ZigBee Device Service Specification

Draft

43 Pages

Abstract

This specification defines the Java API to discover, control and implement ZigBee devices on the OSGi platform and according to OSGi service design patterns. This API maps the representation of ZigBee entities defined by ZigBee Cluster Library into Java classes. OSGi service design patterns are used on the one hand for dynamic discovery, control and eventing of local and networked devices and on the other hand for dynamic network advertising and control of local OSGi services implementing this API.

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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 .

`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	May, 16th, 2012	Andre Bottaro, Orange, andre.bottaro@orange.com
1st Draft	September, 20th, 2012	Bâle presentation
	October, 16th, 2012	API Summary Initialized
	October, 18th, 2012	ZigBeeClusterDescription and ZigBeeCommandDescription section initialized
	December,14th, 2012	Added details and references, cleared comments, fixed few mistakes.

Revision	Date	Comments
v11-reg	January, 15th	Andre Bottaro, Orange Jean-Pierre Poutcheu, Orange 1. ZigBeeDeviceDescription and ZigBeeDeviceDescriptionSet classes are added and the registration of device descriptions is explained. The base driver and any bundle are now able to register the set of ZigBeeDeviceDescription objects which they have the knowledge. Those sets are registered with ZigBeeDeviceDescriptionSet interface. 2. ZigBeeEvent.getCluster() added in order to be able to retrieve the ids of the devicenode, the endpoint and the cluster which attributes values are notified. 3. Masaki 1st point: ZigBeeEndpoint now provides getDeviceNode() method in ZigBeeEndpoint class without any input argument. 4. Masaki 2nd point: ZigBeeEndpoint class now provides a method to retrieve all available input ZigBeeCluster objects and a method to retrieve all output ones. 5.Whenever getXXXid() can be changed into getId() without ambiguity, the change is made. The same change is applied to getXXXName, getXXXVersion(). For instance, ZigBeeCluster.getClusterId() is changed into ZigBeeCluster.getId(). 6. ZigBeeDataType.getJavaDataType() has now the same signature as UpnPDataType.getJavaDataType(). 7. ZigBeeHost.getPanId() is removed and the method is added to the parent class: ZigBeeDeviceNode.getPanId() is added. 8. PAN_ID property was a property only specified for exported ZigBeeEndpoint services. It is now specified for all ZigBeeEndpoint services. Other properties are added to improve filtering features made on ZigBeeEndpoint services. 9. An Endpoint was able to be registered once and exported on several networks by distinct hosts. This lead to an issue: which host to return in ZigBeeEndpoint.getDeviceNode() method? Thus, the spec has been changed: a distinct ZigBeeEndpoint object has now to be created and registered for every distinct targeted network (identified by a distinct PAN_ID)

Revision	Date	Comments
v12-reg	January, 29th	Andre Bottaro, Orange Jean-Pierre Poutcheu, Orange 1. Typed collections (Java 1.5) may remain in the javadoc. That's a bug and they are removed. (javadoc to be sent to the list later). 2. The link between ZigBeeDeviceDescription and ZigBeeClusterDescription was missing in the UML schema. It is now added. 3. Masaki's 4th point: Permit duration taken into account. 4. Standard properties are proposed for the ZigBeeDeviceDescriptionSet service. The right mapping with ZigBee standard names and the format of values is now applied. 5. The list of constant ZigBeeDataTypeDescription objects was missing. The developer needs to be able to retrieve those ZigBee constant objects. It is now specified in a new interface named "ZigBeeDataTypes". 6. Nicola's point on de/serialization of data types. isAnalog(), serialize/deserialise() method names taken into account. 7. Cardinality 0..1 is replaced by * when it involves a table or a vector of objects (attributedescs, clusterdescs, …). 8. Masaki 3rd point: a method « void ZigBeeEndPoint.notExported(ZigBeeException ze) » is added. Explanations are now in the Export section. 9. The ZigBeeDeviceDescriptionSet class was missing in the UML schema. It is now added. (and the 'ZigBee Cluster Descriptor' implementation (grey blox) is removed).
v13-reg	February, 5th	Andre Bottaro, Orange Jean-Pierre Poutcheu, Orange 1. The ZigBee Extended PAN ID is now mentioned and used in the specification.

Revision	Date	Comments
v14-reg	February, 25th	Andre Bottaro, Orange Jean-Pierre Poutcheu, Orange Thanks to Evgeni Grigorov's (Prosyst's) comments and Nicola Portinaro (Telecom Italia's) comments 1. Added a 'leave()' method in ZigBeeDeviceNode javadoc for removing nodes to request the device to leave the network: void leave(boolean rejoin, boolean request, boolean removeChildren, ZigBeeHandler handler) 2. Added a 'checkValue(Object obj)' in ZigBeeParameterDescription which returns true if the parameter value is valid according to his description and possible value ranges and other specific information. 3. Added new filters in listener, with names closer to ZCL documentation ones ZigBeeAttribute.REPORTABLE_CHANGE, ZigBeeAttribute.MIN_REPORT_INTERVAL, ZigBeeAttribute.MAX_REPORT_INTERVAL, ZigBeeAttribute.TIMEOUT_PERIOD 4. Added a 'public void setValue(Object value, ZigBeeHandler handler) throws ZigBeeException' method in ZigBeeAttribute 5. Added a description in 'Implementing a ZigBee Endpoint' about the use case where, an exportable endpoint corresponds to two more than 1 ZigBeeHost, at this time a ZigBeeException is thrown. 6. Added a paragraph to tell the reader that EndPoint 0 and 255 are not registered in the registry. And that EndPoint 241-255 should not be registered since these numbers are said “reserved for future use” in the ZB spec.
v20-reg	May, 6th	Jean-Pierre Poutcheu, Orange Arnaud Rinquin, Orange 1. ZigBeeAttributeHandler,notifyResponse(), use of Map instead of dictionary 2. Moved getAccesType() and isReportable() from ZigBeeAttribute to ZigBeeAttributeDescription 3. UNSIGNED_INTEGER_64 mapped with BigInteger Java class 4. ZigBeeCluster.readAttributeAsByte(...) has been removed 5. Added get and setChannel mask operations in ZigBeeHost

Revision	Date	Comments
v21-reg	May, 15th	Jean-Pierre Poutcheu, Orange Arnaud Rinquin, Orange 1. Added a new Exception ZigBeeNoDescriptionAvailableException 2. Added a new class ZigBeeAttributeRecord 3. Modified ZigBeeCluster.writeAttributes(...) to - void writeAttributes(boolean undivided, int[] attributesIds, byte[] values, ZigBeeAttributesHandler handler) throws ZigBeeNoDescriptionAvailableException; - void writeAttributes(boolean undivided, ZigBeeAttributeRecord[] attributes, ZigBeeAttributesHandler handler) 4. Change ZigBeeHandler.notifyResponse to notifyResponse(int Status, Map values) 5. Nicola's Point : New package org.osgi.service.zigbee.descriptors for all the descriptors 6. Nicola's Point: ZigBeeException use hex value are used for constants. (Thx to Nicola) 7. Evgeni's Point: Removed ZigBeeCoordinator.getLinkKey() and ZigBeeCoordinator.getMasterKey() methods
v22-reg	May, 22th	Jean-Pierre Poutcheu, Orange Arnaud Rinquin, Orange 1. Explain that 'no response' command are used when handler is null in writeAttributes commands 2. Explain that map use attribute ids as key and objects as values
v23-reg	May, 29th	Jean-Pierre Poutcheu, Orange Arnaud Rinquin, Orange 1. Added a new section about ZigBeeAttributeRecord class 2. Added getInvalidNumber() method in ZigBeeDataTypeDescription
v24-reg	June, 5th	Jean-Pierre Poutcheu, Orange Arnaud Rinquin, Orange 1. Moved getSimpleDescriptor() from ZigBee Node section to Endpoint section 2. Changed getInputCluster()/getOutputCluster() by getServerCluster()/getClientCluster()

Revision	Date	Comments
v25-reg	June, 12th	Jean-Pierre Poutcheu, Orange André Bottaro, Orange 1. Renamed ZigBeeDeviceNode interface by ZigBeeNode 2. Updated 'Operation Summary' section to take into account the registration of ZigBeeNode as an OSGi service by the base driver. 3. In ZigBeeEndpoint, getDeviceNode() replaced by getNodeAddress(), which returns the node IEEE Address 4. In ZigBeeNode interface, static field ID replaced by IEEE_ADDRESS 5. Updated figure 6.2: 'Device Node' → 'Node'
v26-reg	June, 19th	Jean-Pierre Poutcheu, Orange André Bottaro, Orange 1. Updated figure 6.1: 'ZigBeeDeviceNode' → 'ZigBeeNode' 2. Moved refreshNetwork(ZigBeeHandler) from ZigBeeCoordinator to ZigBeeHost 3. Added start() in ZigBeeHost
v27-reg	June, 28th	Jean-Pierre Poutcheu, Orange André Bottaro, Orange 1. Deleted all the mention about ZigBeeCoordinator 2. Updated figure 6.1: Removed ZigBeeCoordinator interface 3. More explanation in ZigBee Networking section about the role of ZigBeeHost
v28-reg	July, 3rd	Jean-Pierre Poutcheu, Orange André Bottaro, Orange ZigBeeHost.setOperationalMode(short) replaced by ZigBeeHost.setLogicalType(short)
v29-reg	July, 17th	Jean-Pierre Poutcheu, Orange André Bottaro, Orange 1. Deleted ZigBeeAttributesHandler interface 2. IEEE Address managed as a Long Java type
v30-reg	July, 25th	Jean-Pierre Poutcheu, Orange André Bottaro, Orange 1. Added properties ZigBeeNode.HOST_PID and ZigBeeEndpoint.HOST_PID_TARGET 2. Updated endpoint export section to take into account HOST_PID_PARGET property when exporting an endpoint.

Revision	Date	Comments
v31-reg	August, 29th	Jean-Pierre Poutcheu, Orange André Bottaro, Orange 1. Added ZigBeeGlobalClusterDescription.getClusterFunctionalDomain () 2. Added a table in ZigBeeHandler section describing Map parameter response for onSuccess(Map) and onFailure(Map)
v32-reg	September, 3th	Antonin Chazalet, Orange André Bottaro, Orange 1. Fix typo, spelling, and grammar. 2. Remove several methods duplicated from Javadoc. 3. Enhance some sentences.
v33-reg	September, 9th	Antonin Chazalet, Orange André Bottaro, Orange 1. Enhance ZigBee Handler part. 2. Fix references. 3. Merge import/export HOST_PID. 4. Add some open questions as comments.
v34-reg	September, 17th	Antonin Chazalet, Orange André Bottaro, Orange 1. Delete invoke(Object[] values, ZigBeeDataTypeDescription[] inputTypes, ZigBeeDataTypeDescription[] outputTypes, ZigBeeHandler handler) 2. Add serialize, and deserialize methods to ZigBeeCommandDescription. These methods are designed to ease the use of ZigBeeCommand.invoke(byte[] bytes, ZigBeeHandler handler). 3. Add ZigBeeHost.stop() method.

