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Large-scale Integrated Project (IP)

D.18.2.2: FIWARE GE Open Specifications (I2ND Chapter)

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1 Introduction

<u>IMPORTANT NOTE</u>: after the discontinuation of most of the GEris in the I2ND chapter, there is one single GEri applicable to this document, <u>Advanced Middleware (Kiara)</u>. This component has focused the evolution in R5 in the development of encryption mechanisms contained in a single Feature. Most of the effort will be allocated to tasks other than development of new functionality: in-depth code review, optimization of code, support to adopters and participations in events and demos.

Despite the fact that the deliverable is therefore short, we must deliver it to comply with our formal obligations and also for the sake of consistency with the procedures across different technical chapters in FIWARE.

1.1 Executive Summary

This document describes the Generic Enablers in the Advanced Middleware and Interfaces to Networks and Robotics (I2ND) chapter, their basic functionality and their interactions. These Generic Enablers form the core business framework of the FIWARE platform by supporting the business functionality for commercializing services.

The functionality of the framework is illustrated with several abstract use case diagrams, which show how the individual GE can be used to construct a domain-specific application environment and system architecture.

Each GE Open Specification is first described at a generic level, elaborating on the functional and non-functional properties. Then it is supplemented by a number of specifications according to the interface protocols, API and data formats that are delivered in separate individual documents, one per GE.

This document has the available Open Specifications that have been created in FIWARE as a result of the work in Release 5 of the platform.

There is a major shift in the approach of the Open Specifications in FIWARE. Whereas in the initial Releases (from Release 1 to Release 3) the Open Specification APIs were published on the wiki, from Release 4 onwards the information will be created and published in a more modern and manageable format using auxiliary tools such as apiary and github.

This document is accompanied by a set of annexes contained in separate documents, each one providing the detailed Open Specification API of each GE.

1.2 About This Document

FIWARE GE Open Specifications describe the open specifications linked to Generic Enablers GEs of the FIWARE platform (and their corresponding components) being developed in one particular chapter.

GE Open Specifications contain relevant information for users of FIWARE to consume related GE implementations and/or to build compliant products, which can work as alternative implementations of GEs developed in FIWARE. The later may even replace a GE implementation developed in FIWARE within a particular FIWARE instance. GE Open Specifications typically include, but not necessarily are limited to, information such as:

- Description of the scope, behaviour and intended use of the GE
- Terminology, definitions and abbreviations to clarify the meanings of the specification
- Legal information with the terms of use
- The Architecture document is generally included as is for the sake of completeness
- Signature and behaviour of operations linked to APIs (Application Programming Interfaces) that the GE should export. Signature may be specified in a particular language binding or through a RESTful interface described using API Blueprint format as per https://github.com/apiaryio/api-blueprint/blob/master/API%20Blueprint%20Specification.md .
- Description of protocols that support interoperability with other GE or third party products
- Description of non-functional features

1.3 Intended Audience

The document targets interested parties in architecture and API design, implementation and usage of FIWARE Generic Enablers from the FIWARE platform.

1.4 Structure of this Document

The document is generated out of a set of documents provided in the public FIWARE wiki. For the current version of the documents, please visit the public wiki at http://wiki.fiware.org/

The following resources were used to generate this document:

- FIWARE.OpenSpecification.I2ND.Middleware

The present document has been created from the wiki using automated tools and part of the links may not work. You may occasionally find oddities in the text format that side effects of the process but they do not deter the quality of the technical contents.

1.5 Keyword list

FIWARE, FI-Core, Acceleration Programme, Accelerators, PPP, Architecture Board, Steering Board, Roadmap, Reference Architecture, Generic Enabler, Open Specifications, I2ND, Cloud, IoT, Data/Media and Context Management, Applications/Services and Data Delivery, Delivery Framework , Security, Advanced Middleware, Interfaces to Networks and Robotics, Communities, Tools , Sustainability Support Tools, ICT, es.Internet, Apiary, Github, Latin American Platform.

