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AND NEXT-GENERATION NETWORKS

Next Generation Networks – Frameworks and functional  
architecture models

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## **Framework of the web of things**

Recommendation ITU-T Y.2063



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# Recommendation ITU-T Y.2063

## Framework of the web of things

### Summary

Recommendation ITU-T Y.2063 provides a framework of the web of things (WoT). As the use of various devices has become so widespread, it is difficult to access data on these devices in a unified way. The WoT allows physical devices to be accessed as resources of both the web and services/applications based upon a web-based service environment, as well as through legacy telecommunications.

This Recommendation describes the overview of the WoT and identifies the requirements to support the WoT. In addition, this Recommendation specifies the functional architecture including a deployment model for the WoT.

### History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T Y.2063	2012-07-29	13

### Keywords

Web, web of things, WoT.

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# Recommendation ITU-T Y.2063

## Framework of the web of things

### 1 Scope

This Recommendation provides a framework of the web of things (WoT). The Recommendation covers the followings:

- overview of the WoT
- requirements to support the WoT
- deployment models of the WoT
- functional architecture for the WoT.

This Recommendation demonstrates how physical devices can interact with web resources. This Recommendation also includes WoT use cases in Appendix I and information flows in Appendix II. The detailed web technology including the semantics and ontology is beyond the scope of this Recommendation.

NOTE – This Recommendation only addresses physical devices within a broad scope of "things" [ITU-T Y.2060].

### 2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.2002] Recommendation ITU-T Y.2002 (2009), *Overview of ubiquitous networking and of its support in NGN*.

[ITU-T Y.2060] Recommendation ITU-T Y.2060 (2012), *Overview of the Internet of things*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

**3.1.1 client** [b-W3C WACterms]: The role adopted by an application when it is retrieving and/or rendering resources or resource manifestations.

**3.1.2 device** [b-W3C dig loss]: An apparatus through which a user can perceive and interact with the web.

NOTE – In the IoT, a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing [ITU-T Y.2060].

**3.1.3 Internet of things (IoT)** [ITU-T Y.2060]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broad perspective, the IoT can be perceived as a vision with technological and societal implications.

**3.1.4 resource** [b-IETF RFC 3986]: The term "resource" is used in a general sense for whatever might be identified by a URI.

NOTE – Familiar examples include an electronic document, an image, a source of information with a consistent purpose (e.g., "today's weather report for Los Angeles"), a service (e.g., an HTTP-to-SMS gateway), and a collection of other resources. A resource is not necessarily accessible via the Internet; e.g., human beings, corporations, and bound books in a library can also be resources. Likewise, abstract concepts can be resources, such as the operators and operands of a mathematical equation, the types of a relationship (e.g., "parent" or "employee"), or numeric values (e.g., zero, one, and infinity).

**3.1.5 server** [b-W3C WACterms]: The role adopted by an application when it is supplying resources or resource manifestations.

**3.1.6 the World Wide Web (WWW, or simply the web)** [b-W3C web arch]: An information space in which the items of interest, referred to as resources, are identified by global identifiers called Uniform Resource Identifiers (URI).

**3.1.7 thing** [ITU-T Y.2060]: With regard to the Internet of things, this is an object of the physical world (physical things) or the information world (virtual things), which is capable of being identified and integrated into communication networks.

**3.1.8 URI** [b-IETF RFC 3986]: A simple and extensible means for identifying a resource.

**3.1.9 user agent** [b-W3C dig loss]: A client within a device that performs rendering. Browsers are examples of user agents, as are web robots that automatically traverse the web collecting information.

**3.1.10 web resource** [b-W3C WACterms]: A resource, identified by a URI, that is a member of the web core.

## **3.2 Term defined in this Recommendation**

This Recommendation defines the following term:

**3.2.1 Web of things (WoT):** A way to realize the IoT where (physical and virtual) things are connected and controlled through the World Wide Web.

