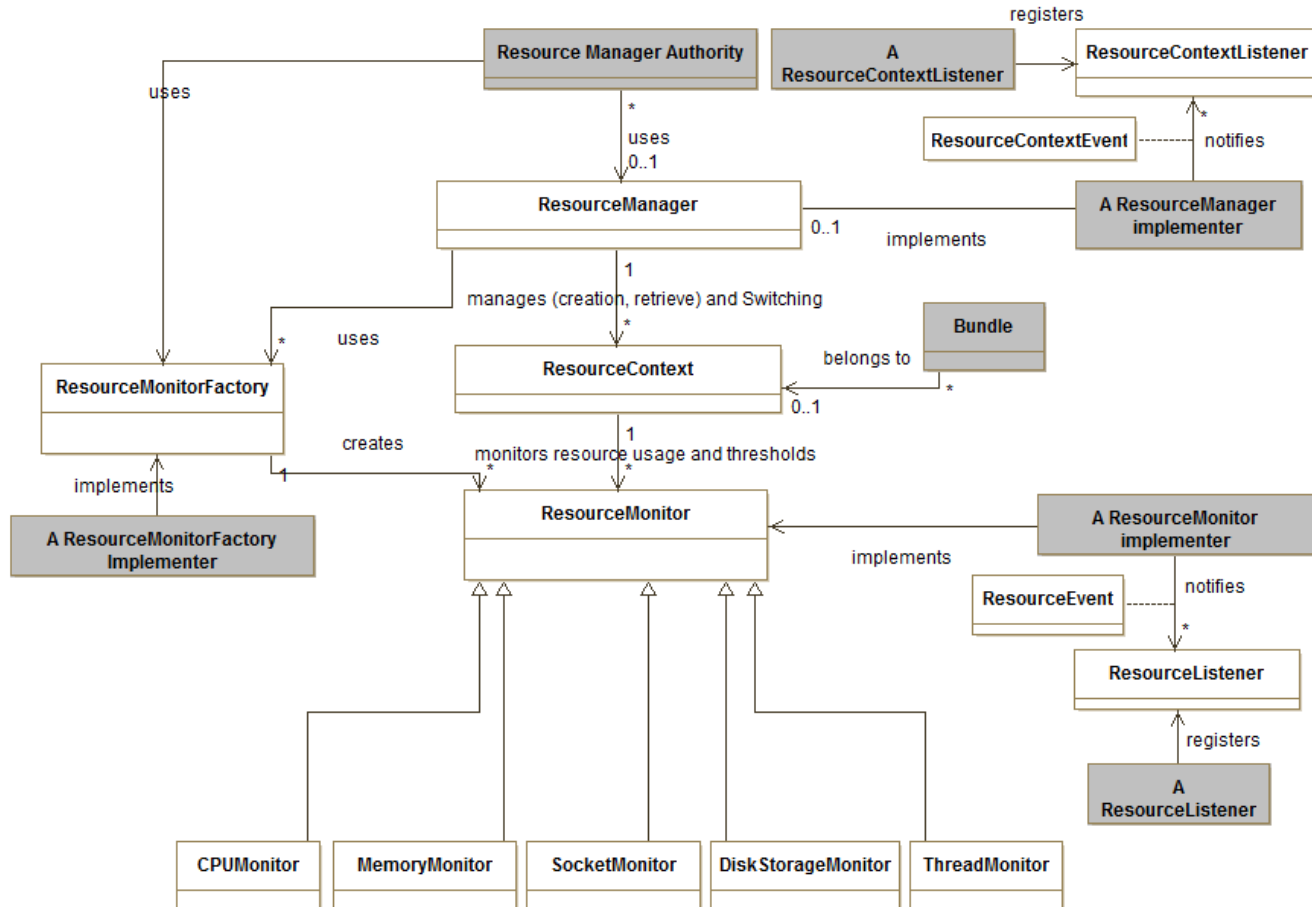


Figure 2: Resource management class diagram specification

Operation summary

Resource Management Authorities use the Resource Manager service to create Resource Contexts. These authorities set bundles or group of bundles to Resource Contexts. They also request every Resource Monitor Factory to create Resource Monitors for a resource type. These Resource Monitors are associated to a single Resource Context.

When activated, Resource Monitors provide the current resource usage per Resource Context. Then, they check whether the current resource usage is compatible with the thresholds held by their associated Resource Listeners. When one of these thresholds is violated, the related Resource Monitor notifies the Resource Listener holding this threshold.

The Resource Manager manages the set of Resource Contexts. Resource Contexts are persistent between platform restarts. Resource Context Listeners are notified when a Resource Context is created or deleted or when a Resource Context configuration (i.e., adding or removing of bundle) is updated.

Resource Context

A Resource Context instance is a logical entity used to account resource usage. Every Resource Context defines a bundle scope which can be either a single bundle or a set of bundles. Once the bundle scope is defined, resources used by those bundles are monitored through a set of per-resource-type Resource Monitor instances.

Resource Context instances are persistent. The persistence of those instances is directly managed by the Resource Manager instance.

Each Resource Context is uniquely identified by a name. It can be retrieved through the `getName()` method. It can not be changed, i.e. it is definitively set when the Resource Context instance is created.

The Resource Context bundle scope is retrieved through the `getBundles()` method. This bundle scope can be extended through the `addBundle(Bundle)` method. Bundles can also be removed from a Resource Context through the `removeBundle(Bundle, ResourceContext)` method. For this last method, a Resource Context instance MAY be specified in order to associate the removed bundle to another Resource Context instance.

Resource Monitor instances are retrieved through `getResourceMonitor(String resourceType)` method or the `getMonitors()` method. The list of available resource types is retrieved through the Resource Manager singleton instance.

Resource Monitor instances are added to and removed from a Resource Context instance by calling either `addMonitor()` method or `removeMonitor()` method. Both methods SHOULD only be called by `ResourceMonitorFactory` instances (see `ResourceMonitorFactory.createMonitor()` method).

A Resource Context is retrieved through the Resource Manager service.

A Resource Context instance can be deleted through `removeContext(ResourceContext)` method. The Resource Context input argument then defines a destination Resource Context instance for the bundles belonging to the to-be-removed Resource Context instance.

System Resource Context

The System Resource Context is the Resource Context of the core framework. It is retrieved through the Resource Manager service.

The name of this context is “system”.

Framework Resource Context

The Framework Resource Context is a Resource Context monitoring resources of the platform as a whole. It is retrieved through the Resource Manager service. This Resource Context holds all hosted bundles allowing access to the whole platform resource consumption.

The name of this context is “framework”.

Resource Monitor

A Resource Monitor instance monitors a resource type consumed by the bundles of a specific Resource Context instance.

A Resource Context instance holds at most one Resource Monitor instance per monitor-able resource type. Resource Monitor instances are retrieved through their related Resource Context instance. Resource Monitor instances give access to their related Resource Context instance through a call to `getContext()` method.

The monitored resource type is retrieved through `getType()` method.

The current usage of a resource consumed by a Resource Context instance is given through `getUsage()` method. This method returns a Java Object to be casted to the appropriate Java object type depending on the Resource type. The next table provides the expected Java Object type for each specified resource type:

Type of Resource	Expected Java Object type	Value description
CPU	Long	Cumulative CPU time in ns
Memory	Long	Allocated memory in bytes
Threads	Long	Number of alive thread.
Socket	Long	Number of in-use socket.
Disk storage space	Long	Bytes on the bundle persistent storage area

For example, for a Memory Monitor instance, a call to `MemoryMonitor.getUsage()` returns a Long java object indicating the amount of memory the related Resource Context instance is consuming.

A Resource Monitor instance is enabled and disabled through `enable()` and `disable()` methods. The state (enabled or disabled) of a Resource Monitor is retrieved through a call to `isEnabled()` method.

A Resource Monitor instance can also be deleted (`delete()` method). `isDeleted()` method returns true if the ResourceMonitor instance has been deleted.

Five types of Resource Monitor are specified:

- CPU Monitor
- Memory Monitor
- Socket Monitor
- Disk Storage Monitor
- Thread Monitor

The support of any Resource Monitor is optional. This list MAY be extended by the solution vendor. The list of the types that are supported on the OSGi platform can be computed by querying ResourceMonitorFactory services.

Resource Monitor Factory

A Resource Monitor Factory is a service that provides Resource Monitor instances of a specific resource type (e.g., CPUMonitor, MemoryMonitor...) for every Resource Context.

Every Resource Monitor Factory service is registered with the `org.osgi.resourcemanagement.ResourceType` mandatory property. This property indicates which type of Resource Monitor a Resource Monitor Factory is able to create. The type can also be retrieved through a call to `ResourceMonitorFactory.getType()`. The type MUST be unique (two Resource Monitor Factory instances MUST not have the same type).

New Resource Monitor instances are created by a call to `createResourceMonitor(ResourceContext)`. This method returns a new Resource Monitor instance associated to the provided Resource Context instance (the ResourceMonitorFactory MUST call `ResourceContext.addMonitor()` to associate the newly created ResourceMonitor with the provided ResourceContext instance). The newly created Resource Monitor is disabled, i.e., it is initially not monitoring the Resource Context resource consumption. It can be activated through a call to `ResourceMonitor.enable()`.

Resource Monitor instances are deleted by calling `ResourceMonitor.delete()` method.

A Resource Monitor instance MUST only be created through its ResourceMonitorFactory.

Resource Monitor Factory instances should be only used by the Resource Manager singleton instance. The Resource Manager singleton instance performs a service lookup on all existing Resource Monitor Factories. It

uses a Resource Monitor Factory instance when it has to create a new Resource Context instance and their associated Resource Monitor instances.

CPU Monitor

A CPU Monitor instance is a Resource Monitor used to monitor the CPU usage of the bundles belonging to a Resource Context.

CPU usage and thresholds are expressed as a cumulative number of nanoseconds (Long). The encapsulated value can be retrieved with the `CPUMonitor.getCPUUsage()` method.

In case where a threshold is reached, the CPU Monitor instance generates an event triggering Resource Authorities defined corrective actions (e.g., decrease thread priority).

Memory Monitor

A Memory Monitor instance monitors and limits the memory used by the bundles of a Resource Context instance.

Memory is accounted as bytes. Memory usage and thresholds are Long java objects. The encapsulated value can be retrieved through the `getMemoryUsage()` method.

When an error threshold is reached, the next memory allocation MAY throw a `MemoryException` in the associated context.

Socket Monitor

A Socket Monitor instance monitors and limits the number of existing sockets (e.g., TCP, UDP) which are considered to be in use (e.g., listening for incoming packet, bound, or sending outgoing packets).

A Socket is considered to be in-use state when a native socket file descriptor is created. It leaves this state when this socket file descriptor is deleted.

The number of in-use sockets is a Long. The encapsulated value can be retrieved using `SocketMonitor.getSocketUsage()` method.

When an ERROR threshold is reached, the next socket file descriptor creation in the associated context MAY throw a `SocketException`.

Disk Storage Monitor

A Disk Storage Monitor instance monitors and limits the use of persistent storage within Bundle Persistent Storage Area a Resource Context (the bundles actually belonging to it) consumes.

Disk Storage is expressed as a number of bytes of type Long. The encapsulated value can be retrieved using `DiskStorageMonitor.getUsedDiskStorage()` method.

A `IOException` MAY be thrown in the associated context when an error threshold is reached.

Thread Monitor

A Thread Monitor instance monitors and limits the number of alive Java Thread objects for a Resource Context instance. A Thread is considered to be alive when it is in the `RUNNABLE`, `BLOCKED`, `WAITING` or `TIMED_WAITING` java state.

Usage and thresholds are Java Long objects. The encapsulated value can be retrieved using `ThreadMonitor.getAliveThreads()` method.

When an error threshold is reached, any further thread activation will be prevented in the associated context. An `InternalError` exception MAY also be thrown in the associated context.

Resource Listener

A Resource Listener receives notifications about resource usage for a specific Resource Context and a specific type of resource. A notification will be sent to a Resource Listener when one of its thresholds is violated.

A Resource Listener holds two types of threshold:

- A lower threshold type. This kind of threshold is reached when the monitored resource usage decreases below the threshold.
- An upper threshold type. An upper threshold is reached when the monitored resource usage exceeds this threshold.

Each of them have two levels:

- a WARNING level
- an ERROR level.

A threshold has the following state diagram, which transitions are associated to events:

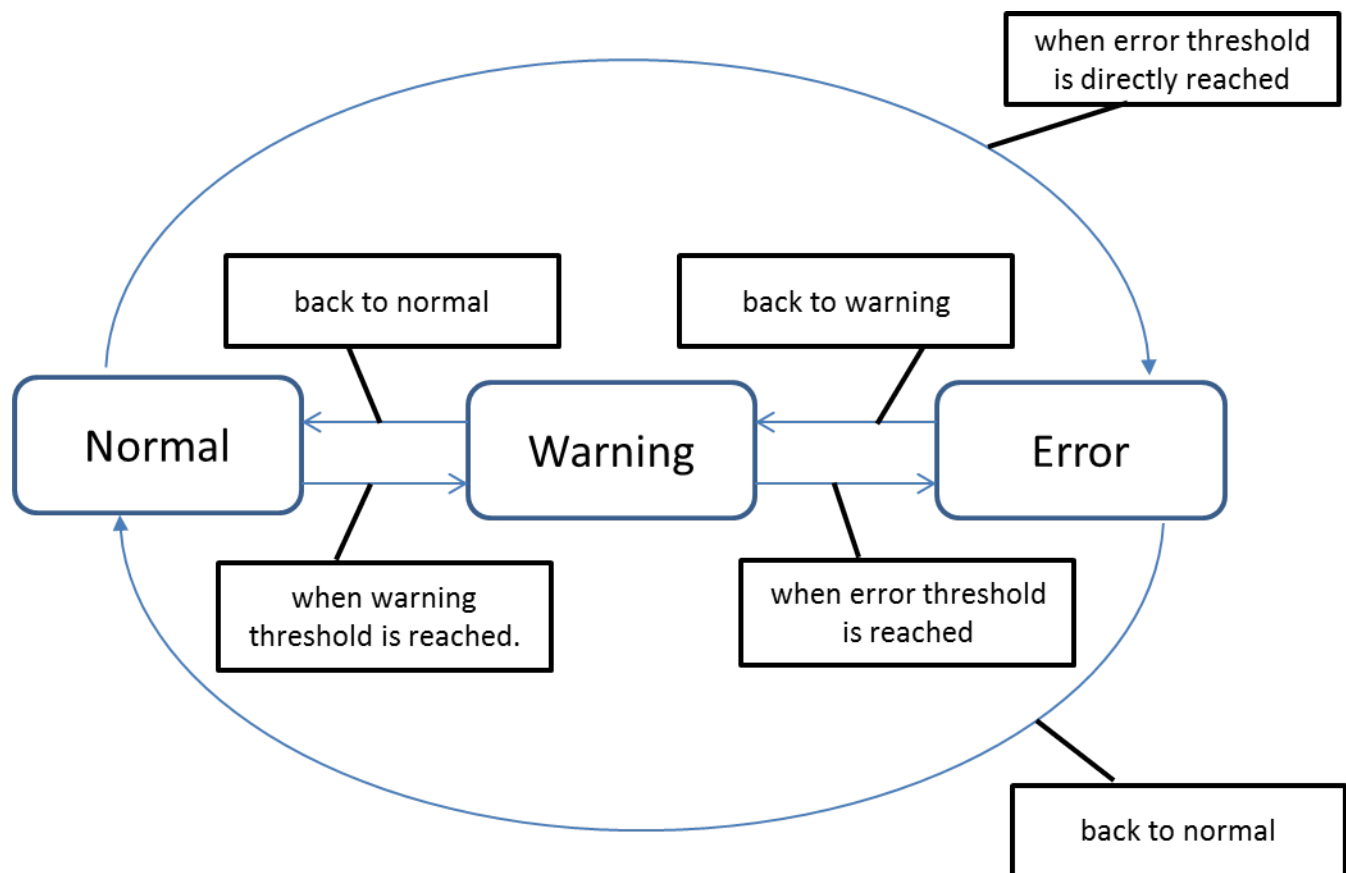


Figure 3: Threshold state diagram

A threshold state depends on the current consumption of resource and the type of threshold (upper or lower threshold).