1.6 Changes History

Release	Major changes description	Date	Editor
v1	Initial Version	2016-11-14	TID

1.7 Table of Contents

1.8 Quick Reference Table

This table contains a summary of the basic links to the detailed API on our public resources

- **Open Specification**: link to the Open Specification as included in http://wiki.fiware.org/Summary_of_FIWARE_Open_Specifications (in principle, it is the same one as in the "Structure of this Document" section.
- **API definition source**: link to the API Blueprint markdown (apib file) in GitHub. If the GE does not have a REST interface, link to alternative source if applicable.
- **API Specification Document(HTML version)**: link to the rendered definition and published as HTML in GitHub(output of the internal automated tool FABRE or alternatively Apiary output)
- **Apiary project** (optional): link to the API site in apiary.io

Middleware	Open Specification	FIWARE.OpenSpecification.I2ND.Middleware
	API definition source	N/A
	API Specification Document(HTML version)	http://fiware-middleware.github.io/KIARA/
	Apiary project	N.A.

The official KIARA implementation is complemented by the software of Fast RTPS and its associated manuals, that we deliver as an incubated GE. KIARA Pub/Sub Pattern implements the RTPS protocol in JAVA, and Fast RTPS in C++ and has been adopted in Robotics by ROS (The Robotic Operating System), thus is the perfect bridge between FIWARE and Robotics. The RTPS protocol is defined in an Open Specification of the OMG (http://www.omg.org/spec/DDSI-RTPS/2.2/)

2 FIWARE.OpenSpecification.I2ND.Middleware

Name	FIWARE.OpenSpecification.I2ND.Middleware
Chapter	I2ND
Catalogue-Link to Implementation	Kiara Advanced Middleware
Owner	EPROS , ZHAW , DFKI

2.1 Preface

Within this document you find a self-contained open specification of a FIWARE generic enabler, please consult as well the FIWARE Product Vision, the website on http://www.fiware.org and similar pages in order to understand the complete context of the FIWARE platform.

2.2 Copyright

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2.3 Legal Notice

Please check the following Legal Notice to understand the rights to use these specifications.

2.4 Overview

This specification describes the Advanced Middleware GE, which enables flexible, efficient, scalable, and secure communication between distributed applications and to/between FIWARE GEs.

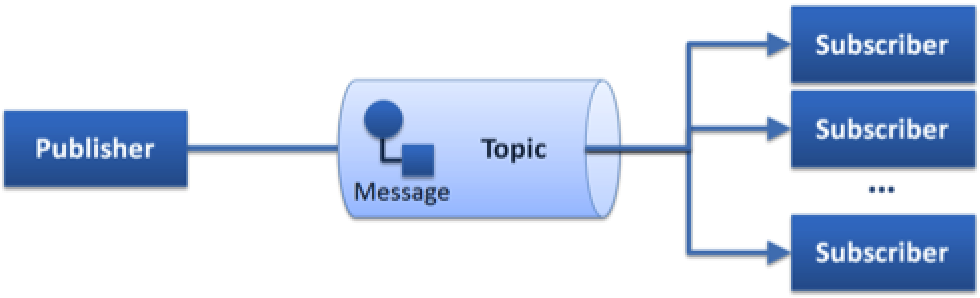
Middleware in general provides a software layer between the application and the communication network and allows application to abstract from the intricacies of how to send a piece of data to a service offered by another application and possibly return results. The middleware offers functionality to find and establish a connection to a service, negotiate the best wire and transport protocols, access the applications data structures and encode the necessary data in a format suitable for the chosen protocol, and finally send that data and possibly receive results in return. In a similar way an application can use the middleware also to offer services to other applications by registering suitable service functionality and interfaces, which can then be used as targets of communication.

2.5 Basic Concepts

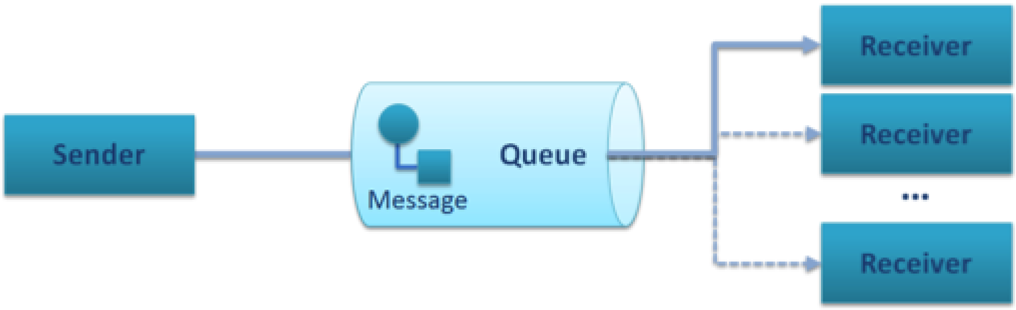
In this section several basic concepts of the Advanced Communication Middleware are explained. We assume that the reader is familiar with the basic functionality of communication middleware like CORBA or WebServices.