## **4 Abbreviations and acronyms**

This Recommendation uses the following abbreviations and acronyms:

FE	Functional Entity
HTTP	Hyper Text Transport Protocol
ID	Identifier
IoT	Internet of Things
JINI	Java Intelligent Network Infrastructure
NGN	Next Generation Network
REST	Representational State Transfer
UPnP	Universal Plug and Play
URI	Unique Resource Identifiers

WoT	Web of Things
WWW	World Wide Web

## 5 Conventions

In this Recommendation,

- The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this Recommendation is to be claimed.
- The keywords "can optionally" indicate an optional requirement which is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option and the feature can be optionally enabled by the network operator/service provider. Rather, it means the vendor may optionally provide the feature and still claim conformance with the specification.

## 6 Overview of the web of things

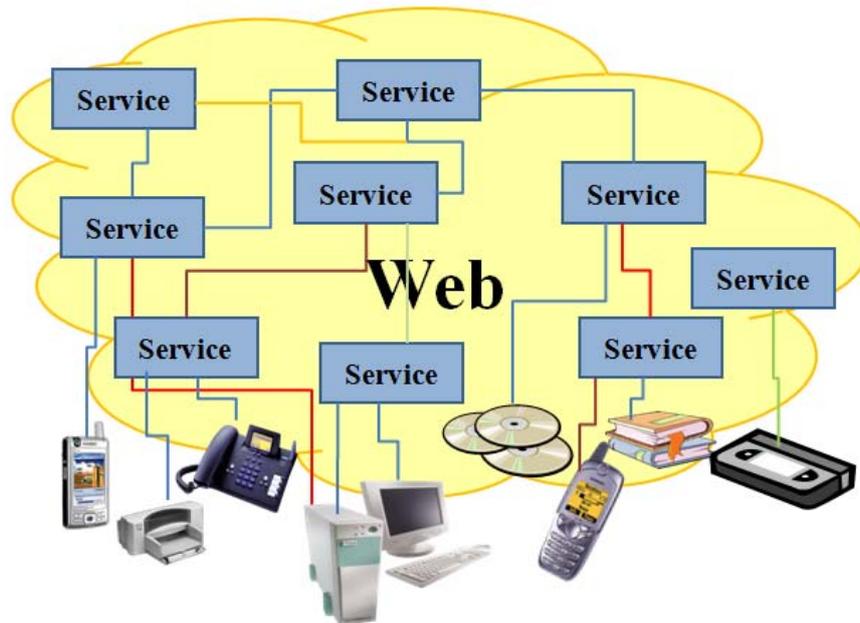
From the perspective of the creation of applications, the development of applications that run on top of physical devices is a difficult process that requires expert knowledge and time. In this context, many efforts are being veered towards networking to devices. There are a number of solutions to expose the functionality of devices upon which to build applications; for example, JINI and UPnP are a set of open protocols for allowing devices to collaborate in a peer-to-peer fashion. However physical devices are still dedicated to particular systems/applications. They cannot be controlled and managed without using dedicated protocol and proprietary interfaces due to the following reasons:

- a lack of interoperability across open and proprietary platforms: there are many hardware platforms, operating systems, databases, middleware and applications.
- Many heterogeneous networks: they cannot exchange content and information easily.
- Different data type: All systems worldwide have their own data representation formats and it is difficult to ensure compatibility between them.

The Internet of things (IoT) tries to find a way interconnecting things based on interoperable information and communication technologies. Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst maintaining the required privacy [ITU-T Y.2060]. Although the WoT has a similar viewpoint to the IoT, the WoT is intended so that physical devices can be accessed as resources of the web and services/applications can be provided based upon a web-based service environment as well as legacy telecommunications.

The World Wide Web (WWW) is used as a platform to deliver services to an end-user, the web enables business entities and applications to intercommunicate openly with each other over a network. The web has program language independent properties, uses message driven communications and easily bounds to different transport protocols. As a result, web technology allows the exposure of physical devices as resources on the web using a WoT approach. Therefore, users can interact with the devices using web interfaces. The WoT can provide capabilities of device reusability, portability across several heterogeneous networks and accessibility based on web with web standards.