Revision	Date	Comments
v35-reg	September, 30th	Antonin Chazalet, Orange André Bottaro, Orange 1. ZigBeeEvent: change Dictionary getAttributesEvents() to Object getValue() 2. Remove getDescription() from ZigBeeCluster, ZigBeeCommand, and ZigBeeAttributes. 3. In ZigBeeCluster, remove: public void readAttributesAsBytes(int[] attributesIds, ZigBeeHandler handler); and public void writeAttributes(boolean undivided, int[] attributesIds, byte[] values, ZigBeeHandler handler) throws ZigBeeNoDescriptionAvailableException; 4. Introduce ZigBeeCommandHandler 5. Rename ZigBeeException.ATTRIBUTE_NOT_SUPPORTED to UNSUPPORTED_ATTRIBUTE 6. Add constructor in ZigBeeAttributeRecord, and remove setters. 7. Remove setters/getters methods with bytes parameters in ZigBeeAttribute. 8. Introduce ZigBeeAttributesHandler. 9. ZigBee*Handler.onFailure now takes a ZigBeeException as parameter. 10. Remove getDeviceDescription() from ZigBeeEndpoint.
v36-reg	October, 2th	Antonin Chazalet, Orange André Bottaro, Orange 1. ZigBeeEventListener: remove filter. 2. Event API: Specify mandatory, and optional pseudo properties for event filtering. Add ZigBeeEndpoint.ENDPOINT. 3. Add ZCL document version 4. ZigBeeEventListener: Add public void onFailure(ZigBeeException e); 5. ZigBeeEndpoint: move ENDPOINT – (zigbee.device.endpoint) to ZigBeeEndpoint.ID – (zigbee.endpoint.id); move zigbee.device.clusters.input to zigbee.endpoint.clusters.input; move zigbee.device.clusters.output to zigbee.endpoint.clusters.output. 6. ZigeeCluster: move zigbee.listener.cluster.* to zigbee.cluster.* 7. ZigBeeNode: move zigbee.listener.node.ieee.address to zigbee.node.ieee.address 8. ZigBeeAttribute: move zigbee.listener.attribute.* to zigbee.attribute.*

Revision	Date	Comments
v37-reg	October, 7th October, 10th	Antonin Chazalet, Orange André Bottaro, Orange 1. Remove no longer needed ZigBeeNoDescriptionAvailableException 2. In the ZigBeeHandler section, Map took int as key, and now take Integer (This is a Java requirement). 3. Update ZCL document version (from 075123r01ZB to 075123r04ZB) 4. Add isPartOfAScene() method to ZigBeeAttributeDescription 5. Add a short explanation regarding ZigBeeEvent.
v38-reg	October, 18th	Antonin Chazalet, Orange André Bottaro, Orange 1. ZigBeeAttributeRecord is now a final java class. 2. Remove PAN_ID and EXTENDED_PAN_ID from ZigBeeEventListener interface; the ones from ZigBeeEndpoint interface must be used. 3. Move listener static fields that are listener properties into ZigBeeEventListener: (REPORTABLE_CHANGE, MIN/MAX_INTERVAL, TIME_OUT). Keep the zigbee.attribute. prefix. 4. Event API: Specify mandatory, and optional pseudo-properties for event filtering. Add ATTRIBUTE_DATA_TYPE = "zigbee.attribute.datatype"
v39-reg	November, 4th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update some comments on ZigBeeEventListener's optional properties. 2. ZigBeeEndPoint: Add additional properties.
v40-reg	November, 8th	Antonin Chazalet, Orange André Bottaro, Orange 1. Add EventListener.notifyTimeOut(int) 2. Update javadoc of ZigBeeAttribute.getDataType() 3. ZigBeeEventListener.ATTRIBUTE_DATA_TYPE is now mandatory. Add details on ZigBeeEventListener.MIN_REPORT_INTERVAL, MAX_REPORT_INTERVAL, and REPORTABLE_CHANGE.
v41-reg	November, 12th	Antonin Chazalet, Orange André Bottaro, Orange 1. Minor enhancements. 2. Remove ZigBeeEventListener.TIMEOUT_PERIOD

Revision	Date	Comments
V42-reg	November, 22th	Antonin Chazalet, Orange André Bottaro, Orange 1. Add ZigBeeCommand.invoke(byte[] bytes, ZigBeeCommandHandler handler, String exportedServicePID) throws ZigBeeException. 2. Add ZigBeeEventListener, ZigBeeNode et ZigBeeDeviceDescriptionSet's properties types.
V43-reg	December, 5th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update ZigBeeNode, and ZigBeeEndpoint.
V44-reg	December, 10th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update filter part. 2. Update ZigBeeEventListener, ZigBeeNode et ZigBeeDeviceDescriptionSet's properties types.
V45-reg	December, 18th	Antonin Chazalet, Orange André Bottaro, Orange 1. Add ZigBeeEndPoint.bind(...), and unbind(...) methods. 2. Add ZigBeeEndPoint.getBoundEndPoints(...) method.
V46-reg	December, 23th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update ZigBeeEndpoint's getBoundEndPoints method (see Java API).
V47-reg	January, 20th	André Bottaro, Orange Antonin Chazalet, Orange 1. Update “Implementing a ZigBee Endpoint ” section. 2. Clean up references section.
V48-reg	February, 7th	Antonin Chazalet, Orange André Bottaro, Orange 1. Add Stefano Lenzi as an author. 2. Add/update ZCLHeader, ZCLFrame, ZigBeeCluster, ZigBeeCommandDescription, and ZigBeeCommandHandler. 3. Remove ZigBeeCommand Java interface.
V49-reg	February, 14th	Antonin Chazalet, Orange André Bottaro, Orange 4. Integrate last call decisions: Add ZigBeeGroup, and update ZigBeeCommandHandler javadoc.

Revision	Date	Comments
V50-reg	March, 3th	Antonin Chazalet, Orange André Bottaro, Orange 1. Rename ZigBeeCluster to ZCLCluster, ZigBeeClusterDescription to ZCLClusterDescription, and ZigBeeGlobalClusterDescription to ZCLGlobalClusterDescription. 2. Remove getServerClusters(), and getServerCluster(...) from ZigBeeGroup. 3. Add void invoke(ZCLFrame frame, ZigBeeCommandHandler handler) throws ZigBeeException, and void invoke(ZCLFrame frame, ZigBeeCommandHandler handler, String exportedServicePID) throws ZigBeeException in ZigBeeGroup. 4. Add two broadcast methods on ZigBeeHost. 5. Modify ZigBeeDataTypeDescription: serialize, and deserialize methods are now related to ZCLFrame object. 6. Add getInputStream(), and getOutputStream() methods to ZCLFrame.
V51-reg	March, 4th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update ZigBee Data Types.

Revision	Date	Comments
V52-reg	March, 10th	Antonin Chazalet, Orange André Bottaro, Orange 1. Replace “that occurred in the ZigBee stack.” by "that occurred in the ZigBee stack or internally by the ZigBee Base Driver or by the ZigBee network" 2. Replace “It must also expose, on the ZigBee Network, ZigBee Node services” by “It must also export, on the ZigBee Network, ZigBee Endpoint services” 3. Remove “ZigBeeNode provides getEndPoints() method which returns its associated endpoints.” 4. Rename “ZigBee hierarchy model” to “ZigBee Cluster Library model”. 5. Rephrase “Endpoint 0, also called ZDO” to “Endpoint 0, also called the ZigBee Device Object (ZDO)” 6. Rephrase “to describe the generic device capabilities,” to “for the management operations on both ZigBee node and ZigBee Endpoints”. 7. Rephrase “identifies the profile that is supported by this endpoint.” to “identifies the profile that the Endpoint belongs to. The profile can be either a ZigBee Alliance standard profile or a vendor-specific profile.”. 8. Rephrase “devices identifiers supported by the profile.” to “devices identifiers supported by the set.”. 9. Rephrase “readAttributes(int[] attributeIds, ZigBeeAttributesHandler handler) – The read attributes command is generated when a device wishes to determine the value of one or more attributes located on another device.” to “The ZBD MAY (i.e. ZBD may cache request) generate the read attributes command on behalf of the OSGi application that is invoking the readAttributes method.”. 10. Rephrase “The write attributes command is generated when a device wishes to change the values of one or more attributes located on another device.” to “The ZBD generates the write attributes command on behalf of the OSGi application that is invoking the writeAttributes method.”.
V53-reg	March, 17th	Antonin Chazalet, Orange André Bottaro, Orange 1. Rename ZigBeeEndpoint.ID to ZigBeeEnd.ENDPOINT_ID. 2. Remove ZigBeeEndpoint.DEVICE_DESCRIPTION, and DEVICE_SERIAL. 3. Update data types.
V54-reg	March, 18th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update ZigBeeDescriptionSet. 2. Move HOST_PID from ZigBeeNode to ZigBeeEndpoint, and update spec, and javadoc. 3. Remove HOST_PID_TARGET. 4. Replace ByteBuffer by Byte[]. 5. Update ZigBeeNode, and ZigBeeEndpoint properties.

Revision	Date	Comments
V55-reg	March, 24th	Antonin Chazalet, Orange André Bottaro, Orange 1. Reintroduce DEVICE_DESCRIPTION, and DEVICE_SERIAL in ZigBeeNode section in the RFC. 2. Remove no longer relevant: ZCLClusterDescriptionSet. 3. Remove org.osgi.service.zigbee sub section. 4. Update ZCLGlobalClusterDescription sentences in Entities section. 5. Remove no longer relevant ZigBeeCommand. 6. Update ZigBeeGroup. 7. Rename ZigBeeEventListener to ZCLEventListener. 8. Rename ZigBeeParameterDescription to ZCLParameterDescription. 9. Update ZCLCluster. 10. Rename ZigBeeException to ZCLException. 11. Add a ZigBeeException section (that now handles ZDP exceptions)
V56-reg	March, 28th	Antonin Chazalet, Orange André Bottaro, Orange 1. Replace Byte[] by byte[]. 2. ZigBeeHost.start(), and stop() now throws Exception instead of ZCLException. 3. Update “Scope”'s sentences in Essentials section.
V57-reg	April, 7th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update ZigBee Networking, and Network selection sections. 2. Update ZigBee Node section.
V58-reg	April, 14th	Antonin Chazalet, Orange André Bottaro, Orange 1. Update text font. 2. Update Network coordination sub-section. 3. Rename ZigBeeException by ZDPException.
V59-reg	April, 16th	André Bottaro, Orange Antonin Chazalet, Orange 1. Updated Operation Summary and ZigBee Base Driver sections with more paragraphs and service diagrams. 2. Update fig. 3. 3. Fix a paragraph font.

1 Introduction

ZigBee [1]. is a standard wireless communication protocol designed for low-cost and low-power devices by ZigBee Alliance. ZigBee is widely supported by various types of devices such as smart meters, lights and many kinds of sensors in the residential area. OSGi applications need to communicate with those ZigBee devices.

This specification defines how OSGi bundles can be developed to discover and control ZigBee devices on the one hand, and act as ZigBee devices and interoperate with ZigBee clients on the other hand. In particular, a Java mapping is provided for the standard hierarchical representation of ZigBee devices called ZigBee Cluster Library [2].. The specification also describes the external API of a ZigBee Base Driver according to Device Access specification, the example made by UPnP Device Service specification and spread OSGi practices on residential market [3].[4]..

2 Application Domain

System Architecture

When installing a new ZigBee network into a residential network with a home gateway, there are 2 options. One is to add ZigBee communication capability to your home gateway with an additional hardware such as a USB device called "dongle". The other one is to replace the current home gateway with one which has ZigBee communication capability. In both cases OSGi applications call the ZigBee driver API to communicate with the ZigBee network (and its ZigBee devices) as shown in Erreur : source de la référence non trouvée.