Communication Patterns

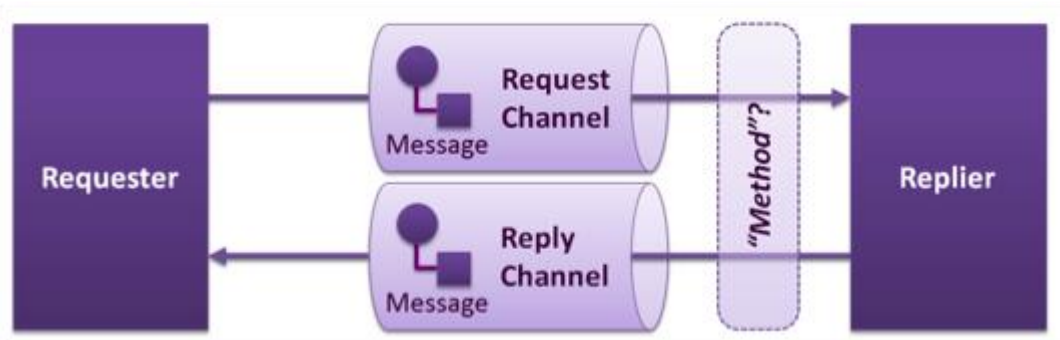
We can distinguish between three main different messaging patterns, Publish/Subscribe, Point-to-Point, and Request/Reply, shown schematically below:



Publish/Subscribe Pattern



Point-To-Point Pattern



Request/Reply Pattern

All available middleware technologies implement one or more of these messaging patterns and may incorporate more advanced patterns on top of them. Most RPC middleware is based on the Request/Reply pattern and more recently, is extended towards support of Publish/Subscribe and/or the Point-To-Point pattern.

W3C Web Service standards define a Request/Reply and a Publish/Subscribe pattern which is built on top on that (WS-Notification). CORBA, in a similar way, build its Publish/Subscribe pattern (Notification Service) on top of a Request/Reply infrastructure. In either case the adopted architecture is largely ruled by historical artifacts instead of performance or functional efficiency. The adopted approach is to emulate the Publish/Subscribe pattern on top of the more complex pattern thus inevitably leading to poor performance and complex implementations.

The approach of the Advanced Middleware takes the other direction. It provides native Publish/Subscribe and implements the Request/Reply pattern on top of this infrastructure. Excellent results can be achieved since the Publish/Subscribe is a meta-pattern, in other words a pattern generator for Point-To-Point and Request/Reply and potential alternatives.

Interface Definition Language (IDL)

The Advanced Middleware GE supports a novel IDL to describe the Data Types and Operations. Following is a list of the main features it supports:

- **IDL, Dynamic Types & Application Types**: It supports the usual schema of IDL compilation to generate support code for the data types.
- **IDL Grammar**: An OMG-like grammar for the IDL as in DDS, Thrift, ZeroC ICE, CORBA, etc.
- **Types**: Support of simple set of basic types, structs, and various high level types such as lists, sets, and dictionaries (maps).
- **Type inheritance, Extensible Types, Versioning**: Advanced data types, extensions, and inheritance, and other advanced features will be supported.
- **Annotation Language**: The IDL is extended with an annotation language to add properties to the data types and operations. These will, for example, allows adding security policies and QoS requirements.
- **Security**: The IDL allows for annotating operations and data types though the annotation feature of our IDL, allowing setting up security even at the field level.