A Resource Listener is registered as an OSGi service. The implementer must provide the two following mandatory properties:

- RESOURCE_CONTEXT property – a String defining the name of Resource Context for which the Listener want to receive threshold notifications.
- RESOURCE_TYPE property – a String defining which type of resource the listener wants to monitor.

It also has to provide at least one of these four properties when registered as an OSGi service:

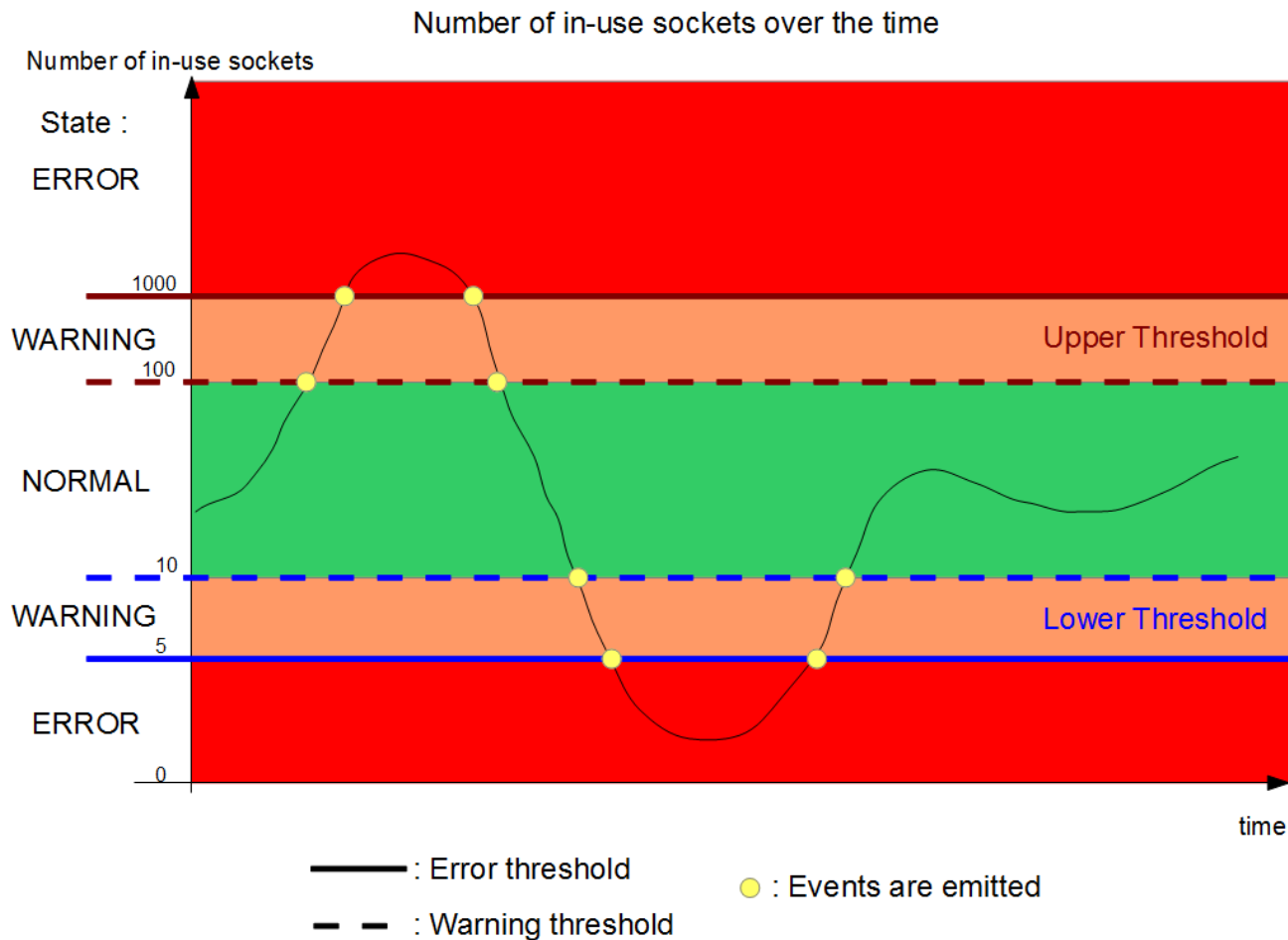
- UPPER_WARNING_THRESHOLD
- UPPER_ERROR_THRESHOLD
- LOWER_WARNING_THRESHOLD
- LOWER_ERROR_THRESHOLD

These properties are mapped to the four types of threshold values a Resource Listener may support. The service properties are used to notify the associated Resource Monitor when one of these threshold values is modified.

Threshold values can also be retrieved through a set of getter methods. All of these methods returns a Comparable object used by the associated Resource Monitor in order to determine the current state of the current usage.

RESOURCE_CONTEXT and RESOURCE_TYPE properties are used by Resource Monitors to identify their associated Resource Listeners. Once associated, a Resource Monitor retrieves the threshold settings using service properties. When one of its thresholds is reached, the Resource Monitor calls ResourceListener.notify(ResourceEvent).

Two examples of resource consumption are explained below, first with in-use sockets monitoring, second with CPU monitoring. The next picture shows the state diagram of the number of in-use state socket over the time.

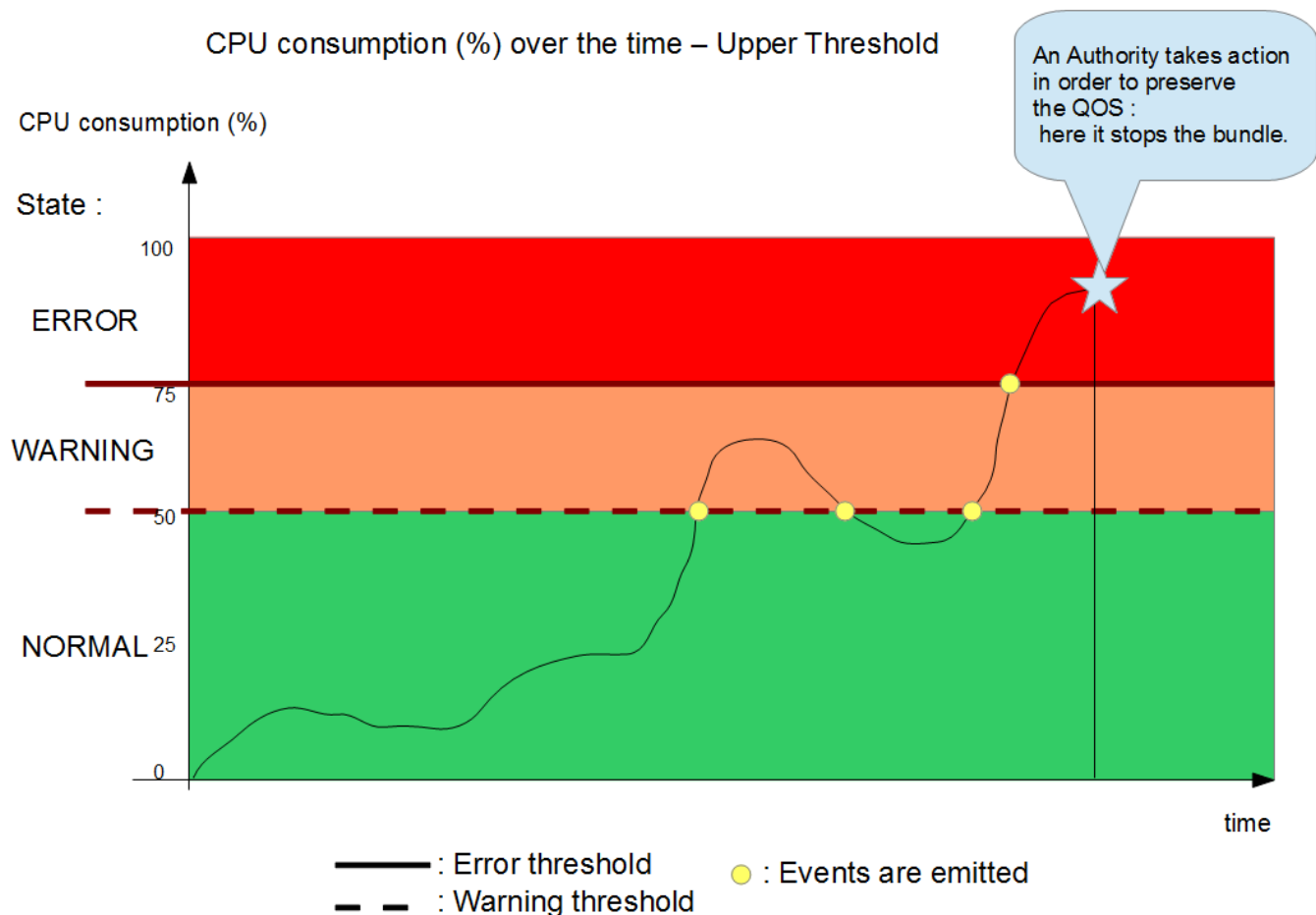


In our example, the lower warning threshold and the lower error threshold of the Resource Listener are respectively set to 10 and 5. When the number of in-use sockets decreases under 10, the usage goes from the NORMAL state to the WARNING state and the Resource Listener receives a WARNING event. If the number of in-use state sockets decreases again and goes down to 5, the usage goes from the WARNING state to the ERROR state and the Resource Listener receives a ERROR Resource Event.

The upper threshold is also set. The upper warning threshold and the upper error threshold are respectively set to 100 and 1000 in-use state sockets. When the number of sockets reaches 100, the usage goes from the NORMAL state to the WARNING state and the Resource Listener receives a WARNING Resource Event. If this number is still increasing and exceeds 1000, then the usage goes from the WARNING state to the ERROR state and the Resource Listener receives an ERROR Resource Event.

This is a typical use case for a Java Web server. Indeed, one of the most important quality of service indicator is the number of in-use state sockets a java web server is handling. A low number of in-use state sockets may indicate the java web server encounters network problems. On the contrary, a high number of in-use state socket may be the result of an external network attack or it could also indicates the java web server is overused and its administrator should take actions to load-balance the charge to another java web server instance.

For other resource types, only upper thresholds may be useful. The next diagram shows the CPU consumption a Resource Context is using over the time:



In this example, only the upper threshold is set. The upper warning threshold is set to 50%, the error one is set to 75%. CPU consumption fluctuates between 0 and 50%, the usage is in the NORMAL state. Then it increases and reaches 50%. The usage then goes from the NORMAL state to the WARNING state and the Resource Listener holding the threshold receives a WARNING Resource Event.

Afterwards, CPU consumption decreases under 50%; the usage goes from the WARNING state to the NORMAL state. The related Resource listener receives a NORMAL Resource Event.

It then increases again and exceeds 50%. The usage goes to the WARNING state. CPU consumption is still increasing and exceeds 75%. At this moment, the usage goes from the WARNING state to the ERROR state and the related Resource Listener receives an ERROR Resource Event.

After some seconds in the ERROR state, the Resource Listener implementation stops the bundle in order to preserve the quality of service.

The choice of the type of threshold (lower or upper, or both of them) depends on the type of resource and the needs of the Resource Management Authorities providing the Resource Listener. Other resources like the free memory may take advantage of a lower threshold.

Resource Event

A Resource Event instance is an event sent to a Resource Listener when one of its thresholds is reached. This event is notified to a Resource Listener through a call to `ResourceListener.notify(ResourceEvent)`.

A Resource Event has a type among the following ones:

- **ERROR** – The resource consumption reaches either the upper or the lower error threshold of the Resource Listener receiving this event,
- **WARNING** – The resource consumption reaches either the upper or the lower warning threshold of the Resource Listener receiving this event.
- **NORMAL** – The resource consumption is back from warning or error state to normal state.

The Resource Listener instance analyzes this event by calling the following methods:

- `getValue()` method returns the resource consumption at the time when the Resource Event instance was generated.
- `isUpperThreshold()` method returns true if the reached threshold is an upper threshold type. If this method returns false, this is a lower threshold.
- `getType()` method indicates the state (WARNING, ERROR, or NORMAL) of the resource usage.
- `getContext()` method returns the Resource Context instance related to this event. The Resource Listener can use it to retrieve the Resource Monitor instance (e.g., `event.getContext().getMonitor(event.getResourceType())`).

Resource Context Listener

A Resource Listener instance receives notifications about Resource Context lifecycle and configuration.

A notification will be sent when:

- A Resource Context is created.
- A Resource Context is updated, i.e., a bundle has been added or removed from a Resource Context instance.
- A Resource Context is deleted.

An application which is interested in notifications has to register a Resource Context Listener instance as an OSGi service. The application may provide a set of properties at registration time to reduce the number of notifications a Resource Listener instance will receive. The available properties are:

- **RESOURCE_CONTEXT** property – An array of String defining the name of Resource Context instances. If defined, a Resource Listener instance will only receive notifications related to these specified Resource Context instances.
- **RESOURCE_TYPE** property – an array of integers defining the type of notifications a Resource Context Listener instance will receive (see types defined in section Resource Context Event).

A Resource Context Listener instance is notified through a call to `notify(ResourceContextEvent)` method.

Resource Context Event

A Resource Context Event instance is an event sent to Resource Context Listener instances through a call to `ResourceContextListener.notify(ResourceContextEvent)` method.

A Resource Context Event has a type among the four following ones:

- **RESOURCE_CONTEXT_CREATED** – A new Resource Context instance has been created.
- **RESOURCE_CONTEXT_REMOVED** – A Resource Context instance has been deleted.
- **BUNDLE_ADDED** – A bundle has been added in the scope of a Resource Context instance
- **BUNDLE_REMOVED** – A bundle has been removed from the scope of a Resource Context instance.

In the case of a **RESOURCE_CONTEXT_ADDED** event or a **RESOURCE_CONTEXT_REMOVED** event, a call to `getContext()` returns the targeted Resource Context instance.

In the case of a **BUNDLE_ADDED** type or **BUNDLE_REMOVED** type, `getBundle()` returns the Bundle object to be added to or removed from. The related Resource Context instance is given by a call to `getContext()`.