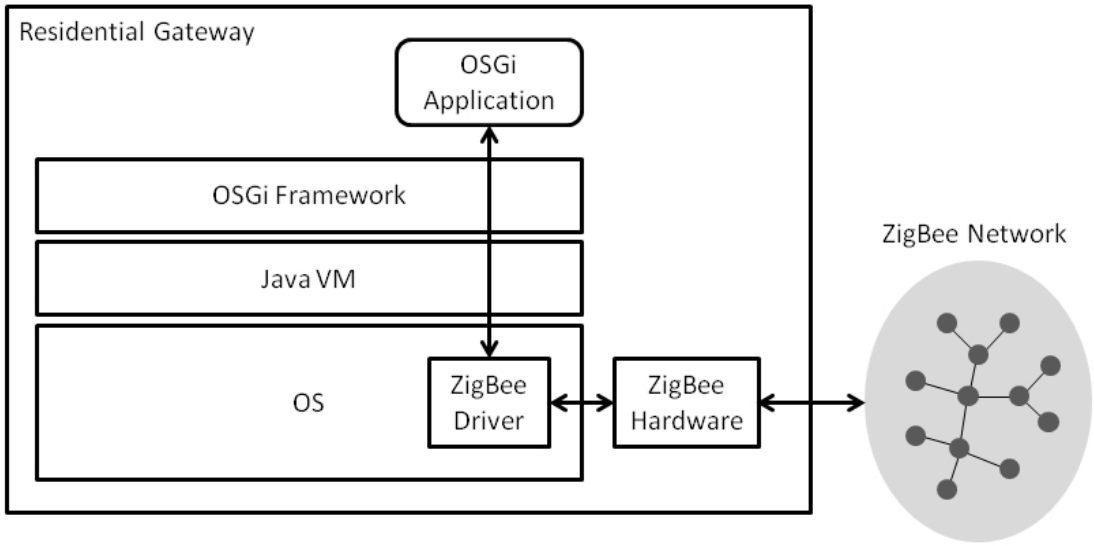

Figure 1 Communication with ZigBee devices through a ZigBee driver

The ZigBee specification defines three types of ZigBee devices: ZigBee Coordinator (ZC), ZigBee Router (ZR) and ZigBee End Device (ZED). In the above case the ZigBee hardware works as the ZigBee Coordinator and the other ZigBee devices are attached to the ZigBee network as ZigBee End Device or ZigBee Router.

– ZigBee Coordinator (ZC) is responsible for managing a ZigBee network and ZigBee devices on the network. There is one, and only one ZigBee Coordinator is in each ZigBee network.

– ZigBee Router (ZR) is capable of extending a ZigBee network by relaying messages from other ZigBee devices.

– ZigBee End Device (ZED) has functionality to communicate with either ZigBee Coordinator or ZigBee Router.

ZigBee Stack

The ZigBee stack is shown in Erreur : source de la référence non trouvée. The two bottom layers, the PHY layer and the MAC layer, are defined by IEEE802.15.4 standard. The ZigBee standard defines network (NWK) layer, application (APL) layer and security layer on top of it. The NWK layer is responsible for managing the network formation and routing. The APL layer hosts application objects developed by manufacturers. The security service provider is responsible for encryption and authentication.

The application layer consists of three functional blocks: application support sub-layer, ZigBee Device Object (ZDO) and application framework. The application support sub-layer provides the transmission capability of data and management messages. The ZDO provides common functionality used by all applications. The application framework is the environment where application objects are hosted to control and manage the protocol layers.

There are two interfaces available to applications: APSDE-SAP and ZDO public interface. The APSDE-SAP

provides data transmission functionality between ZigBee devices. The ZDO public interface provides applications with management functionality such as device discovery, service discovery and network management.

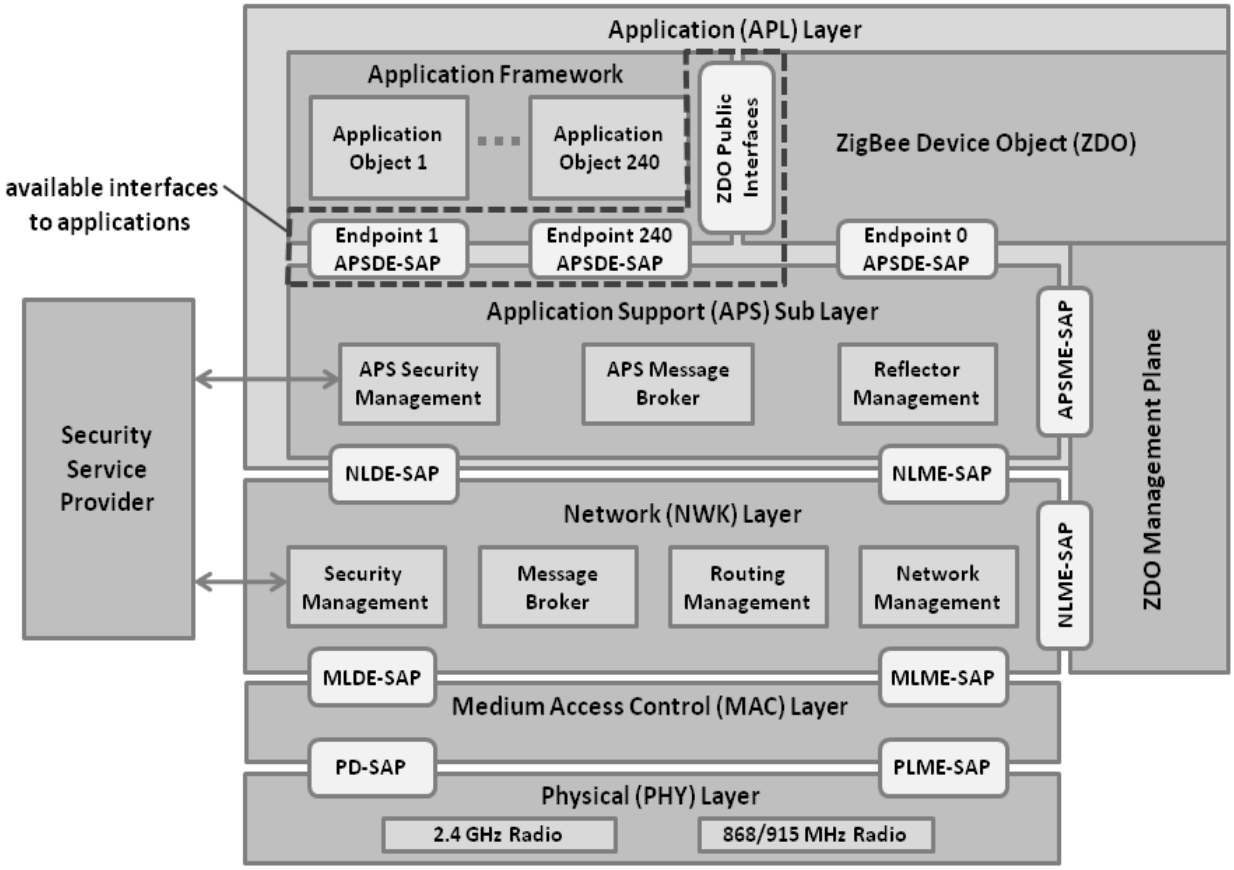

Figure 2: ZigBee Stack

Application Profiles and ZigBee Cluster Library (ZCL)

The application profiles allow interoperability between products developed by different vendors for a specific application. For example, in a light control scenario, switches developed by a vendor can turn on and turn off lights developed by another vendor if the both vendors take the same application profile. The ZigBee Alliance has defined nine public application profiles such as Home Automation (HA) and ZigBee Smart Energy (ZSE).

An application profile defines its application domain, a list of specific devices supported in the profile and a list of clusters supported by the devices. A cluster is a relevant collection of commands and attributes which together define an interface for a specific functionality. The clusters used in public application profiles are defined in the ZigBee Cluster Library (ZCL) specification. The ZCL specification defines a number of clusters and categories them into groups by their functionality.

3 Problem Description

As described in the section Erreur : source de la référence non trouvée, OSGi applications which communicate with ZigBee devices are supposed to call the API of the driver provided by the vendor. The API is proprietary and different vendor by vendor since it is not standardized in the ZigBee specification. This causes the following problems:

1) Application developers need to know which vendor's ZigBee hardware is used with the target residential gateway in advance before developing their applications.
2) An application which was developed for a certain environment may not work for other environments.

Those problems make it difficult for third parties to develop portable (OSGi) applications communicating with ZigBee devices.

The standard ZigBee API demanded in this RFP would give developers a unified way of communicating with ZigBee devices. The developers will no longer need to care about the proprietary API of drivers but will simply use the standard one.

4 Requirements

R1: The solution MUST provide an API for data transmission supported by APSDE-SAP.

R2: The solution MUST provide a base driver interface as an OSGi service for management operations supported by ZDO: device and service discovery, security management, network management, binding management, node management and group management.

R3: The solution SHOULD enable applications to trigger a re-scan of the network to refresh the registry with actual ZigBee device services.

R4: The solution MUST provide API for switching the type of the local ZigBee device among ZC, ZR and ZED.

R5: The solution MUST provide a mechanism which notifies OSGi applications of events occurred in the ZigBee network and devices.

R6: The solution MUST provide an installation capability of cluster libraries within OSGi service-oriented architecture.

R7: The solution MUST register a Device Service object representing each found ZigBee device into Service Registry and unregister the Device Service object when the ZigBee device is unavailable.

R8: The solution MAY define the driver provisioning process in accordance with the OSGi Device Access specification.

R9: The solution MUST be independent from the interface used to control the ZigBee network. The solution MUST likewise work with network controllers based on ZigBee built-in chips, ZigBee USB dongles and high level protocols offered by ZigBee Gateway Devices compliant with the ZigBee Alliance specification.

5 Technical Solution

Essentials

- *Scope* – This specification is limited to general device discovery and control aspects of the ZigBee and the ZigBee Cluster Library specifications. Aspects concerning the representation of specific ZigBee profiles are not addressed.
- *Transparency* – ZigBee devices discovered on the network and devices locally implemented on the platform are represented in the OSGi service registry with the same API.
- *Lightweight implementation option* – The full description of ZigBee device services on the OSGi platform is optional. Some base driver implementations may implement all the classes including ZigBee device description classes while implementations targeting constrained devices are able to implement only the part that is necessary for ZigBee device discovery and control.
- *Network Selection* – It must be possible to restrict the use of the ZigBee protocols to a selection of the connected networks.
- *Logical node type selection* – It is possible to make an OSGi-based device appearing as a ZigBee end device, a ZigBee router or a ZigBee coordinator.
- *Event handling* – Bundles are able to listen to ZigBee events.
- *Discover and Control ZigBee Endpoints as OSGi services* – Available ZigBee endpoints are dynamically reified as OSGi services in the service registry.
- *Export OSGi services as ZigBee Endpoints* – OSGi services implementing the API defined here and explicitly set to be *exported* should be made available to networks with ZigBee enabled endpoints in a transparent way.