2.6 Generic Architecture

General Note

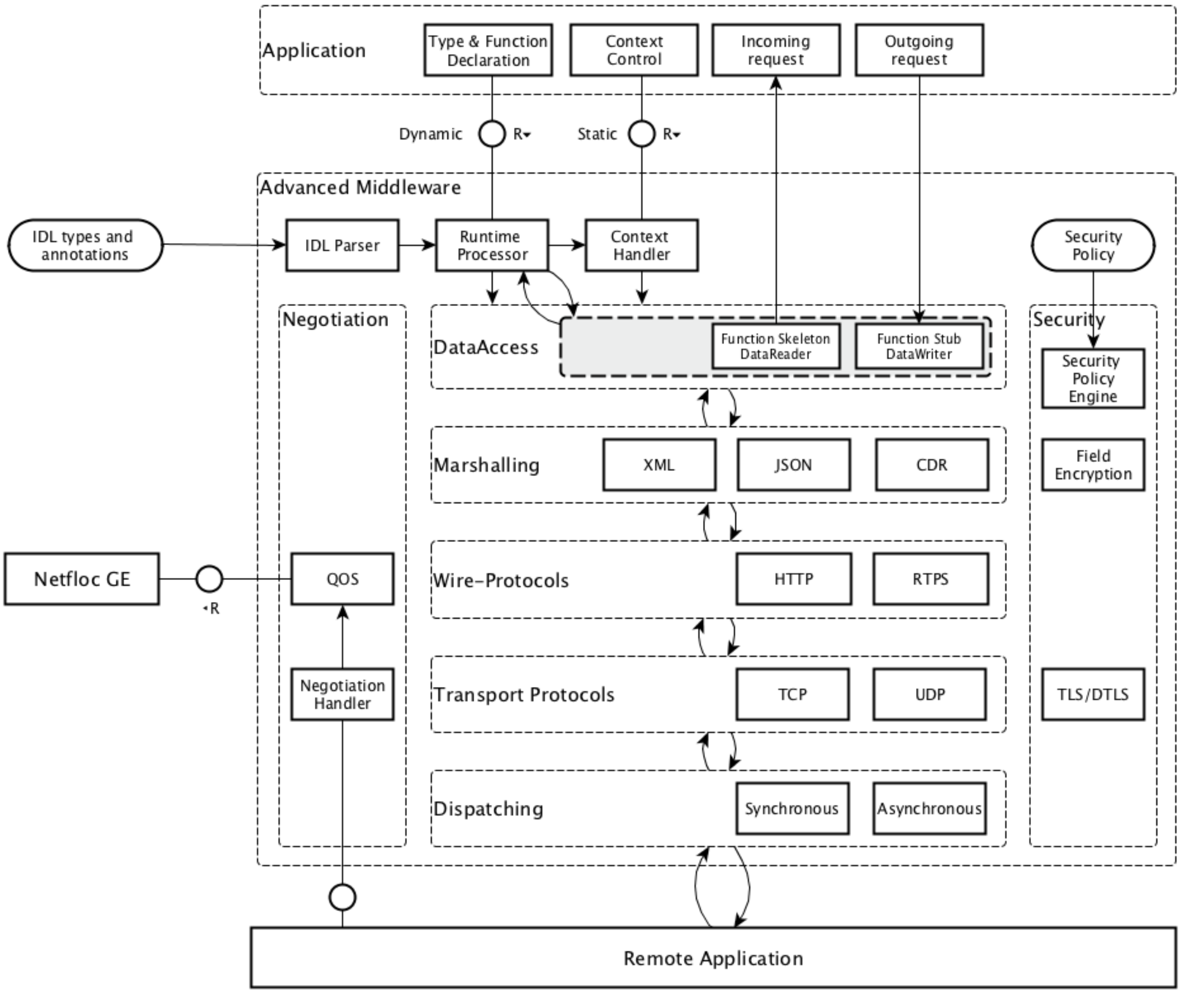
In contrast to other GEs, the Advanced Middleware GE is not a standalone service running in the network, but a set of compile-/runtime tools and a communication library to be integrated with the application.

The Advanced Middleware (AMi) architecture presented here offers a number of key advantages over other available middleware implementations:

- **High-Level Service Architecture:** AMi offers applications a high-level architecture that can shield them from the complexities and dangers of network programming. When applications declare services and data structures they can annotate them with the QoS, security, and other requirements while AMi automatically implement them. Thus application developers can exclusively focus on the application functionality.
- **Security:** The network is the main security threat to most applications today but existing middleware has offered only limited security functionality that has often been added as an afterthought and requires the application developer (who are often not security experts) to configure the security functionality. Instead, AMi offers Security by Design where security has been designed into the architecture from the start. Applications can simply declare their security needs in the form of security policies (security rules) and apply them to data structures and service at development time or even later during deployment definitions. AMi then makes sure that these requirements are met before any communication takes place and applies any suitable security measures (e.g. encryption, signatures, etc.) during the communication.
- **Dynamic Multi-Protocol support:** The AMi architecture can select at run-time the best way to communicate with a remote service. Thus, an AMi application can simultaneously talk with legacy services via their predefined protocols (e.g. DDS). It also supports various communication patterns, like Publish-/Subscribe (PubSub), Point-To-Point, or Request-/Reply (RPC).
- **QoS and Software Defined networking:** Where possible the QoS annotations are also used to configure the network using modern Software Defined networking functionality, e.g. to reserve bandwidth.