Resource Manager

The Resource Manager service manages the Resource Context instances. The Resource Manager service is available through the OSGi service registry.

This service holds the existing Resource Context instances. Resource Context instances are created by calling the `createContext(String, ResourceContext)` method. The caller provides a context name as a string and optionally a template as a ResourceContext object.

The list of existing Resource Context instances can be retrieved through the following methods:

- `getContext(String)` – retrieve a Resource Context instance by name.
- ~~`getContext(Thread)` – retrieve the Resource Context instance related to a Thread.~~
- ~~`getCurrentContext()` – retrieve the Resource Context instance based on the current thread.~~
- `listContexts()` - retrieve all existing Resource Context instances as an array.

The Resource Manager singleton manages the persistence of the Resource Context instances. The following properties are stored:

- name of the Resource Context.
- list of the bundles belonging to the Resource Context.
- list of the Resource Monitor instances. For each one:
 - sampling period.

- monitoring period.

The way the Resource Manager persists the Resource Context instances is implementation specific. The implementer is free to use any file format and file location it wants. At startup, the Resource Manager will load the persisted Resource Context instances to restore shutdown state.

Resource Management Authority

A Resource Management Authority uses the Resource Manager singleton instance to apply Resource Management policies. These entities MAY:

- create and configure Resource Context instances (resource thresholds, bundle scope)
- take any decisions (stop a bundle, uninstall a bundle) if a Resource Context exceeds resource limit.

These policies are out of the scope of this specification.

6 Javadoc

OSGi Javadoc

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Package org.osgi.service.resourcemangement

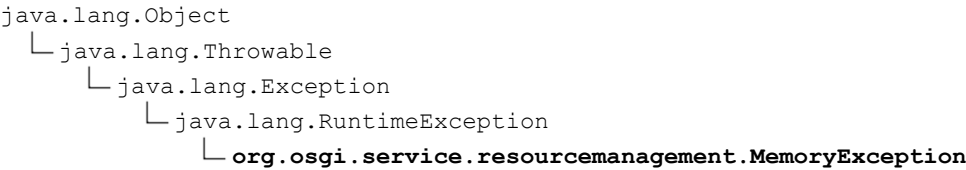
Interface Summary		Page
<u>ResourceContext</u>	Logical entity for resource accounting.	30
<u>ResourceContextListener</u>	A <code>ResourceContextListener</code> is notified whenever: <ul style="list-style-type: none"> a <u>ResourceContext</u> is created or deleted. 	38
<u>ResourceListener</u>	A <code>ResourceListener</code> is an OSGi service which is notified when a Resource Context violates one of the threshold defined by the listener.	43
<u>ResourceManager</u>	Monitor and manage resource contexts.	47
<u>ResourceMonitor</u>	Representation of the state of a resource for a resource context.	51
<u>ResourceMonitorFactory</u>	A <code>ResourceMonitorFactory</code> are OSGi services used to create <code>ResourceMonitor</code> instance.	56

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<u>ResourceEvent</u>	An event sent to <u>ResourceListener</u> when resource usage violates one of their thresholds.	40

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<u>MemoryException</u>	This exception is used to report that a Resource Context has reached an ERROR threshold about memory.	29
<u>ResourceMonitorException</u>	Resource Monitor Exception reports an invalid usage of a monitor.	55
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Class `MemoryException`

[org.osgi.service.resourcemangement](#)



All Implemented Interfaces:
`Serializable`

```
public class MemoryException
extends RuntimeException
```

This exception is used to report that a Resource Context has reached an ERROR threshold about memory.

Immutable

Constructor Summary		Page
MemoryException (long pMemoryUsage)	Create a new MemoryException	29

Method Summary		Page
long getMemoryUsage ()	Retrieves the memory consumption at the moment when this exception was thrown.	29

Constructor Detail

MemoryException

```
public MemoryException(long pMemoryUsage)
```

Create a new MemoryException

Parameters:
pMemoryUsage - the memory consumption at the moment when this exception was thrown

Method Detail

getMemoryUsage

```
public long getMemoryUsage()
```

Retrieves the memory consumption at the moment when this exception was thrown.

Returns:
memory consumption.

Interface ResourceContext

org.osgi.service.resourcemangement

```
public interface ResourceContext
```

Logical entity for resource accounting. A resource context has a group of member bundles, and a bundle can be a member of 1 or 0 resource contexts.

Management agents can use the [ResourceManager.createContext\(String, ResourceContext\)](#) method to create ResourceContext instances.

Management agents can use the [getMonitor\(String\)](#) method to get [ResourceMonitor](#) instances for the supported resource types. These instances can then be used to monitor the usage of the resources, or the set usage limits.

ResourceContexts are retrieved through the [ResourceManager](#) OSGi service.

ThreadSafe

Method Summary		Page
void	addBundle (long bundleId) Adds a bundle to the resource context.	31
void	addResourceMonitor (ResourceMonitor resourceMonitor) Add a new ResourceMonitor instance monitoring resource for this resource context.	32
boolean	equals (Object resourceContext) A ResourceContext rc1 is equals to ResourceContext rc2 if rc1.getName() is equals to rc2.getName().	33
long[]	getBundleIds () Returns the bundle identifiers belonging to this Resource Context.	31
ResourceMonitor	getMonitor (String resourceType) Returns a ResourceMonitor instance for the specified resource type.	32
ResourceMonitor[]	getMonitors () Retrieves all the existing ResourceMonitor belonging to this context.	32
String	getName () Returns the name of the resource context.	31
int	hashCode () Retrieves the hashCode value of a ResourceContext.	33
void	removeBundle (long bundleId) Removes the bundle identified by bundleId from the Resource Context.	31
void	removeBundle (long bundleId, ResourceContext destination) Removes the bundle from this resource context.	31
void	removeContext (ResourceContext destination) Removes a resource context.	33
void	removeResourceMonitor (ResourceMonitor resourceMonitor) Remove a ResourceMonitor instance from the context.	32

Method Detail

getName

String **getName**()

Returns the name of the resource context. Resource context names are unique within a framework instance.

Returns:

The resource context name

getBundleIds

long[] **getBundleIds**()

Returns the bundle identifiers belonging to this Resource Context.

Returns:

An array of `org.osgi.framework.Bundle` objects, or an empty array if no bundles are currently members of this context

addBundle

void **addBundle**(long bundleId)

Adds a bundle to the resource context. The bundle will be a member of the context until it is uninstalled, or explicitly removed from the context with [removeBundle\(long\)](#) method or [removeBundle\(long, ResourceContext\)](#) method.

Resources previously allocated by this bundle (in another resource context) will not be moved to this resource context. The change applies only for future allocations.

A [ResourceContextEvent](#) with type [ResourceContextEvent.BUNDLE_ADDED](#) will be sent.

Parameters:

bundleId - The bundle to add to this resource context

removeBundle

void **removeBundle**(long bundleId)

Removes the bundle identified by bundleId from the Resource Context. The bundle is no longer to this Resource Context.

Parameters:

bundleId - bundle identifier

removeBundle

void **removeBundle**(long bundleId,
[ResourceContext](#) destination)

Removes the bundle from this resource context. If a `destination` context is specified, the bundle will be added in it.

Resources previously allocated by this bundle will not be removed from the resource context. The change applies only for future allocations.

A [ResourceContextEvent](#) with type [ResourceContextEvent.BUNDLE_REMOVED](#) will be sent.

Parameters:

`bundleId` - the identifier of the bundle to be removed from the Resource Context
`destination` - A resource context in which to add the bundle, after removing it from this context. If no destination is provided (i.e. null), the bundle is not associated to a new Resource Context.

getMonitor

[ResourceMonitor](#) **getMonitor**(String resourceType)

Returns a ResourceMonitor instance for the specified resource type. If the ResourceManager implementation does not support this resource type, null is returned

Parameters:

`resourceType` - The resource type, for which a resource monitor is requested

Returns:

A ResourceMonitor instance, or null, if this resource type is not supported

getMonitors

[ResourceMonitor](#)[] **getMonitors**()

Retrieves all the existing ResourceMonitor belonging to this context.

Returns:

an array of ResourceMonitor. May be empty if no ResourceMonitor

addResourceMonitor

void **addResourceMonitor**([ResourceMonitor](#) resourceMonitor)
throws [ResourceMonitorException](#)

Add a new ResourceMonitor instance monitoring resource for this resource context. This method should be called only by ResourceMonitorFactory instance.

Parameters:

`resourceMonitor` - resourceMonitor instance to be added

Throws:

[ResourceMonitorException](#) - if resourceMonitor is associated to another context or resourceMonitor has been deleted.

removeResourceMonitor

void **removeResourceMonitor**([ResourceMonitor](#) resourceMonitor)

Remove a ResourceMonitor instance from the context.

Parameters:

`resourceMonitor` - resource monitor instance to be removed

removeContext

```
void removeContext (ResourceContext destination)
```

Removes a resource context. All resources allocated in this resource context will be moved to the `destination` context. If `destination` is null, these resources will no longer be monitored.

A [ResourceContextEvent](#) with type [ResourceContextEvent.RESOURCE_CONTEXT_DELETED](#) will be sent.

Parameters:

`destination` - The [ResourceContext](#) where the resources currently allocated by this resource context will be moved.

equals

```
boolean equals (Object resourceContext)
```

A ResourceContext rc1 is equals to ResourceContext rc2 if rc1.getName() is equals to rc2.getName().

Overrides:

`equals` in class `Object`

Parameters:

`resourceContext` - resource context

Returns:

true if getName().equals(resourceContext.getName())

hashCode

```
int hashCode ()
```

Retrieves the hashCode value of a ResourceContext. The hashCode value of a ResourceContext is only based on the hashCode value of the name of the context.

Overrides:

`hashCode` in class `Object`

Returns:

hashCode

Class ResourceContextEvent

org.osgi.service.resourcemangement

java.lang.Object

└─ [org.osgi.service.resourcemangement.ResourceContextEvent](#)

```
public class ResourceContextEvent
extends Object
```

Immutable

Field Summary		Page
static int	BUNDLE_ADDED A bundle has been added to e ResourceContext The ResourceContext.addBundle(long) method has been invoked	35
static int	BUNDLE_REMOVED A bundle has been removed from a ResourceContext ResourceContext.removeBundle(long) method or ResourceContext.removeBundle(long, ResourceContext) method have been invoked, or the bundle has been uninstalled	35
static int	RESOURCE_CONTEXT_CREATED A new ResourceContext has been created.	35
static int	RESOURCE_CONTEXT_DELETED A ResourceContext has been deleted The ResourceContext.removeContext(ResourceContext) method has been invoked	35

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Method Summary		Page
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long	getBundleId () Retrieves the identifier of the bundle being added to or removed from the Resource Context.	36
ResourceContext	getContext () Retrieves the Resource Context associated to this event	36
int	getType () Retrieves the type of this Resource Context Event.	36
int	hashCode ()	37
String	toString ()	37

Field Detail

RESOURCE_CONTEXT_CREATED

```
public static final int RESOURCE_CONTEXT_CREATED = 0
```

A new [ResourceContext](#) has been created.

The [ResourceManager.createContext\(String, ResourceContext\)](#) method has been invoked.

RESOURCE_CONTEXT_DELETED

```
public static final int RESOURCE_CONTEXT_DELETED = 1
```

A [ResourceContext](#) has been deleted

The [ResourceContext.removeContext\(ResourceContext\)](#) method has been invoked

BUNDLE_ADDED

```
public static final int BUNDLE_ADDED = 2
```

A bundle has been added to e [ResourceContext](#)

The [ResourceContext.addBundle\(long\)](#) method has been invoked

BUNDLE_REMOVED

```
public static final int BUNDLE_REMOVED = 3
```

A bundle has been removed from a [ResourceContext](#)

[ResourceContext.removeBundle\(long\)](#) method or [ResourceContext.removeBundle\(long, ResourceContext\)](#) method have been invoked, or the bundle has been uninstalled

Constructor Detail

ResourceContextEvent

```
public ResourceContextEvent(int pType,  
                           ResourceContext pResourceContext)
```

Create a new ResourceContextEvent. This constructor should be used when the type of the event is either [RESOURCE_CONTEXT_CREATED](#) or { [1](#).

Parameters:

pType - event type

pResourceContext - context

ResourceContextEvent

```
public ResourceContextEvent(int pType,  
                           ResourceContext pResourceContext,  
                           long pBundleId)
```

Create a new ResourceContextEvent. This constructor should be used when the type of the event is either [BUNDLE_ADDED](#) or [BUNDLE_REMOVED](#).

Parameters:

pType - event type
pResourceContext - context
pBundleId - bundle

Method Detail

getType

```
public int getType()
```

Retrieves the type of this Resource Context Event.

Returns:

the type of the event. One of:

- [RESOURCE_CONTEXT_CREATED](#)
- [RESOURCE_CONTEXT_DELETED](#)
- [BUNDLE_ADDED](#)
- [BUNDLE_REMOVED](#)

getContext

```
public ResourceContext getContext()
```

Retrieves the Resource Context associated to this event

Returns:

Resource Context.

getBundleId

```
public long getBundleId()
```

Retrieves the identifier of the bundle being added to or removed from the Resource Context.

This method returns a valid value only when [getType\(\)](#) returns:

- [BUNDLE_ADDED](#)
- [BUNDLE_REMOVED](#)

Returns:

the bundle id or -1 (invalid value) .

toString

```
public String toString()
```

Overrides:

toString in class Object

hashCode

```
public int hashCode()
```

Overrides:

hashCode in class Object

equals

```
public boolean equals(Object var0)
```

Overrides:

equals in class Object

Interface ResourceContextListener

org.osgi.service.resourcemangement

```
public interface ResourceContextListener
```

A ResourceContextListener is notified whenever:

- a [ResourceContext](#) is created or deleted.
- a bundle is added or removed from a [ResourceContext](#).

A ResourceContextListener is registered as an OSGi service. At the registration time, the following properties may be provided:

- the [RESOURCE_CONTEXT](#) property which limits the Resource Context for which notifications will be received. This property can be either a String value or an array of String. If this property is not set, the Resource Context Listener receives events from all the Resource Context.
- the [EVENT_TYPE](#) property. If set, this property filters the type of event this listener will receive. The value of this property can either a String (then, the Listener receives notifications about a single type) or an array of String (several types). The expected values for this property are the types defined by a [ResourceContextEvent](#):
 - [ResourceContextEvent.RESOURCE_CONTEXT_CREATED](#)
 - [ResourceContextEvent.RESOURCE_CONTEXT_DELETED](#)
 - [ResourceContextEvent.BUNDLE_ADDED](#)
 - [ResourceContextEvent.BUNDLE_REMOVED](#)

Field Summary		Page
String	EVENT_TYPE Property specifying the type of events this listener will receive.	38
String	RESOURCE_CONTEXT Property specifying the ResourceContext (s) for which a notification will be received by this listener.	38

Method Summary		Page
void	notify (ResourceContextEvent event) Notify this listener about a ResourceContext events.	39

Field Detail

RESOURCE_CONTEXT

```
public static final String RESOURCE_CONTEXT = "resource.context"
```

Property specifying the [ResourceContext](#)(s) for which a notification will be received by this listener.