Entities

- *ZigBee Base Driver* – The bundle that implements the bridge between OSGi and ZigBee networks.
- *ZigBee Node* – A physical ZigBee node. This entity is represented by a **ZigBeeNode** object. It is registered as an OSGi service by the Base Driver.
- *ZigBee Endpoint* – A logical device that defines a communication entity within a ZigBee node through which a specific application profile is carried. This concept is represented by a **ZigBeeEndpoint** object. Registered as an OSGi service, an endpoint can be local (implemented by the Framework) or external (implemented by another device on the network).
- *ZigBee Device Description* – Statically describes a ZigBee endpoint by providing its input/output clusters and specifies which of these clusters are mandatory or not. This entity is represented by a **ZigBeeDeviceDescription** object.
- *ZigBee Cluster* – Represents a cluster existing in the network. It holds its cluster description, the current value for each attributes and allows command invocation. This concept is represented by a **ZCLCluster** object.
- *ZigBee Cluster Description* – Cluster description provides details about available commands and attributes for a specific Cluster. A cluster description should be constant. A cluster description hold either Client or Server Cluster description and refers to a global cluster description.
- *ZigBee Global Cluster Description* – Global cluster description holds the server and client cluster description as well as common information such as cluster id, description and name. This concept is represented by a **ZCLGlobalClusterDescription** object.

- *ZigBee Command Description* – Statically describes a specific cluster command by giving its name, id, parameters. This entity is represented by a **ZigBeeCommandDescription** object.
- *ZigBee Parameter Description* – A ZigBee parameter description has a name, a range and a data type. This entity description is represented by a **ZCLParameterDescription** object.
- *ZigBee Attribute* – Holds the current value of an existing cluster attribute, it allows easy (de)encoding. This concept is represented by a **ZigBeeAttribute** object.
- *ZigBee Attribute Description* – Statically describes a ZigBee Attributes (data type, name, default value). It does not hold any current value. This concept is represented by a **ZigBeeAttributeDescription** object.
- *ZigBee Event Listener Service* – A service that listens to events coming from ZigBee devices.
- *ZigBee Event* – An event generated by a ZigBee node. It contains a modified attribute value of a specific cluster. This concept is represented by a **ZigBeeEvent** object.
- *ZigBee Handler* – A ZigBee handler is a helper that manages asynchronous communication with the base driver. This entity is represented, e.g. by **ZigBeeHandler**.
- *ZigBee Host* – The machine that hosts the code to run a ZigBee device or client. It contains information related to the Host. If the host is in the coordinator logical node type, it enables networking configuration. It is registered as an OSGi service. This concept is represented by **ZigBeeHost**.
- *ZigBee Client* – An application that is intended to control ZigBee devices services.
- *ZCL Exception* – An exception that delivers errors that occurred in the ZigBee stack or internally by the ZigBee Base Driver or by the ZigBee network.
- *ZigBee Exception* – This class represents root exception for all the code related to ZigBee/ZDP (see Table 2.137 ZDP Enumerations Description in ZIGBEE SPECIFICATION: 1_053474r17ZB_TSC-ZigBee-Specification.pdf)
- *ZCL Frame* – A ZCL frame that must used when invoking a command.
- *ZCL Header* – A ZCL header that describes the header of a ZCL frame.
- *ZigBee Group* – Enables group management. It is registered as an OSGi service.

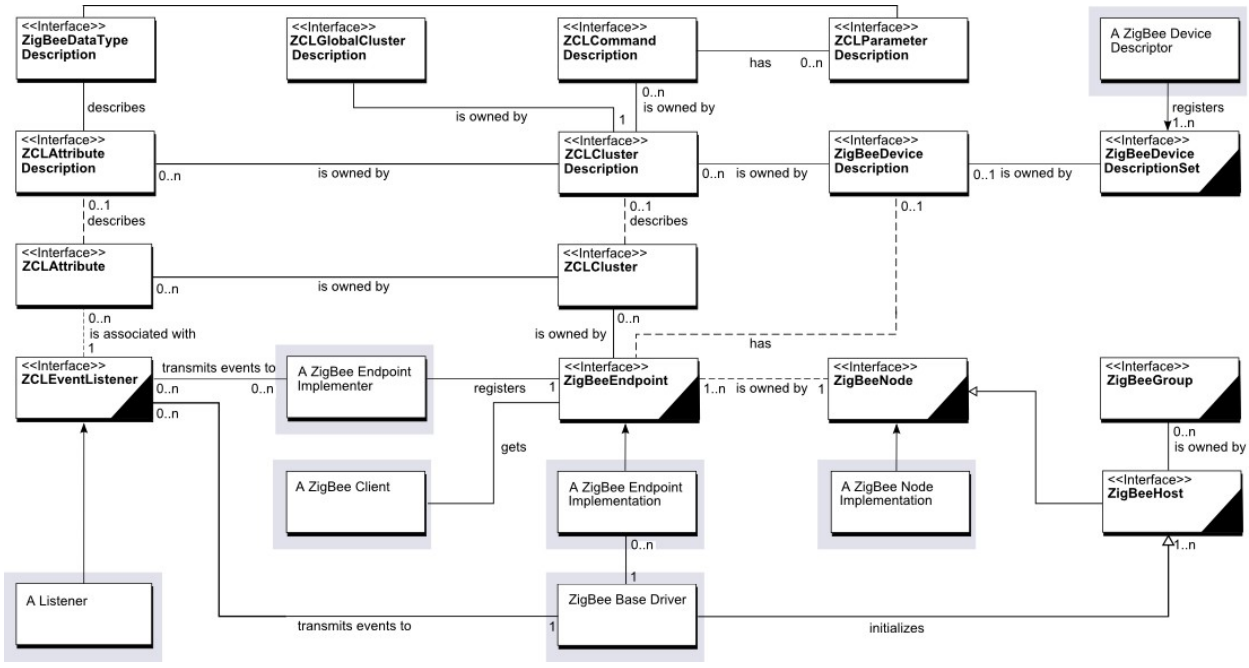

Figure 3 ZigBee Service Specification class Diagram org.osgi.service.zigbee package

Operation Summary

OSGi applications interact with ZigBee devices through their object representation (proxies) registered in OSGi service registry. To make a ZigBee device available as an OSGi service to ZigBee clients on the framework, an OSGi service object must be registered under the **ZigBeeNode** interface with the OSGi framework and an OSGi service must be registered under the **ZigBeeEndpoint** interface with the OSGi framework for every endpoint that is contained by the ZigBee node.

The ZigBee Base Driver is responsible for mapping networked devices into **ZigBeeNode** and **ZigBeeEndpoint** objects, through the use of a ZigBee radio chip. The latter is represented on the OSGi framework as an object implementing **ZigBeeHost** interface. This is called a *device import* situation (see Figure 4).

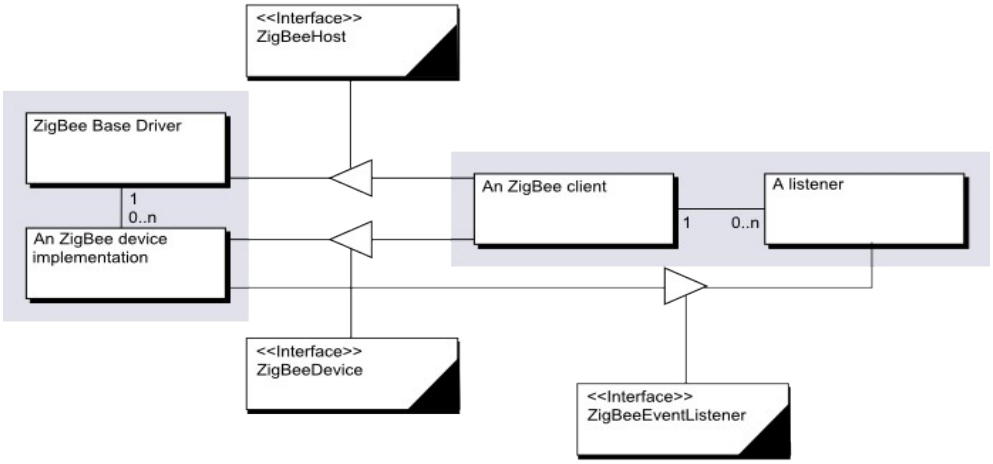

Figure 4: ZigBee device import

OSGi bundles may also expose framework-internal (local) ZigBeeEndpoint instances, registered within the framework (see Figure 5). The Base Driver then should emulate those objects as ZigBee endpoints associated to the ZigBee node represented by the unnderlying ZigBee hots (ZigBee chip) on the ZigBee network. This is a *device export* situation. For more information about this process, please report to the “Exporting a ZigBee device” section below.

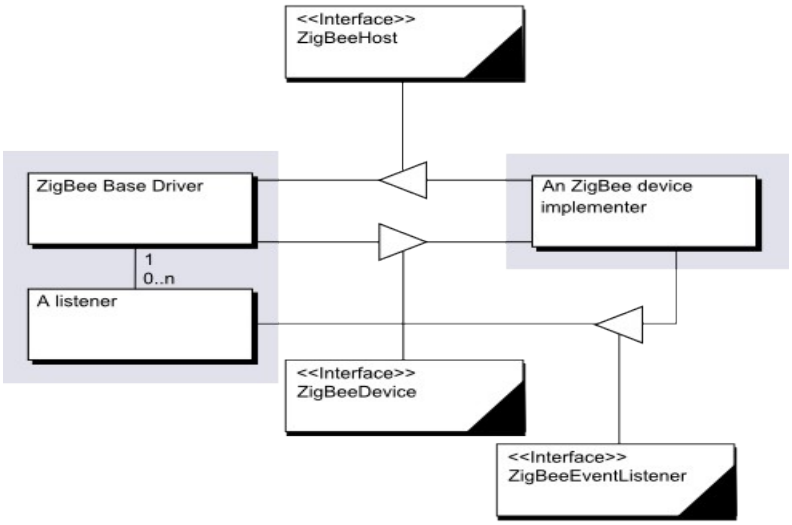

Figure 5: ZigBee device export

To control ZigBee devices, a bundle should track ZigBeeEndpoint services in the OSGi service registry and control them appropriately. OSGi applications can browse the clusters (ZigBeeCluster objects) that are discovered on every registerd ZigBeeEndpoint and attributes (ZigBeeAttribute objects) that are discovered on every ZigBeeCluster. They can invoke commands on these clusters and get the current value of attributes.

Several methods obey an asynchronous mechanism. For instance, ZigBee command invokation is made through the call to ZigBeeCommand invoke method that returns nothing. A handler object – here a ZigBeeCommandHandler – is passed as an argument in this method call. When the command response is to be received, a callback – here **notifyResponse()** – is called on the handler to convey the command response frame. It is called by the base driver in the device import situation and it is called by the local ZigBeeEndpoint in the device export situation.

OSGi bundles – called listeners in Figure 3 – subscribe to attribute value changes through the White Board Pattern ([6].). They register an object under the ZigBeeEventListener interface with properties identifying a ZigBee attribute and a special event filter. This registration is conveyed as a configure report command on the ZigBee network in the device import situation. Reports are received by the base driver and transmitted as ZigBeeEventListener.notifyEvent() method calls on relevant ZigBeeEventListener services in this situation. Local ZigBeeEndpoints directly call these methods to notify listerners with reports in the export situation. The Base Driver conveys events received through listeners from local endpoints as reports to networked devices that have configured the relevant reporting.