Figure 6-1 shows the general concept of WoT. The physical devices are mapping the services into the web and those are considered as web resources so that service developers and/or service providers can easily create web applications for the physical devices.



**Figure 6-1 – General concept of the web of things**

## **7 Requirements for the web of things**

This clause specifies the requirements to support the WoT. The requirements are needed to consider general aspects and functional aspects.

### **7.1 General requirements for the WoT**

The followings are the requirements in the general aspects:

- WoT is required to access physical devices.
  - ✓ The WoT user (e.g., service developer, service provider, applications and user agent, etc.) can access device capabilities on the web.
  - ✓ The service developer and the service provider can create new web services using web technologies. They do not need to know the technical details of a physical device such as a physical device's interfaces and their protocols. They do not waste time and human resources for the physical device application development.
- WoT is required to provide the means that make physical devices accessible to web resources.
- WoT is required to support interoperability among different networks and operating systems.
  - ✓ The user can use WoT services on the web regardless of networks and operating systems.
  - ✓ The service developer can create services across heterogeneous networks with different types of devices and different service providers.
  - ✓ Services can be created regardless of the operating system and programming languages for devices.
- WoT is required to support location transparency.
  - ✓ Devices can be accessed by a user from anywhere on the network without knowing where the devices are located.

- WoT is required to support the compatibility between different data representation formats.

## **7.2 Functional requirements for the WoT**

The following are the requirements for the functional aspects:

- The WoT is required to support service profile management to discover and register services through a web interface.
- The WoT is required to support service control for executing and managing WoT services.
- The WoT is required to support service composition for creating new WoT services.
- The WoT is required to support service access control for protection against unauthorized request/user/access.
- The WoT is required to support an agent that can make physical devices accessible to the web.
- The WoT is required to support resource management for supporting agent control, agent registration/deregistration and agent profile management.
- The WoT is required to support resource ID management for supporting mapping information between devices and agents.

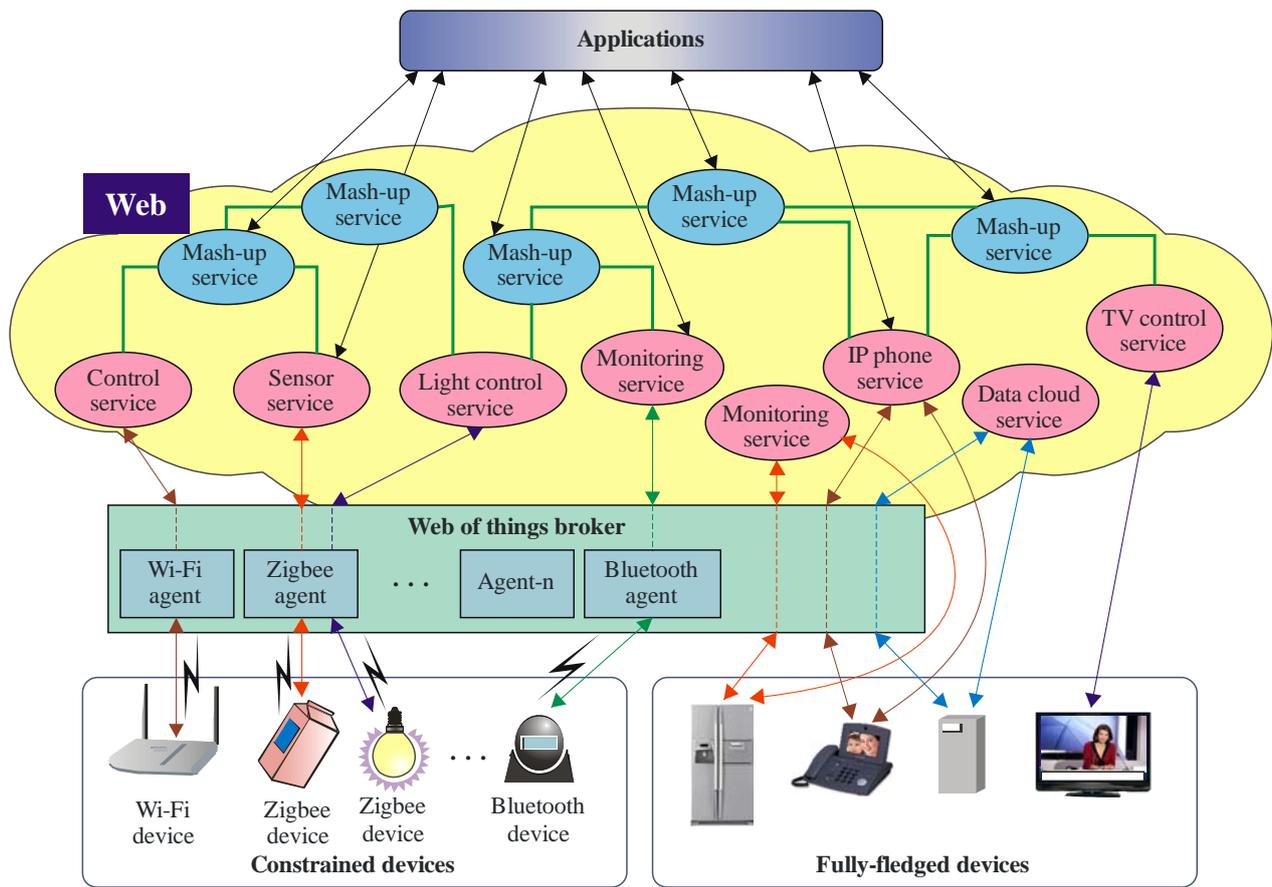
## **8 Conceptual and deployment models of the web of things**