The property value is either a string (i.e the name of the [ResourceContext](#)) and an array of string (several [ResourceContext](#)).

EVENT_TYPE

```
public static final String EVENT_TYPE = "event.type"
```

Property specifying the type of events this listener will receive. The expected values are the [ResourceContextEvent](#) types. It can be a String or an array of String.

Method Detail

notify

```
void notify(ResourceContextEvent event)
```

Notify this listener about a [ResourceContext](#) events.

Parameters:

event - event.

Class ResourceEvent

[org.osgi.service.resourcemangement](#)

```
java.lang.Object
└─ org.osgi.service.resourcemangement.ResourceEvent
```

```
public class ResourceEvent
extends Object
```

An event sent to [ResourceListener](#) when resource usage violates one of their thresholds.

`ResourceEvent` objects are delivered synchronously to all matching [ResourceListener](#) services. A type code is used to identify the event.

See Also:

[ResourceListener](#)

Immutable

Field Summary		Page
static int	ERROR Type of ResourceEvent indicating a threshold goes to the ERROR state.	41
static int	NORMAL Type of ResourceEvent indicating a threshold goes to the NORMAL state.	41
static int	WARNING Type of ResourceEvent indicating a threshold goes to the WARNING state.	41

Constructor Summary		Page
ResourceEvent (int pType, ResourceContext pContext, boolean pIsUpperThreshold, Object pValue)	Create a new ResourceEvent.	41

Method Summary		Page
boolean	equals (Object var0)	42
ResourceContext	getContext () Returns the resource context that caused the event.	42
int	getType () Returns the event type.	41
Object	getValue () Returns the resource consumption value.	41
int	hashCode ()	42
boolean	isUpperThreshold () Returns true if the threshold triggering this event is an upper threshold.	42
String	toString ()	42

Field Detail

NORMAL

```
public static final int NORMAL = 0
```

Type of ResourceEvent indicating a threshold goes to the NORMAL state.

WARNING

```
public static final int WARNING = 1
```

Type of ResourceEvent indicating a threshold goes to the WARNING state.

ERROR

```
public static final int ERROR = 2
```

Type of ResourceEvent indicating a threshold goes to the ERROR state.

Constructor Detail

ResourceEvent

```
public ResourceEvent(int pType,  
                     ResourceContext pContext,  
                     boolean pIsUpperThreshold,  
                     Object pValue)
```

Create a new ResourceEvent.

Method Detail

getType

```
public int getType()
```

Returns the event type. The type values are:

- [NORMAL](#)
- [WARNING](#)
- [ERROR](#)

Returns:

The event type

getValue

```
public Object getValue()
```

Returns the resource consumption value. Relevant only for event types [NORMAL](#), [WARNING](#) and [ERROR](#).

Returns:

the resource consumption value, or null if a resource monitor is not relevant

getContext

```
public ResourceContext getContext()
```

Returns the resource context that caused the event.

Returns:

The resource context that caused the event.

isUpperThreshold

```
public boolean isUpperThreshold()
```

Returns true if the threshold triggering this event is an upper threshold. This method is only used when [getType\(\)](#) returns [NORMAL](#), [WARNING](#) or [ERROR](#).

Returns:

true if it is an upper threshold.

hashCode

```
public int hashCode()
```

Overrides:

hashCode in class [Object](#)

equals

```
public boolean equals(Object var0)
```

Overrides:

equals in class [Object](#)

toString

```
public String toString()
```

Overrides:

toString in class [Object](#)

Interface ResourceListener

org.osgi.service.resourcemangement

```
public interface ResourceListener
```

A ResourceListener is an OSGi service which is notified when a Resource Context violates one of the threshold defined by the listener.

Every ResourceListener is associated to a specific Resource Context and a specific Resource type. It defines two types of thresholds: a lower and a upper. A lower threshold is reached when the resource usage decreases below the threshold. On the contrary, an upper threshold is reached when the resource usage exceeds the threshold.

Both lower or upper threshold are two levels : a warning level and error level. The warning level indicates the resource usage becomes to be critical but are still acceptable. The error level indicates the resource usage is now critical for the overall system and actions should be taken.

A Resource Listener is registered with these two mandatory properties:

- [RESOURCE_CONTEXT](#) which defines the ResourceContext associated to this Listener
- [RESOURCE_TYPE](#) which the type of resource

The next optional properties are used to specify threshold values. A ResourceListener must at least provides one of them:

- [UPPER_WARNING_THRESHOLD](#)
- [UPPER_ERROR_THRESHOLD](#)
- [LOWER_WARNING_THRESHOLD](#)
- [LOWER_ERROR_THRESHOLD](#)

These threshold values can also be retrieved through methods.

Resource Listeners are associated to a Resource Context and a Resource Monitor based on the [RESOURCE_CONTEXT](#) property and the [RESOURCE_TYPE](#) property (both of them are mandatory at registration time).

Once associated, the ResourceMonitor gets the threshold values through the service properties (i.e [UPPER_WARNING_THRESHOLD](#), [UPPER_ERROR_THRESHOLD](#), [LOWER_WARNING_THRESHOLD](#) and [LOWER_WARNING_THRESHOLD](#)) and store them. Once it detects a new resource consumption, it compares the new resource usage value with the thresholds provided by the Resource Listener. If the resource usage violates one of these thresholds, the Resource Monitor notifies the [ResourceListener](#) through a call to [notify\(ResourceEvent\)](#).

A ResourceMonitor tracks threshold value modification by using a `org.osgi.framework.ServiceListener`.

Field Summary		Page
String	LOWER_ERROR_THRESHOLD Optional property defining the value of the lower error threshold.	45
String	LOWER_WARNING_THRESHOLD Optional property defining the value of the lower warning threshold.	44
String	RESOURCE_CONTEXT Mandatory property specifying the Resource Context associated with the listener.	44
String	RESOURCE_TYPE Mandatory property defining the type of Resource (i.e the ResourceMonitor) associated to this Listener.	44
String	UPPER_ERROR_THRESHOLD Optional property defining the value of the upper error threshold.	44

String	UPPER_WARNING_THRESHOLD Optional property defining the value of the upper warning threshold.	44
--------	---	----

Method Summary		Page
Comparable	getLowerErrorThreshold() Retrieves the lower error threshold value set by the listener.	45
Comparable	getLowerWarningThreshold() Retrieves the lower warning threshold value set by the listener.	45
Comparable	getUpperErrorThreshold() Retrieves the upper error threshold value set by this listener.	46
Comparable	getUpperWarningThreshold() Retrieves the upper warning threshold value set by this listener.	45
void	notify(ResourceEvent event) Receives a resource management notification	45

Field Detail

RESOURCE_CONTEXT

```
public static final String RESOURCE_CONTEXT = "resource.context"
```

Mandatory property specifying the Resource Context associated with the listener.

RESOURCE_TYPE

```
public static final String RESOURCE_TYPE = "resource.type"
```

Mandatory property defining the type of Resource (i.e the ResourceMonitor) associated to this Listener.

UPPER_WARNING_THRESHOLD

```
public static final String UPPER_WARNING_THRESHOLD = "upper.warning.threshold"
```

Optional property defining the value of the upper warning threshold.

UPPER_ERROR_THRESHOLD

```
public static final String UPPER_ERROR_THRESHOLD = "upper.error.threshold"
```

Optional property defining the value of the upper error threshold.

LOWER_WARNING_THRESHOLD

```
public static final String LOWER_WARNING_THRESHOLD = "lower.warning.threshold"
```

Optional property defining the value of the lower warning threshold.

LOWER_ERROR_THRESHOLD

```
public static final String LOWER_ERROR_THRESHOLD = "lower.error.threshold"
```

Optional property defining the value of the lower error threshold.

Method Detail

notify

```
void notify(ResourceEvent event)
```

Receives a resource management notification

Parameters:

event - The [ResourceEvent](#) object

getLowerWarningThreshold

```
Comparable getLowerWarningThreshold()
```

Retrieves the lower warning threshold value set by the listener. If the resource usage decreases under this threshold value, the [notify\(ResourceEvent\)](#) will be called. The provided [ResourceEvent](#) then indicates the WARNING state is reached.

Returns:

a comparable object or null if no threshold is set.

getLowerErrorThreshold

```
Comparable getLowerErrorThreshold()
```

Retrieves the lower error threshold value set by the listener. If the resource usage decreases under this threshold, the [notify\(ResourceEvent\)](#) will be called. The provided [ResourceEvent](#) then indicates the ERROR state is reached.

Returns:

a comparable object or null if no threshold is set.

getUpperWarningThreshold

```
Comparable getUpperWarningThreshold()
```

Retrieves the upper warning threshold value set by this listener. If the resource usage exceeds this threshold, the [notify\(ResourceEvent\)](#) method will be called. The provided [ResourceEvent](#) then indicates the WARNING state is reached.

Returns:

a comparable object or null if no threshold is reached.

getUpperErrorThreshold

Comparable **getUpperErrorThreshold()**

Retrieves the upper error threshold value set by this listener. If the resource usage exceeds this threshold, the [notify\(ResourceEvent\)](#) will be called. The provided [ResourceEvent](#) then indicates the ERROR state is reached.

Returns:

a comparable object or null if no threshold is reached.

Interface ResourceManager

org.osgi.service.resourcemanagement

```
public interface ResourceManager
```

Monitor and manage resource contexts.

The ResourceManager is a service OSGi.

ThreadSafe

Field Summary		Page
String	FRAMEWORK_CONTEXT_NAME The name of the special, optional resource context, representing the whole OSGi framework.	48
String	RES_TYPE_CPU The name of the CPU resource type, used to monitor and control the CPU time used by a resource context.	48
String	RES_TYPE_DISK_STORAGE The name of the disk storage resource type, used to monitor and control the size of the persistent storage used by a resource context.	48
String	RES_TYPE_MEMORY The name of the memory resource type, used to monitor and control the size of the java heap used by a resource context.	48
String	RES_TYPE_SOCKET The name of the socket resource type, used to monitor and control the number of existing sockets used by a resource context.	48
String	RES_TYPE_THREADS The name of the threads resource type, used to monitor and control the number of threads created by a resource context.	48
String	SYSTEM_CONTEXT_NAME The name of the Resource Context associated with System bundle (bundle 0).	48

Method Summary		Page
ResourceContext	createContext (String name, ResourceContext template) Creates a new ResourceContext .	49
ResourceContext	getContext (String name) Returns the context with the specified name	49
ResourceContext	getContext (long bundleId) Returns the ResourceContext associated to the provided bundle	49
String[]	getSupportedTypes () Returns a list with the supported resource type names.	50
ResourceContext []	listContext () Lists all available resource contexts .	49

Field Detail

RES_TYPE_THREADS

```
public static final String RES_TYPE_THREADS = "resource.type.threads"
```

The name of the threads resource type, used to monitor and control the number of threads created by a resource context. `ResourceManager` implementations must create [ThreadMonitor](#) instances for this resource type.

RES_TYPE_CPU

```
public static final String RES_TYPE_CPU = "resource.type.cpu"
```

The name of the CPU resource type, used to monitor and control the CPU time used by a resource context. `ResourceManager` implementations must create [CPUMonitor](#) instances for this resource type.

RES_TYPE_DISK_STORAGE

```
public static final String RES_TYPE_DISK_STORAGE = "resource.type.disk.storage"
```

The name of the disk storage resource type, used to monitor and control the size of the persistent storage used by a resource context. `ResourceManager` implementations must create [DiskStorageMonitor](#) instances for this resource type.

RES_TYPE_MEMORY

```
public static final String RES_TYPE_MEMORY = "resource.type.memory"
```

The name of the memory resource type, used to monitor and control the size of the java heap used by a resource context. `ResourceManager` implementations must create [MemoryMonitor](#) instances for this resource type.

RES_TYPE_SOCKET

```
public static final String RES_TYPE_SOCKET = "resource.type.socket"
```

The name of the socket resource type, used to monitor and control the number of existing sockets used by a resource context. `ResourceManager` implementations must create [SocketMonitor](#) instances for this resource type.

FRAMEWORK_CONTEXT_NAME

```
public static final String FRAMEWORK_CONTEXT_NAME = "framework"
```

The name of the special, optional resource context, representing the whole OSGi framework.

SYSTEM_CONTEXT_NAME

```
public static final String SYSTEM_CONTEXT_NAME = "system"
```


The name of the Resource Context associated with System bundle (bundle 0).

Method Detail

listContext

[ResourceContext](#)[] **listContext**()

Lists all available [resource contexts](#). The list will contain the special [FRAMEWORK_CONTEXT_NAME](#) context and the [SYSTEM_CONTEXT_NAME](#) context, if it is supported.

Returns:

An array of [ResourceContext](#) objects, or an empty array, if no contexts have been created.

createContext

[ResourceContext](#) **createContext**(String name,
[ResourceContext](#) template)

Creates a new [ResourceContext](#).

A [ResourceContextEvent](#) with type [ResourceContextEvent.RESOURCE_CONTEXT_CREATED](#) will be sent.

Parameters:

name - The name identifying the context. Names must be unique within the framework instance.

template - If a template is provided, the new resource context will inherit all resource monitoring settings (enabled monitors, thresholds) from the template.

Returns:

A new [ResourceContext](#) instance.

getContext

[ResourceContext](#) **getContext**(String name)

Returns the context with the specified name

Parameters:

name - The resource context name

Returns:

An existing [ResourceContext](#) with the specified name, or null if such a context doesn't exist

getContext

[ResourceContext](#) **getContext**(long bundleId)

Returns the [ResourceContext](#) associated to the provided bundle

Parameters:

bundleId - bundle identifier

Returns:

the [ResourceContext](#) associated to bundle b or null if the bundle b does not belong to a Resource Context.

getSupportedTypes

`String[] getSupportedTypes()`

Returns a list with the supported resource type names.

Returns:

An array containing the names of all resource types that this ResourceManager implementation supports.

Interface ResourceMonitor

org.osgi.service.resourcemangement

All Known Subinterfaces:

[CPUMonitor](#), [DiskStorageMonitor](#), [MemoryMonitor](#), [SocketMonitor](#), [ThreadMonitor](#)

```
public interface ResourceMonitor
```

Representation of the state of a resource for a resource context.

ResourceMonitor objects are returned by the [ResourceContext.getMonitor\(String\)](#) method.

The `ResourceMonitor` object may be used to:

- Enable/Disable the monitoring of the corresponding resource type for the corresponding resource context
- View the current usage of the resource by this resource context

A resource monitor can have a sampling period, a monitored period, or both. For example, for CPU monitoring, the resource management implementation can get the CPU usage of the running threads once per minute, and calculate the CPU usage per context in percentages based on the last ten such measurements. This will make a 60 000 milliseconds sampling period, and a 600 000 milliseconds monitored period.