Endpoints, clusters, commands and attributes are specified by ZigBee Alliance or vendor-specific descriptions. Those descriptions may be provided on the OSGi platform by any bundle through the registration of ZigBeeDeviceDescriptionSet services (see Figure 6). Every service is a set of descriptions that enables applications to retrieve information about the clusters, commands, attributes supported by the described type of endpoint.

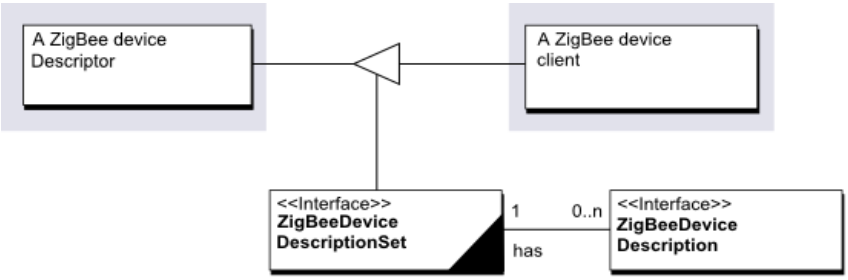

Figure 6: Using a set of device descriptions

ZigBee Base Driver

Most of the functionality described in the operation summary is implemented in a ZigBee *base driver*. A ZigBee base driver is a bundle that implements the ZigBee protocols and handles the interaction with bundles that use the ZigBee devices. It must discover ZigBee devices on the ZigBee network and map each discovered device into OSGi registered ZigBee Node services. It must also *export*, on the ZigBee Network, ZigBeeEndpoint services (programmatically registered as OSGi services).

Several base drivers may be deployed on a residential OSGi device, one for every supported network technology. An OSGi *device abstraction layer* may then be implemented as a layer of *refined drivers* above a layer of *base drivers*. The refined driver is responsible for adapting technology-specific device services registered by the base driver into device services of another model (see AbstractDevice interface in Figure 7). In the case of a generic device abstraction layer, the model is agnostic to technologies.

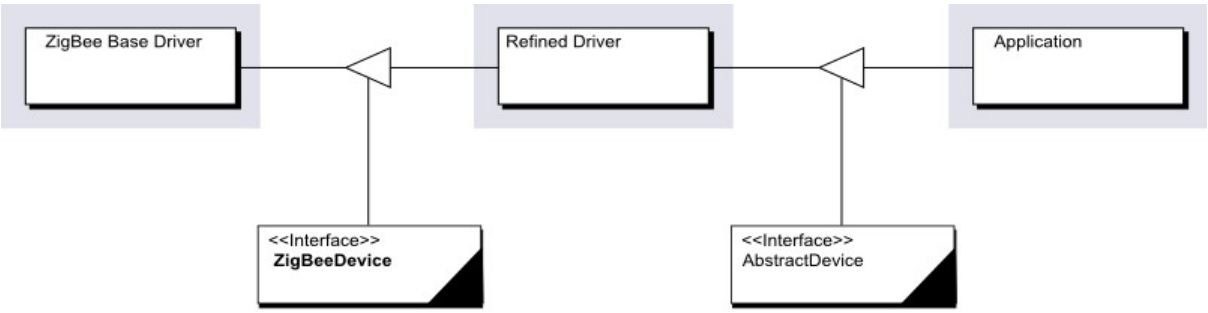

Figure 7: The ZigBee Base Driver and a refined driver representing devices in an abstract model

The ZigBee Alliance defines their own abstract model with ZigBee Profiles, e.g., Home Automation, Lighting, and refined drivers may provide the implementation of all ZigBee standard devices with ZigBee-specific Java interfaces. The AbstractDevice interface of Figure 7 is then replaced by a ZigBee-specific Java interface in that case. The need and the choice of the abstraction depends on the targeted application domain.

ZigBee Node

A ZigBee node represents a physical ZigBee device and should adhere to a specific application profile that can be either public or private. Profiles define the environment of the application, the type of devices and the clusters used for them to communicate.

A physical device is reified and registered as a **ZigBeeNode** service in the Framework. A ZigBee node holds several ZigBee endpoints that are registered as **ZigBeeEndpoint** objects.

ZigBee nodes properties are defined in the ZigBee Specification. These properties must be registered in the OSGi Framework services registry so they are searchable. **ZigBeeNode** must be registered with the following properties:

- IEEE_ADDRESS – (`zigbee.node.ieee.address/Long`)
- LOGICAL_TYPE – (`zigbee.node.description.type/Short`) specifies the device type of the ZigBee node. The ZigBee specification defines three types of nodes: ZigBee coordinator, ZigBee router and ZigBee end device.
- MANUFACTURER_CODE – (`zigbee.node.description.manufacturer.code/Integer`) specifies a manufacturer code that is allocated by the ZigBee Alliance, relating to the device manufacturer.
- POWER_SOURCE – (`zigbee.node.power.source/Boolean`) is the ZigBee power source, i.e. 3rd bit of "MAC Capabilities" in Node Descriptor. Set to 1 if the current power source is mains power, set to 0 otherwise.
- RECEIVER_ON_WHEN_IDLE – (`zigbee.node.receiver.on.when.idle/Integer`) represents the ZigBee receiver on when idle, i.e. 4th bit of "MAC Capabilities" in Node Descriptor. Set to 1 if the device does not disable its receiver to conserve power during idle periods, set to 0 otherwise.
- PAN_ID – (`zigbee.node.pan.id/Integer`) (Personal Area Network Identifier) is a 16-bit value that identifies a ZigBee network. Every **ZigBeeNode** object is associated to a PAN ID, which can be retrieved through the ZigBeeNode.getPanId() method.
- EXTENDED_PAN_ID – (`zigbee.node.pan.extended.id/Long`) Extended PAN ID is a 64-bit numbers that uniquely identify a PAN. It is intended to enhance selection of a PAN and enable recognition of network after PAN ID change (due to previous conflict). ZigBeeNode.getExtendedPanId() returns the network extended PAN ID if specified.

Note that: PAN_ID and EXTENDED_PAN_ID are optional, but at least one of these properties MUST be specified.

- org.osgi.service.device.Constants.DEVICE_CATEGORY (see OSGI Compendium: 103 Device Access Specification) – (“DEVICE_CATEGORY”) describes a table of the categories to which the device belongs. One of the value MUST be “ZigBee” (org.osgi.service.zigbee.ZigBeeEndpoint.DEVICE_CATEGORY).

Additional properties (defined in Device Access – 103.2.1) may be set:

- DEVICE_DESCRIPTION – if the complex descriptor of the device is available, the value MUST be set and MUST be the value returned by ZigBeeComplexDescriptor.getModelName().
- DEVICE_SERIAL – if the complex descriptor of the device is available, the value MUST be set and MUST be the value returned by ZigBeeComplexDescriptor.getSerialNumber().

Finally, service.pid property MUST be set.

ZigBee nodes describes themselves using descriptor data structures:

- getNodeDescriptor() – Returns a **ZigBeeNodeDescriptor** object representing Node Descriptor which contains information about the node capabilities.
- getPowerDescriptor() – Returns a **ZigBeePowerDescriptor** object representing Node Power Descriptor which gives a dynamic indication of the node power status.
- getComplexDescriptor() – Returns a **ZigBeeComplexDescriptor** object representing Complex Descriptor which contains extended information for each device descriptions contained in this node. Returns null if no Complex Descriptor is provided.
- getUserDescriptor() – Returns a **ZigBeeUserDescriptor** object representing User Descriptor which contains information that allows the user to identify the device using user-friendly character string. Returns null if no User Descriptor is provided.

ZigBeeNode object also provides simple methods to handle standard ZigBee Device Object networking feature: getLinksQuality(), getRoutingTable(), and leave().

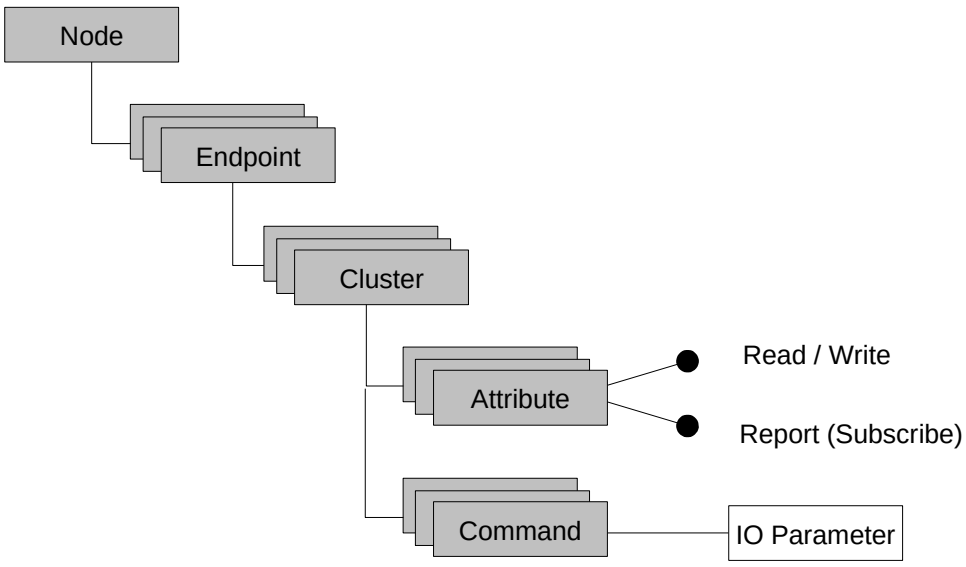

Figure 8: ZigBee Cluster Library model

All interfaces corresponding to the ZigBee Cluster Library model (see Figure 5) must be implemented in order to discover and control asynchronously ZigBee devices. Classes related to the description of these entities (named with suffix "*Description" may optionally be implemented. This rule follows the fact that ZigBee device descriptions are not downloadable on the device itself and are often given to developers in an out-of-band manner.

ZigBee Endpoint

Communication between devices is done through an addressable component called ZigBee endpoint which holds a number of ZigBee clusters. A ZigBee cluster represents a functional unit in a device.

An endpoint defines a communication entity within a device through which a specific application is carried. So, it represents a logical device object used for communication.

For example, a remote control light might allocate Endpoint 7 for the control of lights in the master bedroom, Endpoint 9 to manage the heating and air conditioning system, and Endpoint 14 for controlling the security system.

The ZigBee specification defines that a maximum of 240 Endpoints is allowed per **ZigBeeNode**. Endpoint 0, also called the ZigBee Device Object (ZDO), is reserved for the management operations on both ZigBee node and ZigBee Endpoints, Endpoint 255 is reserved for broadcasting to all endpoints, Endpoints 241-254 are reserved for future use.