The Advanced Middleware GE components

The following layer diagram shows the main components of the Advanced Communication Middleware GE.



Advanced Middleware Architecture Overview

n the diagram the main communication flow goes from top to bottom for sending data, respectively and from bottom to top for receiving data. As in a typical layer diagram each layer is responsible for specific features and builds on top of the layers below. Some modules are cross cutting and go therefore over several layers (e.g. Security).

Here are some of the highlights of the AMi architecture shown in above diagram:

- AMi clearly separates the definition of WHAT data must be communicated (the communication contract via one of many interface definition languages (IDLs)) from WHERE that data comes from in the application and from HOW that data is transmitted. This separation of concerns is critical to support some advanced functionality and be portable to a wide range of services and their communication mechanisms.
- AMi supports multiple IDLs to define what data needs to be communicated. On establishing the connection the interface definition of a service are obtained (explicitly or implicitly).
- AMi offers annotations for QoS, security, or other features that can be added to the data declared by the application, to the IDL, as well as later during deployment. They

are used by the middleware to automatically implement its functionality by requesting QoS functionality from the network layer or automatically enforcing security measures.

- As the connection to a service is established, both sides choose a common mechanism and protocol (negotiation) to best communicate with each other.

The most efficient transport and protocol method supported by both sides will be selected. AMi has been designed to also support Software Defined Networking in order to configure QOS parameters in the network.

- AMi offers an efficient dispatching mechanism for scheduling incoming request to the correct service implementation.

Below we give a short description of the different layers and components.

API & Data Access

The application accesses the communication middleware using a set of defined function calls provided by the API-layer. They may vary depending on the communication pattern (see below).

The main functionality of the Data Access Layer is to provide the mapping of data types and Function Stubs/Skeletons (request/response pattern) or DataReaders/-Writers (publish/subscribe or point-to-point pattern).

The Advanced Middleware GE provides two variants of this functionality:

- A **basic static compile-time Data-Mapping and generation of Function Stubs/Skeletons or DataReaders/-Writers** , created by a compile time IDL-Parser/Generator from the remote service description, which is provided in an Interface Definition Language (IDL) syntax based on the Object Management Group (OMG) IDL (see below), which is submitted as a W3C draft.
- A **dynamic runtime Data-Mapping and invocation of Function or DataReader/-Writer proxies** , by parsing the IDL description of the remote service at runtime and map it to the function/data definition provided by the developer when setting up the connection.

Quality of Service (QoS) parameters and Security Policies may be provided through the API and/or IDL-Annotations. This information will be used by the QoS and Security modules to ensure the requested guarantees.

Depending on the communication pattern, different communication mechanisms will be used.

- For **publish/subscribe** and **point-to-point** scenarios, the DDS services and operations will be provided. When opening connections, a **DataWriter** for publishers/sender and a **DataReader** for subscribers/receivers will be created, which can be used by the application to send or receive DDS messages.
- For **request/reply** scenarios the **Function Stubs/Skeletons** created at compile-time can be used to send or receive requests/replies.

Marshalling

Depending on configuration, communication pattern and type of end-points the data will be serialized to the required transmission format when sending and deserialized to the application data structures when receiving.

- **Common Data Representation (CDR)** an OMG specification used for all DDS/RTPS and high-speed communication.
- **Extensible Markup Language (XML)** for WebService compatibility.
- **JavaScript Object Notation (JSON)** for WebService compatibility.

Wire Protocols

Depending on configuration, communication pattern and type of end-points the matching Wire-Protocol will be chosen.

- For **publish/subscribe** and **point-to-point** patterns the **Real Time Publish Subscribe (RTPS)** Protocol is used.
- For **request/reply** pattern with WebService compatibility the **HTTP** Protocol is used.
- For **request/reply** pattern between DDS end-points the **Real Time Publish Subscribe (RTPS)** Protocol is used.

Dispatching

The dispatching module is supporting various threading models and scheduling mechanisms. The module is providing single-threaded, multi-threaded and thread-pool operation and allows synchronous and asynchronous operation. Priority or time constraint scheduling mechanisms can be specified through QoS parameters.

Transport Mechanisms

Based on the QoS parameters and the runtime-environment the **QoS module** will decide which transport mechanisms and protocols to choose for data transmission.