ThreadSafe

Method Summary		Page
void	delete() Disable and delete this instance of Resource Monitor.	52
void	disable() Disable the monitoring of this resource type for the resource context associated with this monitor instance.	53
void	enable() Enable the monitoring of this resource type for the resource context associated with this monitor instance.	53
boolean	equals(Object resourceMonitor) Checks if resourceMonitor is equals to the current instance.	54
ResourceContext	getContext() Returns the resource context that this monitor belongs to	52
long	getMonitoredPeriod() Returns the time period for which the usage of this resource type is monitored.	54
String	getResourceType() The name of the resource type that this monitor represents	52
long	getSamplingPeriod() Returns the sampling period for this resource type.	53
Comparable	getUsage() Returns an object representing the current usage of this resource type by this resource context.	53
int	hashCode() Retrieves the hashCode value of this ResourceMonitor.	54
boolean	isDeleted() Returns true if the ResourceMonitor instance has been deleted, i.e. the delete() method has been called previously.	52

boolean	isEnabled() Checks if the monitoring for this resource type is enabled for this resource context	52
void	notifyIncomingThread (Thread t) Reports thread t is now attached to the ResourceContext associated to this monitor.	54
void	notifyOutgoingThread (Thread t) Reports thread t is leaving the ResourceContext associated with this monitor.	54

Method Detail

getContext

[ResourceContext](#) **getContext()**

Returns the resource context that this monitor belongs to

Returns:

The associated [ResourceContext](#)

getResourceType

String **getResourceType()**

The name of the resource type that this monitor represents

Returns:

The name of the monitored resource type

delete

void **delete()**

Disable and delete this instance of Resource Monitor. This method MUST update the list of ResourceMonitor instances hold by the Resource Context ([getContext\(\).removeMonitor\(this\)](#)).

isEnabled

boolean **isEnabled()**

Checks if the monitoring for this resource type is enabled for this resource context

Returns:

`true` if monitoring for this resource type is enabled for this context, `false` otherwise

isDeleted

boolean **isDeleted()**

Returns true if the ResourceMonitor instance has been deleted, i.e. the [delete\(\)](#) method has been called previously.

Returns:

true if deleted.

enable

```
void enable()  
    throws ResourceMonitorException,  
           IllegalStateException
```

Enable the monitoring of this resource type for the resource context associated with this monitor instance. This method SHOULD also update the current resource consumption value (to take into account all previous resource allocations and releases occurred during the time the monitor was disabled).

Throws:

[ResourceMonitorException](#) - if the ResourceMonitor instance can not be enabled (for example some MemoryMonitor implementations evaluate the memory consumption by tracking memory allocation operation at runtime. This kind of Monitor can not get instantaneous memory value. Such Monitor instances need to be enabled at starting time.)

IllegalStateException - if the ResourceMonitor instance has been previously deleted

disable

```
void disable()  
    throws IllegalStateException
```

Disable the monitoring of this resource type for the resource context associated with this monitor instance. The resource usage is not available until it is enabled again.

Throws:

IllegalStateException - if the ResourceMonitor instance has been previously deleted

getUsage

```
Comparable getUsage()  
    throws IllegalStateException
```

Returns an object representing the current usage of this resource type by this resource context.

Returns:

The current usage of this resource type.

Throws:

IllegalStateException - if the ResourceMonitor instance is not enabled.

getSamplingPeriod

```
long getSamplingPeriod()
```

Returns the sampling period for this resource type.

Returns:

The sampling period in milliseconds, or -1 if a sampling period is not relevant for this resource type.

getMonitoredPeriod

long **getMonitoredPeriod()**

Returns the time period for which the usage of this resource type is monitored.

Returns:

The monitored period in milliseconds, or -1 if a monitored period is not relevant for this resource type.

notifyIncomingThread

void **notifyIncomingThread**(Thread t)

Reports thread t is now attached to the [ResourceContext](#) associated to this monitor.

Parameters:

t - the newly attached thread

notifyOutgoingThread

void **notifyOutgoingThread**(Thread t)

Reports thread t is leaving the [ResourceContext](#) associated with this monitor.

Parameters:

t - leaving thread

equals

boolean **equals**(Object resourceMonitor)

Checks if resourceMonitor is equals to the current instance. A ResourceMonitor rm1 is equals to a ResourceMonitor rm2 if rm1.getContext().equals(rm2.getContext()) and r1.getType().equals(rm2.getType()).

Overrides:

equals in class Object

Returns:

true if the current instance is equals to the provided resourceMonitor

hashCode

int **hashCode**()

Retrieves the hashCode value of this ResourceMonitor. The hashCode value is based on the hashCode value of the associated ResourceContext and the hashCode value of the type.

Overrides:

hashCode in class Object

Returns:

hashcode

Class ResourceMonitorException

[org.osgi.service.resourcemangement](#)



All Implemented Interfaces:

Serializable

```
public class ResourceMonitorException
extends Exception
```

Resource Monitor Exception reports an invalid usage of a monitor.

Constructor Summary	Page
ResourceMonitorException (String msg) Create a new ResourceMonitorException	55

Constructor Detail

ResourceMonitorException

```
public ResourceMonitorException (String msg)
```

Create a new ResourceMonitorException

Parameters:

msg - message

Interface ResourceMonitorFactory

[org.osgi.service.resourcemangement](#)

public interface **ResourceMonitorFactory**

A ResourceMonitorFactory are OSGI services used to create ResourceMonitor instance. These factories should only be used by ResourceManager singleton or authorities.

Field Summary		Page
String	RESOURCE_TYPE_PROPERTY RESOURCE_TYPE_PROPERTY	56

Method Summary		Page
ResourceMonitor	createResourceMonitor (ResourceContext resourceContext) Create a new ResourceMonitor instance.	56
String	getType () Return the type of ResourceMonitor instance this factory is able to create.	56

Field Detail

RESOURCE_TYPE_PROPERTY

```
public static final String RESOURCE_TYPE_PROPERTY = "org.osgi.resourcemangement.ResourceType"  
  
RESOURCE_TYPE_PROPERTY
```

Method Detail

getType

String **getType**()

Return the type of ResourceMonitor instance this factory is able to create.

Returns:
factory type

createResourceMonitor

```
ResourceMonitor createResourceMonitor (ResourceContext resourceContext)  
throws ResourceMonitorException
```

Create a new ResourceMonitor instance. This instance is associated with the ResourceContext instance provided as argument ([ResourceContext.addResourceMonitor\(ResourceMonitor\)](#) is called by the factory). The newly ResourceMonitor instance is disabled. It can be enabled by calling [ResourceMonitor.enable\(\)](#).

Parameters:

`resourceContext` - ResourceContext instance associated with the newly created ResourceMonitor instance

Returns:

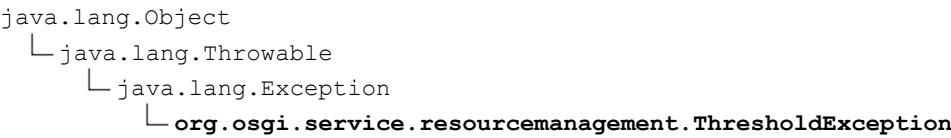
a ResourceMonitor instance

Throws:

[ResourceMonitorException](#)

Class ThresholdException

[org.osgi.service.resourcemangement](#)



All Implemented Interfaces:

Serializable

```
public class ThresholdException
extends Exception
```

Threshold exception are thrown an invalid threshold setting is detected.

Constructor Summary	Page
ThresholdException()	58

Constructor Detail

ThresholdException

```
public ThresholdException()
```

Package org.osgi.service.resourcemangement.monitor

Interface Summary		Page
<i>CPU</i>Monitor	A ResourceMonitor for the ResourceManager.RES_TYPE_CPU resource type.	60
<i>DiskStorage</i>Monitor	A ResourceMonitor for the ResourceManager.RES_TYPE_DISK_STORAGE resource type.	61
<i>Memory</i>Monitor	A ResourceMonitor for the ResourceManager.RES_TYPE_MEMORY resource type.	62
<i>Socket</i>Monitor	A ResourceMonitor for the ResourceManager.RES_TYPE_SOCKET resource type.	63
<i>Thread</i>Monitor	A ResourceMonitor for the ResourceManager.RES_TYPE_THREADS resource type.	64

Interface CPUMonitor

[org.osgi.service.resourcemanager.monitor](#)

All Superinterfaces:
[ResourceMonitor](#)

```
public interface CPUMonitor
extends ResourceMonitor
```

A [ResourceMonitor](#) for the [ResourceManager.RES_TYPE_CPU](#) resource type. CPUMonitor instance monitors the CPU consumed by a [ResourceContext](#) instance.

Method Summary		Page
int	getCPUUsage() Returns the CPU usage as a cumulative number of nanoseconds The ResourceMonitor.getUsage() method returns the same value, wrapped in a Long	60

Methods inherited from interface org.osgi.service.resourcemanager.ResourceMonitor
delete , disable , enable , equals , getContext , getMonitoredPeriod , getResourceType , getSamplingPeriod , getUsage , hashCode , isDeleted , isEnabled , notifyIncomingThread , notifyOutgoingThread

Method Detail

getCPUUsage

```
int getCPUUsage()
```

Returns the CPU usage as a cumulative number of nanoseconds

The [ResourceMonitor.getUsage\(\)](#) method returns the same value, wrapped in a Long

Returns:
the CPU usage in nanoseconds

Interface *DiskStorageMonitor*

[org.osgi.service.resourcemangement.monitor](#)

All Superinterfaces:
[ResourceMonitor](#)

```
public interface DiskStorageMonitor
extends ResourceMonitor
```

A [ResourceMonitor](#) for the [ResourceManager.RES_TYPE_DISK_STORAGE](#) resource type. A *DiskStorageMonitor* instance monitors and limits the persistent storage of the bundle belonging to the [ResourceContext](#)

Method Summary		Page
long	getUsedDiskStorage() Returns the sum of the size of the persistent storage areas of the bundles in this resource context.	61

Methods inherited from interface [org.osgi.service.resourcemangement.ResourceMonitor](#)

[delete](#), [disable](#), [enable](#), [equals](#), [getContext](#), [getMonitoredPeriod](#), [getResourceType](#), [getSamplingPeriod](#), [getUsage](#), [hashCode](#), [isDeleted](#), [isEnabled](#), [notifyIncomingThread](#), [notifyOutgoingThread](#)

Method Detail

getUsedDiskStorage

```
long getUsedDiskStorage()
```

Returns the sum of the size of the persistent storage areas of the bundles in this resource context.

The [ResourceMonitor.getUsage\(\)](#) method returns the same value, wrapped in a `Long`

Returns:
the sum of the sizes of the persistent storage areas in bytes

Interface MemoryMonitor

[org.osgi.service.resourcemangement.monitor](#)

All Superinterfaces:
[ResourceMonitor](#)

```
public interface MemoryMonitor
extends ResourceMonitor
```

A [ResourceMonitor](#) for the [ResourceManager.RES_TYPE_MEMORY](#) resource type. A MemoryMonitor instance monitors and limits the memory used by a [ResourceContext](#) instance.

Method Summary		Page
long	getUsedMemory() Returns the size of the java heap used by the bundles in this resource context.	62

Methods inherited from interface org.osgi.service.resourcemangement. ResourceMonitor
delete , disable , enable , equals , getContext , getMonitoredPeriod , getResourceType , getSamplingPeriod , getUsage , hashCode , isDeleted , isEnabled , notifyIncomingThread , notifyOutgoingThread

Method Detail

getUsedMemory

```
long getUsedMemory()
```

Returns the size of the java heap used by the bundles in this resource context.

The [ResourceMonitor.getUsage\(\)](#) method returns the same value, wrapped in a Long

Returns:
the size of the used java heap in bytes

Interface SocketMonitor

[org.osgi.service.resourcemanager.monitor](#)

All Superinterfaces:

[ResourceMonitor](#)

```
public interface SocketMonitor
extends ResourceMonitor
```

A [ResourceMonitor](#) for the [ResourceManager.RES_TYPE_SOCKET](#) resource type. [SocketMonitor](#) instance are used to monitor and limit the number of in-use sockets per [ResourceContext](#) instance. [SocketMonitor](#) instance handle all types of sockets (TCP, UDP, ...).

A TCP socket is considered to be in-use when it is bound (`Socket.bind(java.net.SocketAddress)`) or when it is connected (`Socket.connect(java.net.SocketAddress)`). It leaves the in-use state when the socket is closed (`Socket.close()`).

A UDP socket is in-use when it is bound (`DatagramSocket.bind(java.net.SocketAddress)`) or connected (`DatagramSocket.connect(java.net.SocketAddress)`). A UDP Socket leaves the in-use state when it is closed (`DatagramSocket.close()`).

Method Summary		Page
long	getSocketUsage() Returns the number of existing socket created by a ResourceContext .	63

Methods inherited from interface [org.osgi.service.resourcemanager.ResourceMonitor](#)

[delete](#), [disable](#), [enable](#), [equals](#), [getContext](#), [getMonitoredPeriod](#), [getResourceType](#), [getSamplingPeriod](#), [getUsage](#), [hashCode](#), [isDeleted](#), [isEnabled](#), [notifyIncomingThread](#), [notifyOutgoingThread](#)

Method Detail

getSocketUsage

```
long getSocketUsage()
```

Returns the number of existing socket created by a [ResourceContext](#).

The [ResourceMonitor.getUsage\(\)](#) method returns the same value, wrapped in a `Long`

Returns:

the number of existing socket.

Interface ThreadMonitor

[org.osgi.service.resourcemangement.monitor](#)

All Superinterfaces:
[ResourceMonitor](#)

```
public interface ThreadMonitor
extends ResourceMonitor
```

A [ResourceMonitor](#) for the [ResourceManager.RES_TYPE_THREADS](#) resource type. A ThreadMonitor instance monitors and limits the thread created by a [ResourceContext](#) instance.

Method Summary		Page
int	getAliveThreads() Returns the number of alive threads created by the bundles in this resource context.	64

Methods inherited from interface org.osgi.service.resourcemangement.ResourceMonitor
delete , disable , enable , equals , getContext , getMonitoredPeriod , getResourceType , getSamplingPeriod , getUsage , hashCode , isDeleted , isEnabled , notifyIncomingThread , notifyOutgoingThread

Method Detail

getAliveThreads

```
int getAliveThreads()
```

Returns the number of alive threads created by the bundles in this resource context. A Thread is considered to be alive when its java state is one of the following:

- RUNNABLE
- BLOCKED
- WAITING
- TIMED_WAITING

The [ResourceMonitor.getUsage\(\)](#) method returns the same value, wrapped in a Integer

Returns:
the number of alive threads created by this resource context

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7 Considered Alternatives

Resource Manager inside the Core framework or in a bundle?

Some framework operations like `Bundle.start()` or `Bundle.stop()` requires a context switching to account resource usage in the context of the related bundle (instead of using the context of the caller of the method). These context switching have to be done automatically by the framework. As a consequence, the Resource Manager solution must be implemented inside the core framework. However, the Resource Manager may take advantage of the extension bundle mechanism.

Adapt pattern or OSGi service?

Each bundle is belonging to one specific resource context. So, the `Bundle.adapt()` method is an easy to use way to get access to its related `ResourceContext` object. It also avoid service management code necessary to require and release a service reference.