### **8.1 Conceptual model**

Figure 8-1 shows the conceptual model of the WoT. Applications can access and use physical devices on the web through a WoT broker or directly. A WoT broker has several agents which have adaptation capabilities to make a physical device's interface work with a web interface. Each agent is dedicated to a specific interface of the subnetwork (e.g., Wi-Fi, Zigbee and Bluetooth).

In a WoT environment, three services can be used. The characteristics of these three services in the WoT are as follows:

- **WoT service:** a service which has 1:1 mapping with services and/or functions in a physical device through the adaptor.  
NOTE – If WoT services are integrated with each other in a WoT broker, it is a composite WoT service.
- **Mash-up service:** combined services which integrate WoT services in a WoT broker with web services outside of the WoT broker.
- **Web service:** services that can be accessed on the web.



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**Figure 8-1 – Conceptual model of the web of things**

### 8.1.1 Two types of devices

There are several kinds of physical devices in the physical world (e.g., Wi-Fi, Zigbee device, Bluetooth device, TV, phone, data server). Among them, some devices can neither connect to the Internet nor fully respect the web (or REST architectural style). Regarding the physical devices on the WoT, they are divided into two categories: constrained devices and fully-fledged devices.

*Constrained device:* A constrained device cannot connect to the Internet and it has no functionality of the web. The device interacts with an agent of the WoT broker.

*Fully-fledged device:* A fully-fledged device has the functionalities of the web. The device can interact not only with the WoT broker but also with the services on the web.

### 8.1.2 WoT Broker

The WoT broker has a role for integrating and exposing the devices to the web. This broker has responsibility for communicating between the user of the WoT (e.g., web clients, applications) and fully-fledged devices as well as constrained devices. In the case where a device is communicated with by dedicated software and proprietary interfaces, the device cannot be exposed and integrated on the web directly. The WoT broker enables the seamless integration of the device onto the web. The agent of the WoT broker has a role to control and communicate with physical devices. If a request is received from an application to access physical devices, the WoT broker adapts the request to a proprietary interface of the physical device through an agent.