Endpoint 0 and Endpoint 255 capabilities are not exposed, only Endpoints 1-240 should be registered as services. Endpoints are registered under the **ZigBeeEndpoint** interface with the following properties:

- ENDPOINT_ID – (`zigbee.endpoint.id/Integer`) specifies the endpoint address within the node. Applications shall only use endpoints 1-240.
- PROFILE_ID – (`zigbee.device.profile.id/Integer`) identifies the profile that the Endpoint belongs to. The profile can be either a ZigBee Alliance standard profile or a vendor-specific profile. The ZigBee specification defines several profile identifiers, and some others are vendor specific.
- HOST_PID (`zigbee.endpoint.host.pid/String`) – The ZigBee local host identifier is intended to uniquely identify the ZigBee local host, since there could be many hosts on the same platform. All the nodes that belong to a specific network MUST specify the value of the associated host number.
- DEVICE_ID – (`zigbee.device.id/Integer`) identifies the device description supported by this endpoint. Like the profiles identifiers, the ZigBee specification defines several device identifiers, and some others are vendor specific.
- DEVICE_VERSION – (`zigbee.device.version/Integer`) specifies the device description version supported by this endpoint.
- INPUT_CLUSTERS – (`zigbee.endpoint.clusters.input/String[]`) specifies the list of input cluster ids supported by this endpoint. Input cluster at the end are called Server cluster.
- OUTPUT_CLUSTERS – (`zigbee.endpoint.clusters.output/String[]`) specifies the list of output cluster ids supported by this endpoint. Output cluster at the end are called Client cluster.
- org.osgi.service.device.Constants.DEVICE_CATEGORY (see OSGI Compendium: 103 Device Access Specification) – ("DEVICE_CATEGORY") describes a table of the categories to which the device belongs. One of the value MUST be "ZigBee" (org.osgi.service.zigbee.ZigBeeEndpoint.DEVICE_CATEGORY).

Finally, service.pid property MUST be set. In device import case, it is a free unique identifier that enables OSGi ZigBee clients to identify any imported endpoint across node reboots. In endpoint export case, it is a free unique identifier that enables the base driver to identify any exported endpoint across local bundle restarts.

A **ZigBeeEndpoint** may contain a number of input or output clusters. **ZigBeeEndpoint** provides getServerCluster(int clusterId) and getClientCluster(int clusterId) to return a specific server input or client output cluster.

Each endpoint must provide a simple descriptor. getSimpleDescriptor() returns a **ZigBeeSimpleDescriptor** object which contains general information about the endpoint.

ZigBeeEndpoint interface provides two methods to bind and unbind ZigBee clusters: bind(...) and unbind(...). The entity that wants to bind clusters is responsible for initializing, maintaining and removing the bindings across ZigBeeEndpoint service events. This entity is the local OSGi Application that asked this binding or the ZigBee Base Driver if the binding has been requested by a remote ZigBee node.

ZigBeeEndPoint interface provides a getBoundEndPoints(...) method that provides the table of bound ZigBeeEndpoints identified by their service PIDs.

ZigBee Device Description

A ZigBee endpoint may have a description used to define and instantiate his input and output clusters, but also describes which of these clusters are mandatory or not.

ZigBeeDeviceDescription provides general information about an endpoint, and describes its inputs and outputs clusters.

ZigBee Device Description Set

ZigBeeDeviceDescriptionSet objects are registered as OSGi services by the Base Driver. A ZigBeeDeviceDescriptionSet provides getDeviceSpecification(int deviceId, short version) which returns the device description if provided, or null otherwise. ZigBeeDeviceDescriptionSet service should be registered with the following properties:

- VERSION – (`zigbee.profile.version/Short`) The application profile version.
- PROFILE_ID – see ZigBeeEndpoint.PROFILE_ID property.
- PROFILE_NAME – (`zigbee.profile.name/String`) The profile name.
- MANUFACTURER_CODE – see ZigBeeNode.MANUFACTURER_ID property.
- DEVICES – (`zigbee.profile.devices/Integer[]`) A comma separated list of devices identifiers supported by the set.

ZCL Cluster

Devices communicate with each other by means of clusters, which may be inputs to or outputs from the device. For example, in the ZigBee HA (Home Automation) profile there is a cluster dedicated to the control of lighting subsystems. Clusters are represented under **ZCLCluster** interface.

ZCLCluster objects combine one or more ZigBee frame and ZigBeeAttribute.

ZCLCluster provides some methods for reading and writing attributes values:

- readAttributes(int[] attributeIds, ZigBeeMapHandler handler) – The ZBD MAY (i.e. ZBD may cache request) generate the read attributes command on behalf of the OSGi application that is invoking the readAttributes method.
- writeAttributes(boolean undivided, ZigBeeAttributeRecord[] attributes, ZigBeeMapHandler handler) – The ZBD generates the write attributes command on behalf of the OSGi application that is invoking the writeAttributes method. If handler is set to null, the base driver should use a 'no response' ZigBee general command (see Chapter 2.4 General Commands in ZCL specification). The boolean undivided parameter specifies that if any attribute cannot be written (e.g. If an attribute is not implemented on the device, or a

value to be written is outside the valid range), no attribute values are changed.

ZCLCluster objects use ZCLFrame to invoke ZigBee commands using a handler based response; operations parameters are attributes that will be manipulated:

- invoke(ZCLFrame frame, ZigBeeCommandHandler handler) – bytes is a sequence of byte and represents the command frame. The source endpoint is not specified in this method call. To send the appropriate message on the network, the base driver must generate a source endpoint. The latter must not correspond to any exported endpoint.
- invoke(ZCLFrame, ZigBeeCommandHandler handler, String exportedServicePID) – bytes is a sequence of byte and represents the command frame, and exportedServicePID is the source endpoint of the command request. In targeted situations, the source endpoint is the valid service PID of an exported endpoint.

A handler is provided to manage the command response asynchronously.

ZCL Cluster Description

ZCLClusterDescription describes the server or client part of a **ZCLCluster**. It lists the available commands and attributes for this client or server cluster.

Each cluster client and server may have attributes (see ZCL specifications chapter 2.2.1), received and generated commands. **ZCLClusterDescription** provides methods to describe commands, attributes and retrieve general cluster information.

ZCL Global Cluster Description

ZCLGlobalClusterDescription describes a cluster general information: id, name, description. It provides the **ZCLClusterDescription** for both client and server part of this cluster.

ZigBee Command Description

ZigBeeCommandDescription describes a ZigBee command.

ZigBeeCommandDescription contains **ZCLParameterDescription** objects which describe the command parameters. **ZCLParameterDescription** has, for instance, a checkValue(Object value) method which returns true if the parameter value is valid according to its description.

All clusters (server and client) shall support generation, reception and execution of the Default response command.

Each cluster (server or client) that implements attributes shall support reception of, execution of, and response to all commands to discover, read, write, report, configure reporting of, and read reporting configuration of these attributes. Generation of these commands is application dependent.

ZigBeeCommandDescription also provides two methods for serializing (Java Values to bytes), and deserializing (bytes to Java Values). These bytes are, respectively, the parameters, and the returned value sent, respectively received when invoking a ZigBee command.

ZigBee Attribute

A ZigBee cluster is associated with a set of attributes. Each attribute is represented by a **ZigBeeAttribute** interface. ZigBeeAttribute provides getValue(ZigBeeAttributesHandler handler) and setValue(Object value, ZigBeeAttributesHandler handler) to retrieve and set current attribute value.

ZigBee Attribute Description

ZigBeeAttributeDescription describes information about a specific **ZigBeeAttribute.**

ZigBee Data Type Description

ZigBeeAttributeDescription and **ZCLParameterDescription** provides a getDataType() which returns a **ZigBeeDataTypeDescription** object. The interface provides, amongst others, the following methods:

- void serialize(Object param, ByteArrayOutputStream outdata) – Serializes a Java Object corresponding to the Java data type given by getJavaDataType(), and adds the result to the given ByteArrayOutputStream according to ZigBee Cluster Library.
- Object deserialize(ByteArrayInputStream data) – Deserializes the given data into a Java Object of the Java data type given by getJavaDataType().

ZigBee Attribute Record

A **ZigBeeAttributeRecord** object holds some useful information about a given **ZigBee attribute**. It's mainly used by ZCLCluster.writeAttributes(...) for writing operations. **ZigBeeAttributeRecord** provides the following methods:

- getId() – Returns the attribute identifier.
- getDataType() – Returns the attribute data type.
- getValue() – Returns the attribute object value.

ZigBee Handler

The ZigBee Handlers (i.e. **ZigBeeHandler**, **ZigBeeCommandHandler**, and **ZigBeeMapHandler**) help to manage asynchronous communication with the base driver. The defined interfaces are used when requesting the base driver and provide onSuccess(...) and onFailure(...) methods for managing responses.

This table shows the methods that uses a **Handler** and the following description of the map parameter:

Methods	Map parameter description
ZCLCluster.readAttributes(int[] attributesIds, ZigBeeMapHandler handler)	For each Map entry, the key is the attribute identifier of **Integer** type and the value is the associated attribute value of **Object** type (or null if an UNSUPPORTED_ATTRIBUTE occurred).
ZCLCluster.writeAttributes(boolean undivided, ZCLAttributeRecord[] attributesRecords, ZigBeeMapHandler handler)	For each Map entry, the key is the attribute identifier of **Integer** type and the value is the associated attribute status, i.e. SUCCESS, INVALID_VALUE, etc. In case **undivided** equals **false**, **onSuccess()** is always called to notify the response. In case **undivided** equals **true** and an error has occurred, **onFailure** is called with a ZCLException.
ZCLCluster.invoke(ZCLFrame frame, ZigBeeCommandHandler handler)	The notifyResponse method takes the response of **ZCLFrame** type as parameter.
ZCLCluster.invoke(ZCLFrame frame, ZigBeeCommandHandler handler, String exportedServicePID)	The notifyResponse method takes the response of **ZCLFrame** type as parameter.
ZCLAttribute.getValue(ZigBeeHandler handler)	Only one Map entry, the key is the attribute identifier of **Integer** type and the value is the associated attribute value of **byte[]** type. In case of a failure, **onFailure** is

	called with a ZCLException.
ZCLAttribute.setValue(Object value, ZigBeeHandler handler)	Only one Map entry, the key is the attribute identifier of **Integer** type and the value is **true** if the attribute value has been written or **false** otherwise.

ZigBee Data Types

ZigBeeDataTypes provides all standard ZigBee type descriptions as **ZigBeeDataTypeDescription** objects assigned to public final static fields (constants).

Here is the table of encoding relations between ZigBee types and Java types:

ZigBeeDataType constant	ZigBee type	Java type
SIGNED_INTEGER_8 BITMAP_8 GENERAL_DATA_8	Signed 8-bit integer 8-bit bitmap 8-bit data	Byte
SIGNED_INTEGER_16 BITMAP_16 GENERAL_DATA_16 UNSIGNED_INTEGER_8	Signed 16-bit integer 16-bit bitmap 16-bit data Unsigned 8-bit integer	Short
SIGNED_INTEGER_24 SIGNED_INTEGER_32 BITMAP_24 BITMAP_32 GENERAL_DATA_24 GENERAL_DATA_32 UNSIGNED_INTEGER_16 UNSIGNED_INTEGER_24	Signed 24-bit integer Signed 32-bit integer 24-bit bitmap 32-bit bitmap 24-bit data 32-bit data Unsigned 16-bit integer Unsigned 24-bit integer	Integer
SIGNED_INTEGER_40 SIGNED_INTEGER_48 SIGNED_INTEGER_56 SIGNED_INTEGER_64 BITMAP_40 BITMAP_48 BITMAP_56 BITMAP_64 GENERAL_DATA_40 GENERAL_DATA_48 GENERAL_DATA_56 GENERAL_DATA_64 UNSIGNED_INTEGER_32 UNSIGNED_INTEGER_40 UNSIGNED_INTEGER_48 UNSIGNED_INTEGER_56	Signed 40-bit integer Signed 48-bit integer Signed 56-bit integer Signed 64-bit integer 40-bit bitmap 48-bit bitmap 56-bit bitmap 64-bit bitmap 40-bit data 48-bit data 56-bit data 64-bit data Unsigned 32-bit integer Unsigned 40-bit integer Unsigned 48-bit integer Unsigned 56-bit integer	Long
UNSIGNED_INTEGER_64	Unsigned 64-bit integer	BigInteger
OCTET_STRING LONG_OCTET_STRING SECURITY_KEY	Octet string Long octet string 128-bit Security Key	byte[]

CHARACTER_STRING LONG_CHARACTER_STRING	Character string Long character string	String
BOOLEAN	Logical	Boolean
ENUMERATION_8	8-bit enumeration	Short
ENUMERATION_16 CLUSTER_ID ATTRIBUTE_ID	16-bit enumeration Unsigned 16-bit integer Unsigned 16-bit integer	Integer
BACNET_OID	BACnet OID*(Unsigned 32-bit integer)	Long
IEEE_ADDRESS	IEEE address (MAC-48,EUI-48/64)	Long
TIME_OF_DAY DATE UTC_TIME	Time of day Date UTCTime	Date
FLOATING_SEMI FLOATING_SINGLE	Semi-precision Single precision	Float
FLOATING_DOUBLE	Double precision	Double
ARRAY STRUCTURE BAG	Array Structure Bag	List
SET	Set	Set
UNKNOWN	Unknown	

* BACnet OID (Object identifier) data type is included to allow interworking with BACnet (see [5].). The format is described in the referenced standard.