Moreover, as the Core framework has to be modified in order to perform automatic context switching on specific framework methods, the adapt pattern is definitely the best approach.

03/22/2013: Evgeni (Prosyst) seems not to be 100% sure of the adapt pattern. He indicates that the service approach could be better. Then the discussion moves the reasons why the Start Level Service uses the adapt pattern.

08/20/2013: David Bosschaert proposes to remove the adapt pattern for retrieving Resource Manager and Resource Contexts. From the Enterprise Expert Group point of view, the Resource Manager capability may be implemented outside the OSGi core framework. Introducing the adapt pattern supposes to be a part of the OSGi core framework and implies a high coupling between the Resource Management solution and the core framework. David proposes to use the service mechanism to make available the Resource Manager instance. Then from this Resource Manager service, Resource Context can easily be retrieved.

Eventing paradigms

03/22/2013: Several eventing mechanism have been discussed:

- The Event Admin service. This is the logical service to send notifications on OSGi platform. However, this service is optional and may not be accessible all the time. What to do in these cases?
- Use of the core eventing system:
 - Notifications through `BundleEvent` objects. Notifications **MUST** be sent when a Resource Context instance exceeds one of its resource usage thresholds. As a Resource Context is not limited to a single bundle (it could be a set of bundle), the `BundleEvent` approach seems not to be a good approach.
 - Notifications through `FrameworkEvent` objects. Those events have been designed to notify about general events of the OSGi environment (e.g., The framework has started,...). `FrameworkEvent` instances contains a few fields like the bundle associated to the event, the exception causing this event and a type. Moreover, it is not possible to define filters when registering the `FrameworkListener`.
 - Notifications through a new `ResourceEvent` object. To be defined.
- Whiteboard pattern approach. Some `ResourceListener` instance (to be defined) may be registered as an OSGi service or any other pattern. Each time a `ResourceMonitor` instance detects a resource usage exceeding, it requests for the list of existing `ResourceListener` instances and notify them. Some filters may be applied in order to reduce the number of `ResourceListener` to be notified.

Resource event classes

04/03/2013: Resource Event instances notify applications about threshold exceeding as well as Resource Management configuration updates (e.g., adding/removing Resource Context instance, adding/removing bundles from Resource Context instance). A Resource Listener instance receiving a notification then has to identify which kind of notification it receives (through a call to `ResourceEvent.getType()`) and treat it accordingly.

So it could be interesting to separate concerns by creating two different Event/Listener interfaces. Resource Event and Resource Listener can still deal with threshold exceeding while Resource Context Event and Resource Context Listener will manage any events about Resource Context configuration updates (adding or removing Resource Context, adding or removing bundles).

CPU Monitor

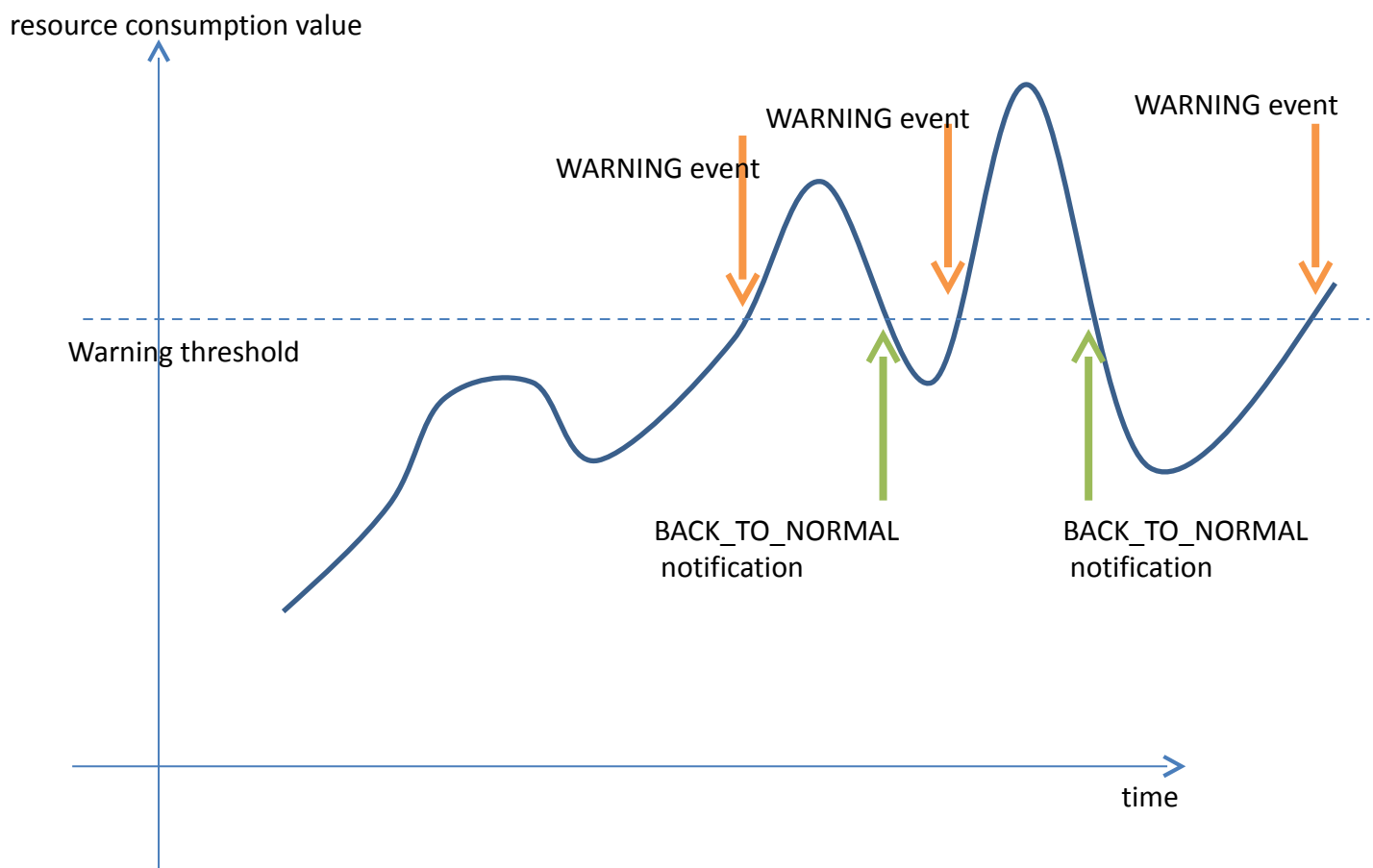
CPU Monitor instances monitor the CPU usage of Resource Context. The CPU usage is expressed as a percentage of usage over the monitoring period.

This percentage may be evaluated using the raw cpu data like the number of nanoseconds a Resource Context uses CPU. CPU Monitor instance evaluates the percentage by making a difference between cumulative values periodically retrieved (sampling period).

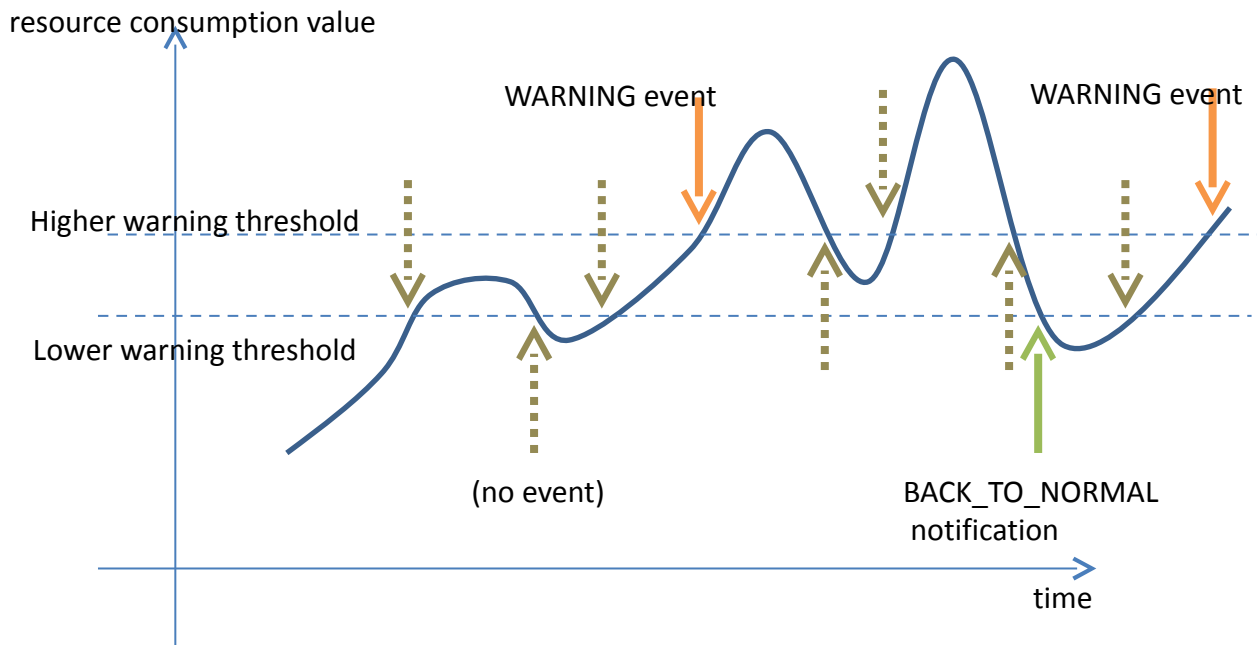
It could be interesting to leave access to the CPU cumulative values. A `getCumulativeUsage()` method may be added to the CPU Monitor interface.

Resource Threshold algorithm and eventing

When the resource consumption exceeds the WARNING threshold, the Resource Threshold instance goes from the NORMAL state to the WARNING state and generates WARNING Resource Event. When the resource consumption decreases below the WARNING threshold, the Resource Threshold instance goes back to the NORMAL state and generates a NORMAL Resource Event notification. In some cases, the resource consumption may fluctuate around the threshold generating several WARNING or NORMAL Resource Event notification. The next chart summarizes the situation:



NTT proposes the Resource Threshold instances are not a fixed straight value but rather a floating value with a lower warning threshold and a higher warning threshold (some kind of range). The NTT's solution is summarized below:



WARNING Resource event are generated only when higher warning threshold is exceeded. The same for NORMAL Resource Event when the resource consumption decreases under the lower warning threshold.

This kind of algorithms decreases the number of Resource Event notifications but increases the implementation complexity.

The RFC does not take any strong position on that particular question. Resource Management solution providers are free to implement such algorithms.

Resource Monitor Factory

ResourceMonitor instances are created by ResourceMonitorFactory. Some ResourceMonitor implementation (e.g., those provided by the framework itself) might not have ResourceMonitorFactory. This is strongly encouraged to provide Resource Monitor Factory instance for all kind of Resource Monitor.

Resource accounting and context switching

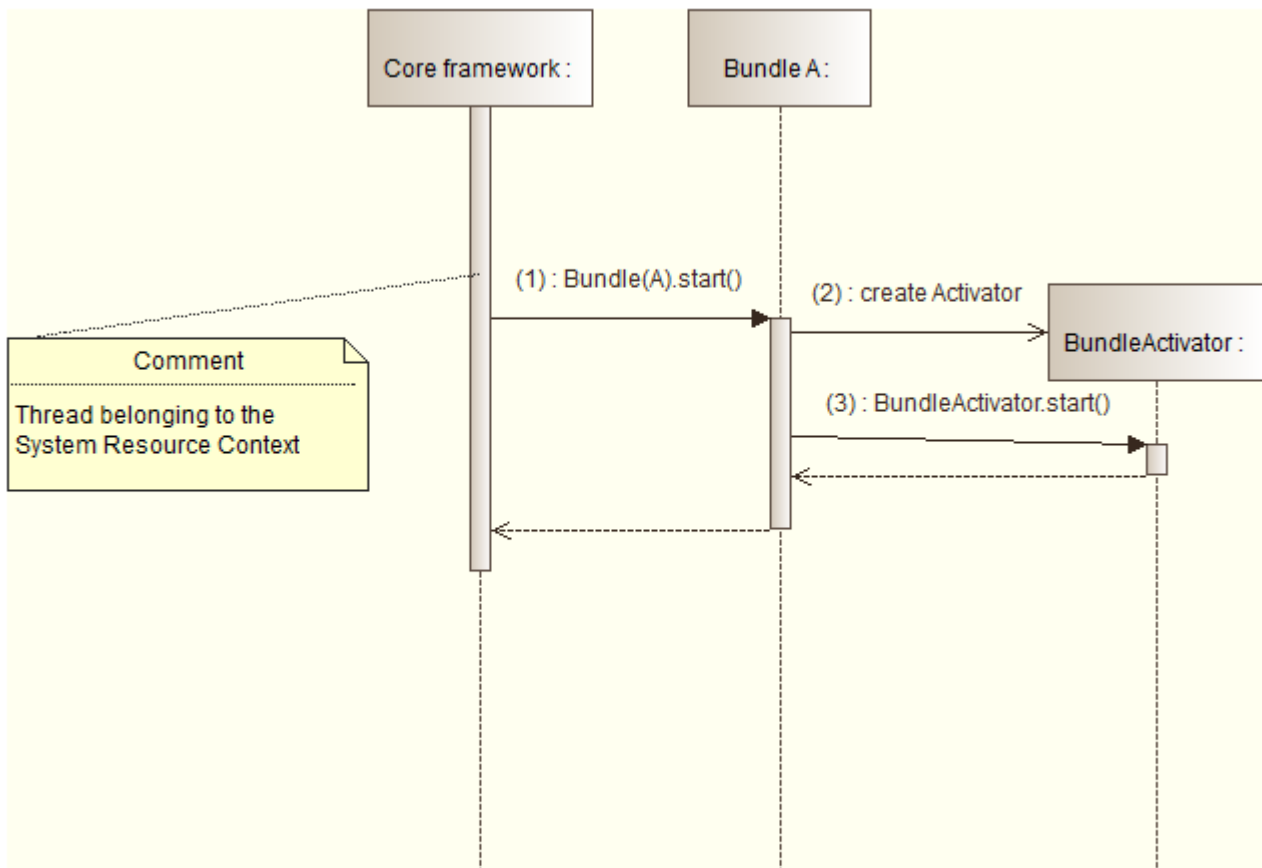
In a previous version, the Resource Manager service also allowed to perform Resource Context switching. The switching feature relied on a specific design for resource monitoring and accounting. For generality, it was decided to remove this feature (after CPEG review).

This feature relies on the association of Java threads with a Resource Context instance. In that case, every Java thread is associated with a single Resource Context instance. A Resource Context switching operation then reallocates a Java thread to another Resource Context instance. Therefore, all further resource allocation made during the execution of the Java thread are accounted to the new Resource Context instance.

This switching feature is executed by a call to the `switchContext(Thread, ResourceContext)` or `switchCurrentContext(ResourceContext)`. Resource Monitors are notified when a context switching operation occurs. When a thread joins a ResourceContext, all ResourceMonitors of the incoming ResourceContext are notified through a call to `ResourceMonitor.notifyIncomingThread(thread)`. On the opposite, when a thread leaves a ResourceContext, all ResourceMonitors of the outgoing ResourceContext are notified through a call to `ResourceMonitor.notifyOutgoingThread(thread)`.