In Software Defined Networking (SDN) environments, the **QoS module** will interface with the Netfloc GE to get additional network information or even provision the network components to provide the requested quality of service or privacy.

Transport Protocols

All standard transport protocols (TCP, UDP) as well as encrypted tunnels (TLS, DTLS) are supported.

Security

The security module is responsible for authentication of communication partners and will ensure in the whole middleware stack the requested data security and privacy. The required information can be provided with Security Annotations in the IDL and by providing a security policy via the API.

Negotiation

The negotiation module provides mechanisms to discover or negotiate the optimal transmission format and protocols when peers are connecting. It discovers automatically the participants in the distributed system, searching through the different transports available (shared memory and UDP by default, TCP for WebService compatibility) and evaluates the communication paradigms and the corresponding associated QoS parameters and security policies.

2.7 Main Interactions

As explained above, the middleware can be used in different communication scenarios. Depending on the scenario, the interaction mechanisms and the set of API-functions for application developers may vary.

API versions

There will be two versions of APIs provided:

- **Static API**
    - Static compile-time parsing of IDL and generation of Stub-/Skeletons and DataReader/DataWriter
- **Dynamic API**
    - Dynamic runtime parsing of IDL and run-time invocation of operations.

Additionally following features will be provided as API extensions:

- Advanced security policy and QoS parameters
- Publish/subscribe functionality compatible to RPC-DDS and DDS applications

Classification of functions

The API-Functions can be classified in the following groups:

- **Preparation:** statically at compile-time (Static API) or dynamically at run-time (Dynamic API)
    - Declare the local applications datatypes/functions (Dynamic API only)
    - Parsing the Interface Definition of the remote side (IDL-Parser)
    - Generate Stubs-/Skeletons, DataReader-/Writer
    - Build your application against the Stubs-/Skeletons, DataReader-/Writer (Static API only)
- **Initialization:**
    - Create the context (set up the environment, global QoS/Transport/Security policy,...)
    - Open connection (provide connection specific parameters: QoS/Transport/Security policy, Authentication, Tunnel encryption, Threading policy,...)
- **Communication**
    - Send Message/Request/Response (sync/async, enforce security)
    - Receive Message/Request/Response (sync/async, enforce security)

- Exception Handling

- **Shutdown**

    - Close connection (cleanup topics, subscribers, publishers)
    - Close the context (Free resources)

Detailed description of the APIs and tools can be found in the User and Programmers guide, which will be updated for every release of the Advanced Middleware GE.

2.8 Basic Design Principles

Implementations of the Advanced Middleware GE have to comply to the following basic design principles:

- All modules have to provide defined and documented APIs.

- Modules may only be accessed through these documented APIs and not use any internal undocumented functions of other modules.

- Modules in the above layer model may only depend on APIs of lower level modules and never access APIs of higher level modules.

- All information required by lower level modules has to be provided by the higher levels modules through the API or from a common configuration.

- If a module provides variants of internal functionalities (e.g. Protocols, Authentication Mechanisms, ...) these should be encapsulated as Plugins with a defined interface.

2.9 Detailed Specifications

Following is a list of Open Specifications linked to this Generic Enabler. Specifications labelled as "PRELIMINARY" are considered stable but subject to minor changes derived from lessons learned during last interactions of the development of a first reference implementation planned for the current Major Release of FIWARE. Specifications labelled as "DRAFT" are planned for future Major Releases of FIWARE but they are provided for the sake of future users.

Open API Specifications

- *Advanced Middleware IDL Specification*
- *Advanced Middleware RPC API Specification*
- *Advanced Middleware RPC Dynamic Types API Specification*
- *Advanced Middleware Publish/Subscribe API Specification*

2.10 Re-utilised Technologies/Specifications

The technologies and specifications re-used in this GE are:

- RTPS - Realtime Publish Subscribe Wire Protocol (OMG Standard V2.1) : Used as the protocol for the Pub/sub mechanism
- CDR - Common Data Representation (CDR Page 4 of the PDF) : Used as the serialization mechanism

2.11 Terms and definitions

This section comprises a summary of terms and definitions introduced during the previous sections. It intends to establish a vocabulary that will be help to carry out discussions internally and with third parties (e.g., Use Case projects in the EU FP7 Future Internet PPP). For a summary of terms and definitions managed at overall FIWARE level, please refer to FIWARE Global Terms and Definitions