Working With a ZigBee Endpoint

All discovered ZigBee endpoints in the local networks are registered under **ZigBeeEndpoint** interface with the OSGi Framework. Every time a ZigBee endpoint appears or quits the network, the associated OSGi service is registered or unregistered in the OSGi service registry. Thanks to the ZigBee Base Driver, the OSGi service availability in the registry mirrors ZigBee device availability on ZigBee networks [3]..

Using a remote ZigBee endpoint thus involves tracking ZigBee Endpoint services in the OSGi service registry. The following code illustrates how this can be done. The sample Controller class extends the ServiceTracker class so that it can track all ZigBee Endpoint services and add them to a user interface, such as a remote controller application.

```
class Controller extends ServiceTracker {
   UI ui;
   Controller( BundleContext context ) {
   super( context, ZigBeeEndpoint.class, null );
   }
   public Object addingService( ServiceReference ref ) {
          ZigBeeEndpoint endpoint = (ZigBeeEndpoint)super.addingService(ref);
          ui.addEndpoint( endpoint );
          return endpoint;
   }
   public void removedService( ServiceReference ref, Object endpoint ) {
          ui.removeEndpoint( (ZigBeeEndpoint) endpoint );
   }
   ...
     }
```

Implementing a ZigBee Endpoint

OSGi services can also be exported as ZigBee endpoints to the local networks, in a way that is transparent to typical ZigBee devices endpoints. This allows developers to bridge legacy devices to ZigBee networks. A **ZigBeeEndpoint** should be registered with the following properties to export an OSGi service as a ZigBee endpoint:

- ZIGBEE_EXPORT – To indicate that the endpoint is an exportable endpoint.

An OSGi platform can be connected to multiple ZigBee networks. HOST_PID, PAN_ID and EXTENDED_PAN_ID are used to select the appropriate network. At least one of these properties MUST be specified. If provided, HOST_PID have priority on PAN_ID and EXTENDED_PAN_ID to identify the host that is targeted for export.

In addition, the **ZigBeeEndpoint** service MUST declare the same properties as an imported endpoint. The bundle registering endpoint services must make sure these properties are set accordingly or that none of these properties are set. In case a ZigBee Host is not initialized yet or the base driver is not active on the OSGi framework, an endpoint implementation could wait for a **ZigBeeHost** to appear in the OSGi service registry before setting these properties.

The Base Driver will export the endpoint on the ZigBee network associated to the ZigBee HOST PID, ZigBee PAN ID or Extended PAN ID. The associated **ZigBeeNode** object MUST be one of the available **ZigBeeHost** objects. Every time an Endpoint is registered or unregistered with both ZIGBEE_EXPORT and PAN IDs properties set, the associated ZigBeeHost service is modified accordingly (getEndPoints() returns a different Enumeration object).

If an error occurs when exporting a ZigBee endpoint, then the base driver calls ZigBeeEndpoint.notExported() method with a relevant **ZCLException** object as the input argument.

The endpoint has to be registered with an ID that is unique. If the chosen ID already exists as a property of a local endpoint with the same host or if it already exists in an optional cache of the base driver, the base driver calls ZigBeeEndpoint.notExported() method with the **ZCLException** object as the input argument with ZCLException.OSGI_EXISTING_ID error code. The base driver may keep IDs in a cache for endpoints that might come back in the registry. The range of potential IDs is 1-240 according to ZigBee specification [1]..

The reader must note that a same ZigBeeEndpoint object can not be registered several times with distinct PAN IDs since ZigBeeEndpoint.getNodeAddress() method can only return one ZigBee Node address..

If the PAN ID corresponds to more than one ZigBeeHost, the ZigBeeEndpoint MUST define the Extended PAN ID property which uniquely identifies a ZigBee network. The base driver will call ZigBeeEndpoint.notExported() with the error code ZCLException.OSGI_MULTIPLE_HOSTS if the Extended PAN ID property is not properly defined in this specific situation.

Moreover, if the HOST PID corresponds to more than one ZigBeeHost, the base driver will also call ZigBeeEndpoint.notExported() with the error code ZCLException.OSGI_MULTIPLE_HOSTS.

Event API

There are two distinct event directions for the ZigBee Service specification.

- External events from the network must be dispatched to listeners inside the OSGi Service Platform. The ZigBee Base driver is responsible for mapping the network events to internal listener events.
- Implementations of ZigBee endpoints must send out events to local listeners. The ZigBee Base driver dispatches events from its own listeners.

ZigBee events are sent using the whiteboard pattern [6]., in which a bundle interested in receiving the ZigBee events registers an object implementing the **ZCLEventListener** interface. The service MUST be registered with PAN_ID (zigbee.node.pan.id) and/or EXTENDED_PAN_ID (zigbee.node.extended.pan.id) properties. These properties indicates the network targeted by the listener since an OSGi platform can host multiple

ZigBee networks.

A filter can be set to limit the events for which a bundle is notified. The ZigBee Base driver must register a ZigBee Event Listener for every attribute report configured in configure reporting commands it receives from the network.

The filter refers to the combination of the properties registered with the ZCLEventListener service. The mandatory properties (i.e. each ZCLEventListener MUST be registered with all the mandatory property) are:

- ZigBeeNode.IEEE_ADDRESS – (zigbee.node.ieee.address/Long) Only events generated by endpoints matching the specific node are delivered.
- ZigBeeEndpoint.ID – (zigbee.endpoint.id/Short) Only events matching a specific endpoint are delivered.
- ZCLCluster.ID – (zigbee.cluster.id/Integer) Only events generated by endpoints matching a specific cluster are delivered.
- ZigBeeAttribute.ID – (zigbee.attribute.id/Integer) Only events generated by endpoints matching a specific attribute are delivered.
- ZCLEventListener.ATTRIBUTE_DATA_TYPE – (zigbee.attribute.datatype/Short) The Attribute data type field contains the data type of the attribute that is to be reported (see ZCL – 2.4.7.1.4 Attribute Data Type Field).

The optional properties are:

- ZCLEventListener.MIN_REPORT_INTERVAL – (zigbee.attribute.min.report.interval/Integer) The minimum interval, in seconds, between issuing reports of the specified attribute. If it is not specified, then the base driver should set the value to 0x0000 in commands (see ZCL – 2.4.7.1.5).
- ZCLEventListener.MAX_REPORT_INTERVAL – (zigbee.attribute.max.report.interval/Integer) The maximum interval, in seconds, between issuing reports of the specified attribute. if it is not specified, then the base driver should set the value to 0xffff in commands (see 2.4.7.1.6).
- ZCLEventListener.REPORTABLE_CHANGE – (zigbee.attribute.reportable.change/Double) The minimum change to the attribute that will result in a report being issued. This property is mandatory if the data type is 'analog'. If the data type is 'digital', the base driver will ignore it.

If the endpoint sets a timeout between two attribute reports, the ZCLEventListener.notifyTimeOut(int) is then called with the set ‘timeout’ argument. In the import situation, the base driver calls this method on the relevant listeners when it receives a configure reporting command with a set TIMEOUT_PERIOD field (see [2]. 2.4.7 Configure Reporting Command)”. In the export situation, the local endpoint calls this method on relevant listeners and, in case the base driver is one of the notified listeners, it sends a configure reporting request with the appropriate TIMEOUT_PERIOD field to interested endpoints on the network.

A ZigBee event is represented by a **ZigBeeEvent** object.

If an event is generated by either the local endpoint or via the base driver for an external device, the notifyZigBeeEvent(ZigBeeEvent event) method is called on all registered **ZCLEventListener** services for which the source event matches the service properties. The way events must be delivered is the same as described in Delivering Events in Life Cycle Layer chapter of the Core specification.

The ZigBee base driver SHOULD group subscriptions into one configure reporting requests) to the targeted ZigBee device. It SHOULD also notify every listener with respect to their specific expectations.

ZCL Exception

The **ZCLException** can be thrown and holds information about the different ZigBee ZCL layers. Error codes specified by ZigBee Alliance are conveyed by the errorCode field of ZCLException objects:

- FAILURE – (1) Operation was not successful.

- MALFORMED_COMMAND – (128) Wrong or missing field command.
- CLUSTER_COMMAND_NOT_SUPPORTED – (129) Cluster command not supported.
- GENERAL_COMMAND_NOT_SUPPORTED – (130) General command not supported.
- MANUF_GENERAL_COMMAND_NOT_SUPPORTED – (131) Manufacturer general command not supported.
- MANUF_CLUSTER_COMMAND_NOT_SUPPORTED – (132) Manufacturer cluster command not supported.
- INVALID_FIELD – (133) Invalid field.
- UNSUPPORTED _ATTRIBUTE– (134) Attribute not supported.
- INVALID_VALUE – (135) Invalid attribute value.
- READ_ONLY – (136) Read only attribute.
- INSUFFICIENT_SPACE – (137) Insufficient amount of free space.
- DUPLICATE_EXISTS – (138) Entry already exists in the table.
- NOT_FOUND – (139) Requested information can not be found.
- UNREPORTABLE_TYPE – (140) Attribute periodic reports cannot be issued.
- INVALID_DATA_TYPE – (141) Incorrect attribute data type.
- HARDWARE_FAILURE – (192) Operation unsuccessful due to a hardware failure.
- SOFTWARE_FAILURE – (193) Operation unsuccessful due to a software failure.
- CALIBRATION_ERROR – (194) An error occurred during calibration.

Some error codes are specified by the OSGi Alliance:

- OSGI_EXISTING_ID (16) – another endpoint exists with the same ID.
- OSGI_MULTIPLE_HOSTS (17) – several hosts exist for this PAN ID target or HOST_PID target.