Below are described three use cases showing an appropriate usage of the context switching feature.

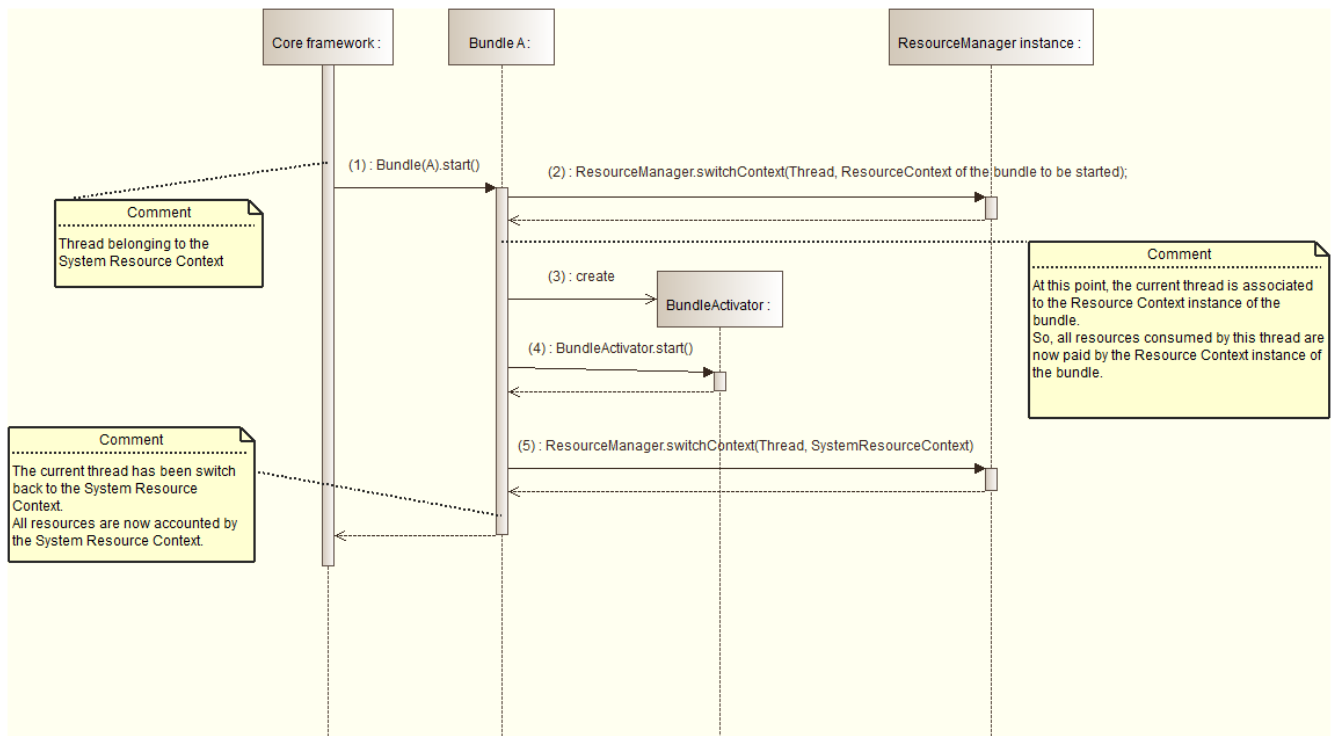
When the platform is starting, the core framework may start automatically bundles. The next sequence diagram describes the actions performed to start a bundle:



For every bundle instance to be started, the core framework calls `Bundle.start()` method (1). `Bundle.start()` method then creates a new instance of the `BundleActivator` implementation class of the `Bundle` (2) and calls `BundleActivator.start()` method (3). `BundleActivator.start()` method is generally used to allocate all resources a bundle needs, start threads and get and/or register services.

The object starting the bundle (actually the thread calling `Bundle.start()` method) belongs to the System Resource Context. As a consequence, resources consumed during `start()` call, including the resources used for the activation of the bundle, are accounted by the System Resource Context.

This situation may not be suitable. In usual situations, these resources may be accounted by the Resource Context instance of the bundle. A context switching operation has thus to be performed to switch to the Resource context instance of the bundle. The next diagram summarizes the actions to perform:



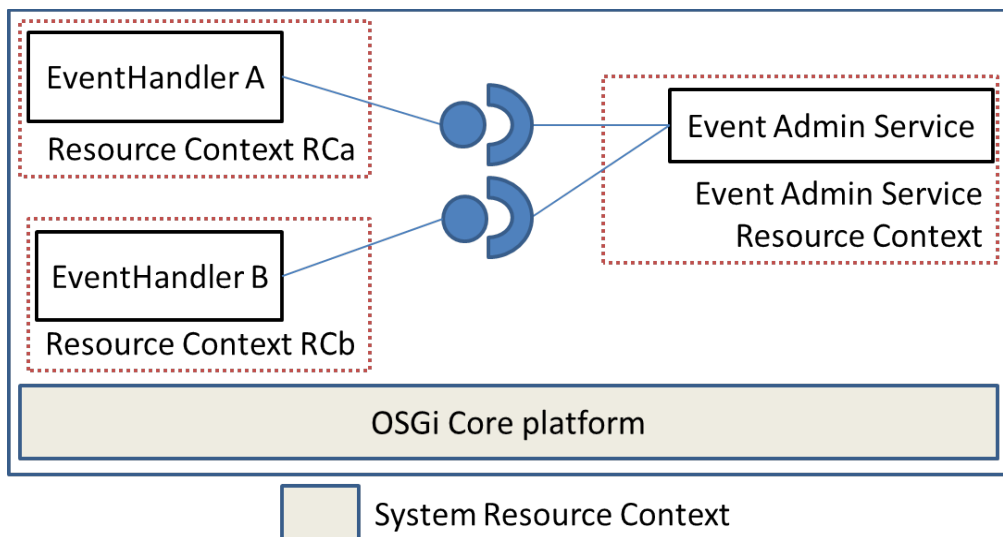
The `ResourceManager.switchContext()` operation (action 2) switches to the Resource Context of the bundle. At this point, all resources consumed by the current thread are accounted by the Resource Context instance of the bundle. Then, a new `BundleActivator` instance is created (action 3) and the `BundleActivator.start()` method is called (action 4). `BundleActivator.start()` method allocates all resources needed by the bundle. Before the completion of the `Bundle.start()` method, a context operation is again executed to switch back to the System Resource Context (action 5).

It is important to note that a context switching operation must be executed twice. The first context switching sets the context to which resources must be accounted. The second switches back to the initial context. The developer **MUST** ensure that these two operations are correctly achieved in order to avoid resource miscellaneous accounting.

This use case clearly shows that a context switching operation is needed at bundle startup to account resource in the appropriate Resource Context instance. Other framework operations requires a context switching execution:

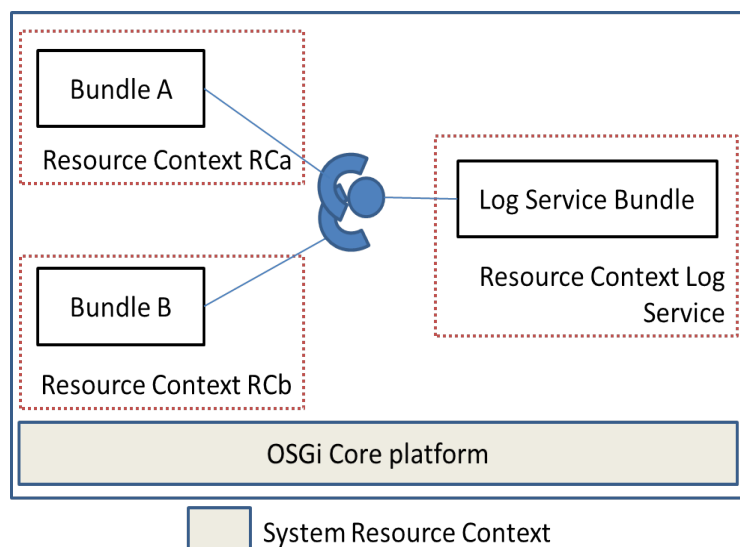
- `BundleActivator.start()` - switch to the to-be-activated bundle Resource Context instance.
- `BundleActivator.stop()` - switch to the to-be-stopped bundle Resource Context instance.
- `ServiceListener.serviceChanged()` - switch to the Resource Context instance of the bundle hosting the `ServiceListener` instance.
- `BundleListener.bundleChanged()` - switch to the Resource Context instance of the bundle hosting the `BundleListener` instance.
- `FrameworkListener.frameworkEvent()` - switch to the Resource Context instance of the bundle hosting the `FrameworkListener` instance.
- `ServiceFactory.getService()` - switch to the Resource Context instance of the bundle requesting the OSGi service.
- `ServiceFactory.ungetService()` - switch to the Resource Context instance of the bundle calling `ungetService`.

Some other Compendium OSGi service like `Http Service` or `Event Admin service` should also take advantage of the context switching operation. The next diagram shows the use case for the `Event Admin service`:



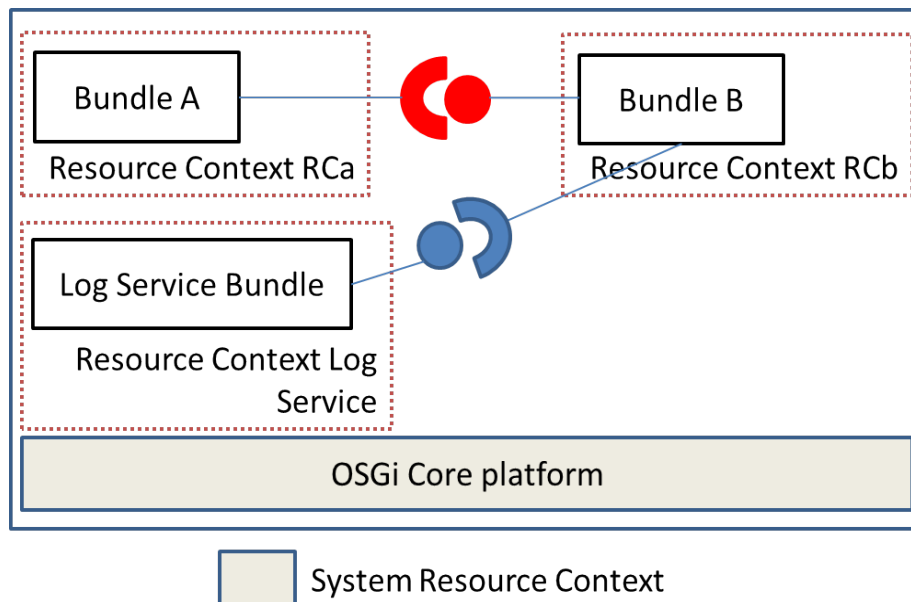
The EventAdmin Service should execute a context switching operation before and after calling `EventHandler.handleEvent(event)`. This operation switches the current context to the context of the bundle providing the Event handler. Then, the resources consumed by the `EventHandler.handleEvent()` method are accounted by the Resource Context associated to the bundle providing the Event Handler and are not paid by the Event Admin service.

Now, the LogService case is considered. Any bundle about to log requires the LogService instance and calls `LogService.log()` method. The next schema shows two bundles A and B belonging respectively to Resource Context RCa and RCb. These two bundles requires the LogService (which belongs to Resource Context Log Service):



In such situation, the resources used by the `LogService.log()` method due to the bundle A are paid by RCa (the Resource Context of A). So, if bundle A overuses the LogService, it may exceeds the resource quotas of RCa which may lead to stop the bundle A (for example). Bundle B is not impacted and can still use the LogService.

Now, the following example is considered:



Bundle A belongs to the Resource Context named RCa. It requires the Red service provided by Bundle B. The Red service provides a single public method called `m()`. `Red.m()` method uses the `LogService` to log useful data. Bundle B belongs to Resource Context RCb, `LogService` bundle belongs to Resource Context Log Service.

When bundle A calls `Red.m()` method, all the resources consumed by `Red.m()` method are paid by RCa (if, for instance, the owner is defined as the owner of the current thread). As `Red.m()` calls also the `LogService.log()` method, the resource consumed by `LogService.log()` method are also paid by RCa.

Now, if the `Red.m()` method executes a context switching operation to switch to RCb (resource context instance of bundle B), then all resources used by `Red.m()` method are paid by RCb including the resources used by the call to the `LogService.log()` method. In this case, a call to `Red.m()` method costs nothing to RCa. However, `Red.m()` method MUST switch back to RCa at the end of its execution. If it is not the case, all resources consumed afterwards could be still paid by RCb. One more time, it is very important for a method that need to execute a switch context operation to switch back to the initial context at the end of its execution.

The three use cases described above show that context switching operation are not suitable in all cases. The most important thing is finally to determine which is the context executing the code. In all cases, a switching context operation notify all `ResourceMonitor` instances of both the outgoing `ResourceContext` and the incoming `ResourceContext`. The `ResourceMonitor` instances of the leaving `ResourceContext` are notified through `ResourceMonitor.notifyOutgoingThread(thread)` where the ones of the incoming `ResourceContext` are notified through `ResourceMonitor.notifyIncomingThread(thread)`.

Compatibility between bundles capabilities

Some bundle implementation should naturally use the Resource Management features and in particular the switching context operation in order to account resource properly. For example, the `Http Service` implementation switch to the Context of the bundle providing the servlet before executing any service methods when receiving an HTTP request.

An open issue is the deployment of resource management non-aware bundles into a resource management aware context. In that particular case, some Resource Context may not be charged correctly.

The present specification gives all the features necessary to implement bundles and framework resource management aware. As a consequence, the platform operator is free to deploy suitable bundles depending on its needs (i.e., in a resource management aware context or not).

Implementation of resource management aware bundles

There are different ways to implement a resource management aware bundle.

The first approach is the direct implementation into the bundle. The bundle implementer is free to execute context switching operation when it is required. The bundle implementer is fully responsible to choose the appropriate Resource Context to charge and it is also responsible to switch back to the initial Resource Context. This approach has some drawbacks. First, it implies to handle Resource Management features into a business features which is sometimes not suitable. Moreover, the platform operator must be confident in the way the bundle implementer uses

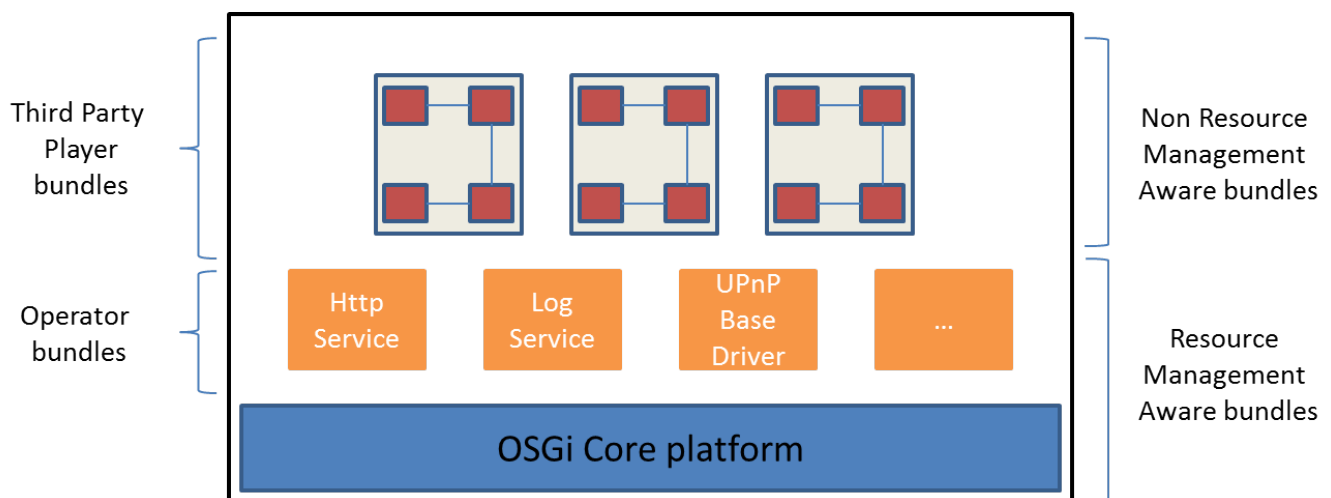
context switching operations (i.e., permissions). Finally, as the context switching operations are made by the bundle itself, the chosen accounting policy is statically defined. This accounting policy may not be convenient in all situations.

The second approach is to take advantage of the weaving feature. The weaving feature allows to inject some byte-code into existing bundles. In this case, the injected byte-code deals with the context switching features. The byte-code injection can be done at runtime or at the compilation time. The advantage of this approach is that the bundle implementer does not need to handle any context switching feature. Moreover, the accounting policy can be changed with a new byte-code injection. The main drawback of this approach is the complexity and acceptability of the use of bytecode injection.

Finally, the last approach is to implement service proxies. This kind of service proxyifies a service which is not resource management aware. The service proxy implements the same interface as the one of the to-be-proxified service and handles all the resource management stuff. This approach is very similar to the weaving approach.

Example 1

Operators involved into the Residential market plan to provide a Resource Management aware OSGi platform on which Third Party Players will deploy bundles:



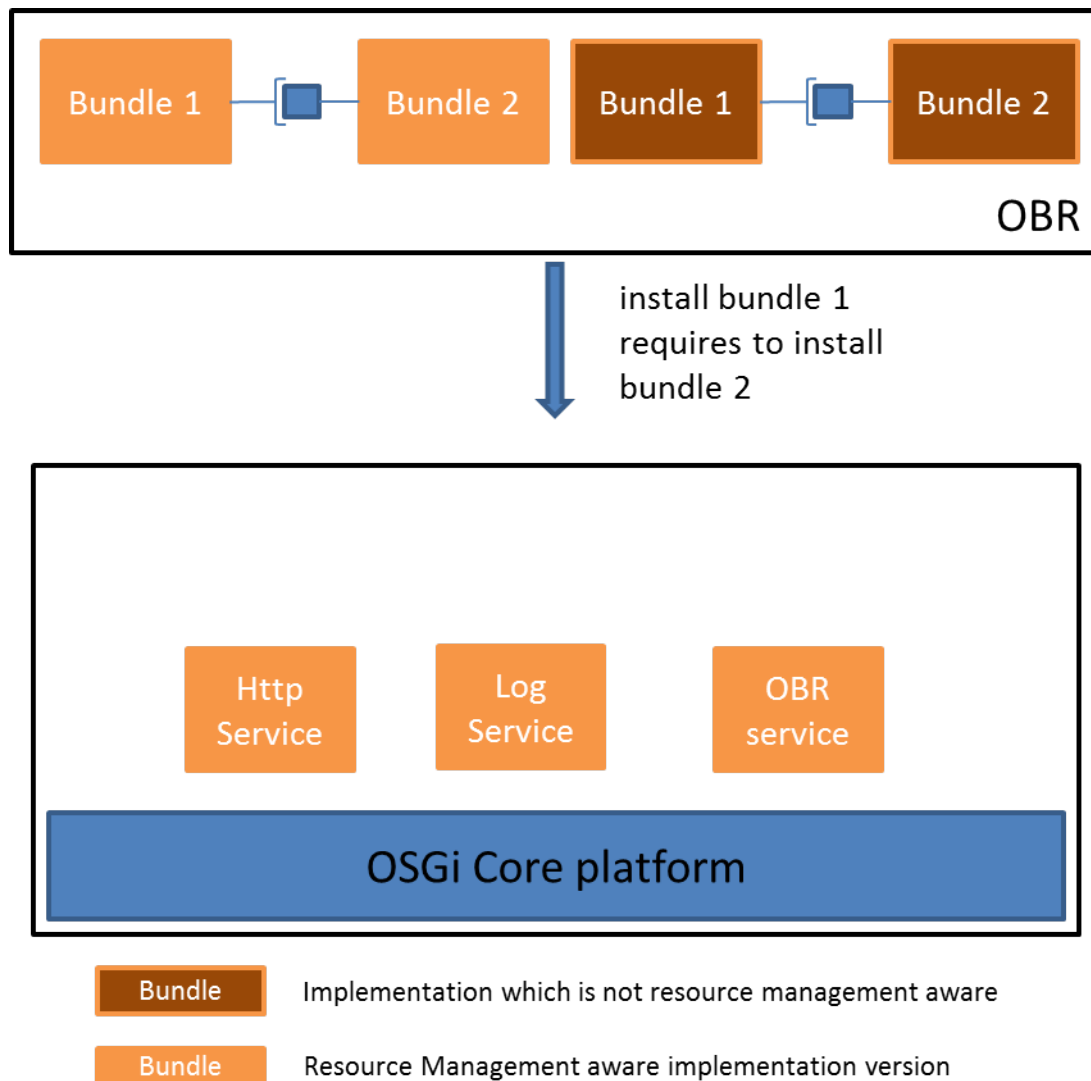
The OSGi platform hosts some operator bundles like HttpService or LogService. All of them are resource management aware, i.e., they automatically execute switch context operation in order to charge resource to the appropriate Resource Context.

All these operator services are used by Third Party Player bundles. Each Third Party Player is isolated from another (they do not share services between them) and the platform operator creates a Resource Context per Third Party Player. Moreover, as Third Party Players may not be trusted, their bundles do not have access to the Resource Management API. This does not prevent the resources to be accounted to the Resource Context belonging to the Third Party Player.

In such situations, Resource Management is transparent for the Third Party Player. Authorities and operator bundles handle resource context switching at the appropriate moment.

Example 2

In the Enterprise context, bundles are deployed using the OBR service. The OBR allows to deploy bundles and all their dependencies computed based on package and service dependencies of to be-installed bundle:



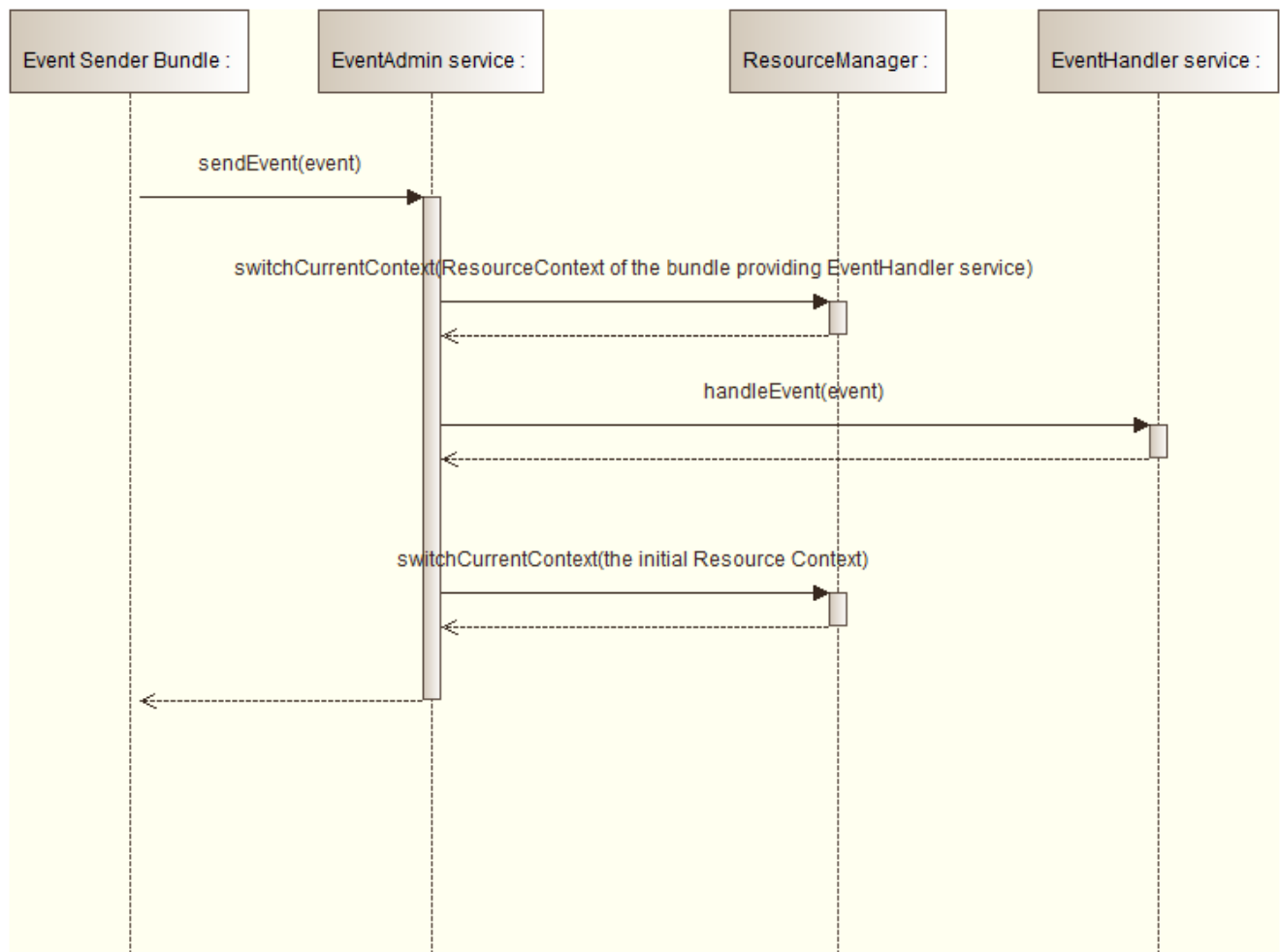
Here, the OBR service is requested to install the bundle 1 which depends on a package provided by bundle 2 (which is not installed on the platform). The OBR then installs the bundle 1 as well as the bundle 2 in order to satisfy the missing dependency.

In the case where the OSGi Core platform is resource management aware, the operator may have to deploy bundles which should be resource management aware. So the OBR service should take care between a bundle implementation which is resource management aware (light orange box on the schema) and a one which is not (dark orange box).

In such cases, either the OBR service is smart to deploy the appropriate version or the operator should do it itself.

Event Admin use-case

The next sequence diagram shows the use-case of the Event Admin:

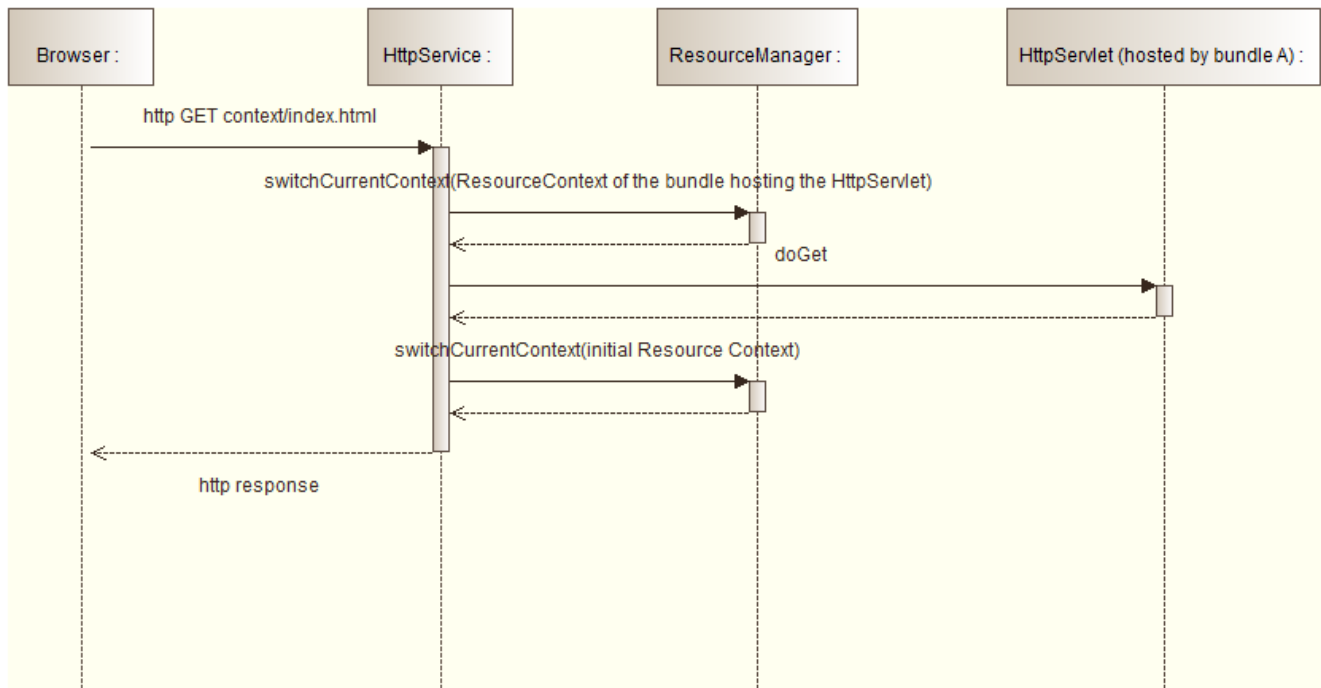


A bundle uses the `EventAdmin.sendEvent()` method to emit an event. The `EventAdmin` service then performs a lookup into the OSGi service registry to find out all the available `EventHandler` services. For every to-be-notified `EventHandler`, the `EventAdmin` performs a switching context operation to be in the Resource Context of the bundle providing the `EventHandler` service. Then it calls the `EventHandler.handleEvent()` method and switches back to the initial Resource Context (the one of the bundle sending the event).

The context switching operation made here allows to charge the bundle receiving the event instead of the bundle sending the event.

Http Service use-case

The Http Service use-case is shown below:



A browser requests an HTTP GET on context/index.html. The HttpService identifies the HttpServlet to be-invoked based on the context of the request. Once identified, the HttpService executes a switch context operation to the Resource Context of the bundle providing the HttpServlet. Then, the HttpService calls the HttpServlet.doGet() method and switches back to the initial context.

The switching context operation allows to charge the bundle providing the HttpServlet instead the bundle exposing the HttpService.

8 Security Considerations

9 Document Support

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Acronyms and Abbreviations

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