ZDP Exception

The **ZDPException** can be thrown and holds information about the ZigBee ZDP layer. Error codes specified by ZigBee Alliance are conveyed by the errorCode field of ZDPException objects:

- INV_REQUESTTYPE – 0x80 The supplied request type was invalid.
- DEVICE_NOT_FOUND – 0x81 The requested device did not exist on a device following a child descriptor request to a parent.
- INVALID_EP – 0x82 The supplied endpoint was equal to 0x00 or between 0xf1 and 0xff.
- NOT_ACTIVE – 0x83 The requested endpoint is not described by a simple descriptor.
- NOT_SUPPORTED – 0x84 The requested optional feature is not supported on the target device.
- TIMEOUT – 0x85 A timeout has occurred with the requested operation.
- NO_MATCH – 0x86 The end device bind request was unsuccessful due to a failure to match any suitable clusters.
- NO_ENTRY – 0x88 The unbind request was unsuccessful due to the coordinator or source device not having an entry in its binding table to unbind.
- NO_DESCRIPTOR – 0x89 A child descriptor was not available following a discovery request to a parent.
- INSUFFICIENT_SPACE – 0x8a The device does not have storage space to support the requested operation.
- NOT_PERMITTED – 0x8b The device is not in the proper state to support the requested operation.
- TABLE_FULL – 0x8c The device does not have table space to support the operation.
- NOT_AUTHORIZED – 0x8d The permissions configuration table on the target indicates that the request is not authorized from this device.

Note that 0x01-0x7f, 0x87, and 0x8e-0xff are reserved.

ZCL Frame

The **ZCLFrame** contains a **ZCLHeader**, and a payload. It must used when invoking a command.

The **ZCLHeader** describes the header of a **ZCLFrame**.

The transaction id of each **ZCLHeader** must be managed by the base driver.

Only getters (not setters) are shared by client applications, the base driver and endpoint implementations. That's why we standardize getters and we don't standardize setters.

ZigBee Group

The **ZigBeeGroup** enables group management (i.e. it provides list, join, and leave methods).

The creation of Groups is made through the **ZigBeeHost** .createGroupService() method.

ZigBeeGroup service should be registered with the following property:

- ID – (`zigbee.group.id/Integer`) The 16bits group address of the device.

And, the following ZigBeeNode properties:

- DEVICE_CATEGORY
- INPUT_CLUSTERS
- HOST_PID

ZigBee Networking

Logical node type

The ZigBee specification defines three types of ZigBee nodes on the network:

- ZigBee Coordinator (ZC) – The most capable device, the coordinator forms the root of the network. There is exactly one ZigBee coordinator in every network. It is able to store information about the network, to act as the Trust Center and repository for security keys. Constant value **ZigBeeNode.**COORDINATOR represents the ZigBee coordinator.

- ZigBee Router (ZR) – A router is capable of extending a ZigBee network by routing data from other ZigBee devices. Constant value **ZigBeeNode.**ROUTER represents a ZigBee router.

- ZigBee End Device (ZED) – An end device contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. Constant value **ZigBeeNode.**END_DEVICE represents a ZigBee end device.

Each discovered **ZigBeeNode** on the network must have a logical node type returned by **ZigBeeNode.getNodeDescriptor().getLogicalType()**.

Network selection

The base driver provides a ZigBee Host object for each available ZigBee local host. A ZigBee local host can represent a ZigBee chip on a USB dongle, a ZigBee built-in chip or a ZigBee Gateway Device (see [7].) This object must be registered under **ZigBeeHost** interface. ZigBee Host object enables to start, and stop the Host, stores the networking configuration information (channel, channel mask, logical type, PAN ID, Extended Pan ID, security level, network key), and provides a method to open the network for devices to join it (permitJoin()).

In ZigBee networks, the coordinator must select a PAN identifier and a channel to start a network. After that, it behaves essentially like a router. The coordinator and routers can allow other devices to join the network and route data.

After an end device joins a router or coordinator, it is able to transmit or receive data through that router or coordinator. The router or coordinator that allowed an end device to join becomes the parent of the end device. Since the end device can sleep, the parent must be able to buffer or retain incoming data packets

destined for the end device until the end device is able to wake up and receive the data.

Network coordination

In case **ZigBeeHost** is configured as the network coordinator, ZigBeeHost.**getNodeDescriptor().getLogicalType()** MUST return ZigBeeNode.COORDINATOR constant value. **ZigBeeHost** object will then be able to use the following operations for managing the network:

- setChannel(byte channel, ZigBeeHandler handler) – Sets the network channel.
- setChannelMask(int mask, ZigBeeHandler handler) – Sets a new configured channel mask.
- refreshNetwork(ZigBeeHandler handler) – Requests the base driver to launch new discovery requests and refresh devices service registration according to current devices availability. This method is made mandatory since ZigBee specification allows devices not to notify the network when they leave it.

Networking considerations

The Network Address is a 16 bits address that is assigned by the coordinator when a node has joined a network and that must be unique for a given network in order for the node to be identified uniquely. **ZigBeeNode** provides getNetworkAddress() and getIEEEAddress() which returns device network address and device IEEE MAC address.

Security

Security management

ZigBee security is based on a 128-bit algorithm built on the security model provided by IEEE 802.15.4. ZigBee specification defines the Trust Center.

The Trust Center is the device trusted by devices within a network to distribute keys for the purpose of network and end-to-end application configuration management. All members of the network shall recognize exactly one Trust Center, and there shall be exactly one Trust Center in each secure network.

Security amongst a network of ZigBee devices is based on link keys and a network key. Unicast communication between entities is secured by means of a 128-bit link key shared by two devices, one of those is normally the Trust Center. Broadcast communications are secured by means of a 128-bit network key shared amongst all devices in the network. The master key is only use as initial shared secret between two devices when they perform the Key Establishment to generate Link Keys.

Security configuration is provided by getSecurityLevel() of **ZigBeeHost** object returning whether the security mode is activated or not on the ZigBee network.

A **ZigBeeHost** with a coordinator logical node type will acts as a the Trust Center according to the ZigBee specification, it can also be any other device of the network. The Trust Center stores all the shared network keys. **ZigBeeHost**.getMasterKey() operation returns the network master key.

Conditional permission

When a bundle registers a ZigBee Endpoint OSGi service, then the basedriver exposes this Endpoint on the outside ZigBee network and this Endpoint has the ability to communicate with the others network devices. The basedriver also provides an equivalent behavior when discovering a ZigBee Endpoint from the outside network and exposing it as an OSGi Service in the OSGi Framework service registry. It is therefore recommended that `ServicePermission[ZigBeeHost|ZigBeeEndpoint|ZCLEventListener, REGISTER|GET]` be used sparingly and only for trusted bundles.

6 Considered Alternatives

- A **ZigBeeAttribute** object can also implement the **ZigBeeLocalAttribute** interface if the device is implemented locally. That is, the device is not imported from the network. The **ZigBeeLocalAttribute** interface provides a getCurrentValue() method that provides direct access to the actual value of the attribute.
- In Java, primitives types are not objects and the generic function decode(byte[]) returns an Object type. That's why Java objects types instead of primitives are used to represents ZigBee types.
- Is it possible to change the logical node type, e.g., an end device becoming a coordinator with a setLogicalType? Those changes are not described in ZigBee specifications and sound to be complex. So there is not setter for the operational mode in this specification.

Which entity has to be registered in the service registry? The ZigBeeEndpoint object and/or the ZigBeeNode object?

First, a decision has been taken (to be re-thought?) during Basel meeting (September 2012) on the number of objects to be registered: In order to avoid a burst events from 2 entities that are hierarchically related, it is decided only to register one object or the other.
Before arguing between the registration of ZigBeeEndpoint objects or the registration of ZigBeeNode objects, let's describe the two main use cases:

- 1st use case is associated to a special application like a light switch client: The client will search for light switch servers (standardized ZigBee endpoints) in the service registry before interacting with them. The bundle associated to the application will search for light switches and only for this type of services in the registry.
- 2nd use case is associated to a ZigBee network administrator (e.g., the user) who wants to explore the network and all the ZigBee devices and embedded services. The application or HMI will dynamically represent to the administrator all the devices that are available on the ZigBee network. So the application looks for ZigBee nodes in the service registry before exploring the endpoints, clusters, commands and attributes that are hierarchically hosted by these nodes.

Arguments in favor of the registration of ZigBeeEndpoint objects:

- The Endpoint brings more metadata and the information on the real functions brought by ZigBee devices. They are the first entity whose instances are standardized in terms of device profiles (e.g., ZigBee Home Automation profile standardizes light switch endpoints whereas nodes are not standardized). So the registration of this entity makes applications benefit from full OSGi service filter features to search for the right ZigBee services (Endpoints). The first use case is then easier in this case. The second use case will be slightly less easy since the application will have to ask for the node id of any endpoint and filter the list of the available unique nodes.
- Declarative Services lazy mode will be possible and very efficient for the first use case. The application will declare a service dependency towards endpoints that are light switch servers. Declarative Services lazy mode will build the service component only when light switches are available and will save hardware resources (cpu, memory) in when light switches are not available on the ZigBee network (and the OSGi service registry).

Arguments in favor of the registration of ZigBeeNode objects:

- The ZigBeeNode is the root object of the object graph of a ZigBee device. The registration of the ZigBeeNode object is thus enough to represent ZigBee network dynamicity and would avoid the multiplicity of events coming from the registration of all ZigBeeEndpoint objects. The discovery phase of

the second case will be immediate to implement. However, in the first use case, the application will have to ask any node whether it hosts a light switch server. Declarative Services lazy mode will not be usable in that case.

Why having startNetwork() and permitJoin(short duration)? (And not rely on bundle API)

Every ZigBee chip/network has to be started in an independent way while the Base Driver maintains the bindings with available ZigBeeEndpoints to be exported (and that could be exported on a chip that is already started and on a chip that is not started). Relying on bundle start and stop would not make this distinction. This is why startNetwork() and permitJoin() methods are needed in the ZigBeeHost class.

Configure reporting and the White Board Pattern

ConfigureReporting command is a general command. Like every general command, it is implemented through a specific object design pattern. (e.g., Read/Write attribute are implemented with Attribute.get/SetValue() method calls)

Here, the Configure Reporting command enables an application (a client) to subscribe to application-specific events notified by a ZigBee device. In Java, you have 3 patterns available to implement eventing: Observer, WhiteBoard Pattern, Publish Subscribe (from the less to the most loosely coupling pattern). In OSGi, the Observer is not an option. Event Admin is the recommended one when it is relevant. The use of Event Admin, because it totally uncouples Publishers and Subscribers, is not possible for ZigBee eventing. That is why the use of Event Admin is not specified. Actually, ZigBee devices adapt their notification to client needs in attributes, frequency and considered range values. For ZigBee devices need to detect client needs, the Whiteboard pattern is the relevant model. We then have applied the WhiteBoard pattern like it was applied first in UPnP Device Service specification.

In brief:

- Applications interested in attribute reporting (ZigBeeEvents) register ZCLEventListener objects into the registry. The Attribute IDs, the frequency, attribute relevant value ranges are configurable into service properties.
- The Base Driver (for imported Endpoints) and locally implemented Endpoints request relevant listeners (relevance through service filtering) and read subscription information into service properties. Then, whenever an event matches a subscription, they call notifyEvent() method on every relevant registered listener.

Thus, registering a ZCLEventListener triggers ‘Configure Reporting’ commands sent by the base driver on networked devices. See ‘Event API’ section in ZigBee RFC and the javadoc for the detailed API specification.

7 Security Considerations

Description of all known vulnerabilities this may either introduce or address as well as scenarios of how the weaknesses could be circumvented.

8 Document Support

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Acronyms and Abbreviations

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