## 8.2 Deployment models

### 8.2.1 WoT deployment model for fully-fledged devices

This deployment model represents the pure essence of physical devices accessing and consuming services in the web. In this model, each physical device can have a web server. Therefore each physical device and its capabilities can be linked to the web and it can be discovered by user agents or applications without any other external element (e.g., WoT broker). Additionally those devices can be linked to the web through the WoT broker as necessary. For example, some capabilities of a fully-fledged device can be needed to composite with other physical devices within the WoT broker and/or a fully-fledged device needs to help some functionality of the WoT broker.

In Figure 8-2, there are four parts according to their communicating methods. Basically each part can communicate using the HTTP protocol. However the WoT broker can optionally communicate with devices using each proprietary interface.

The WoT broker has the role of intermediation between physical devices and applications. The WoT broker can create a new service using the services of each physical device. From the perspective of applications, applications can access the physical devices on the web directly or through the WoT broker. In addition, applications can access mash-up services which are combined or aggregated with existing services on physical devices.

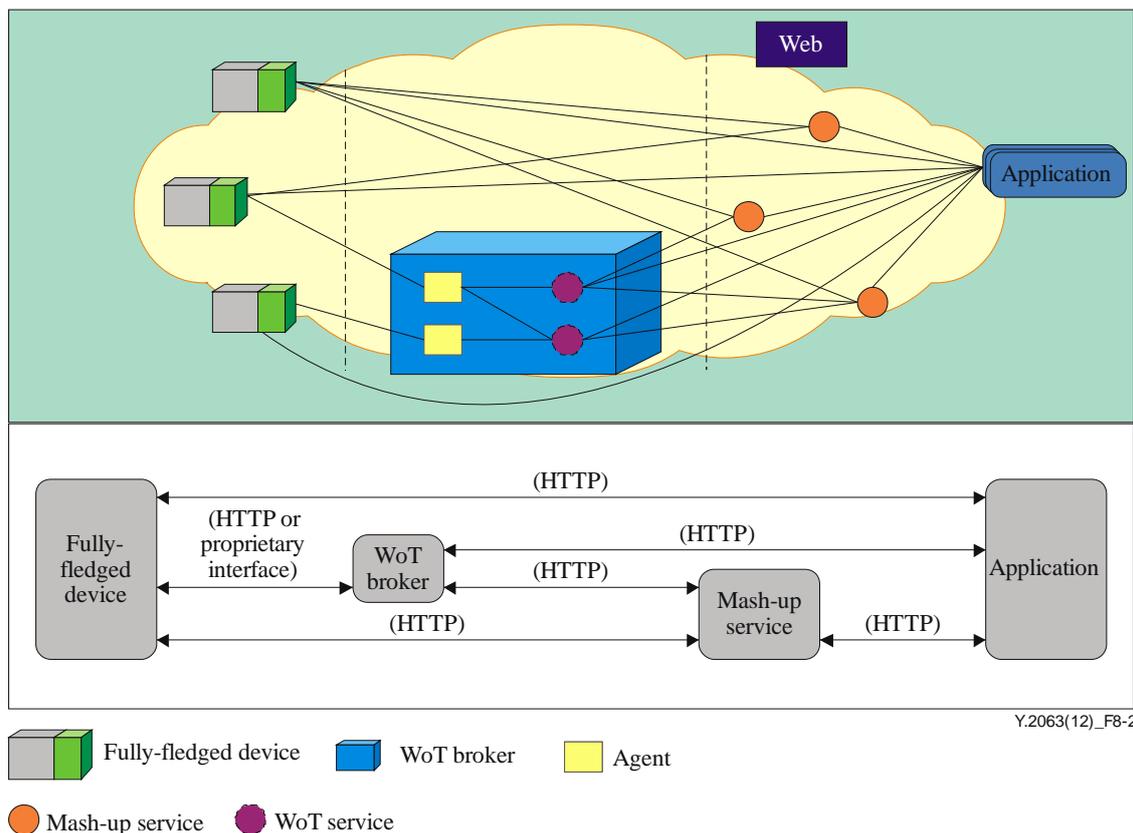
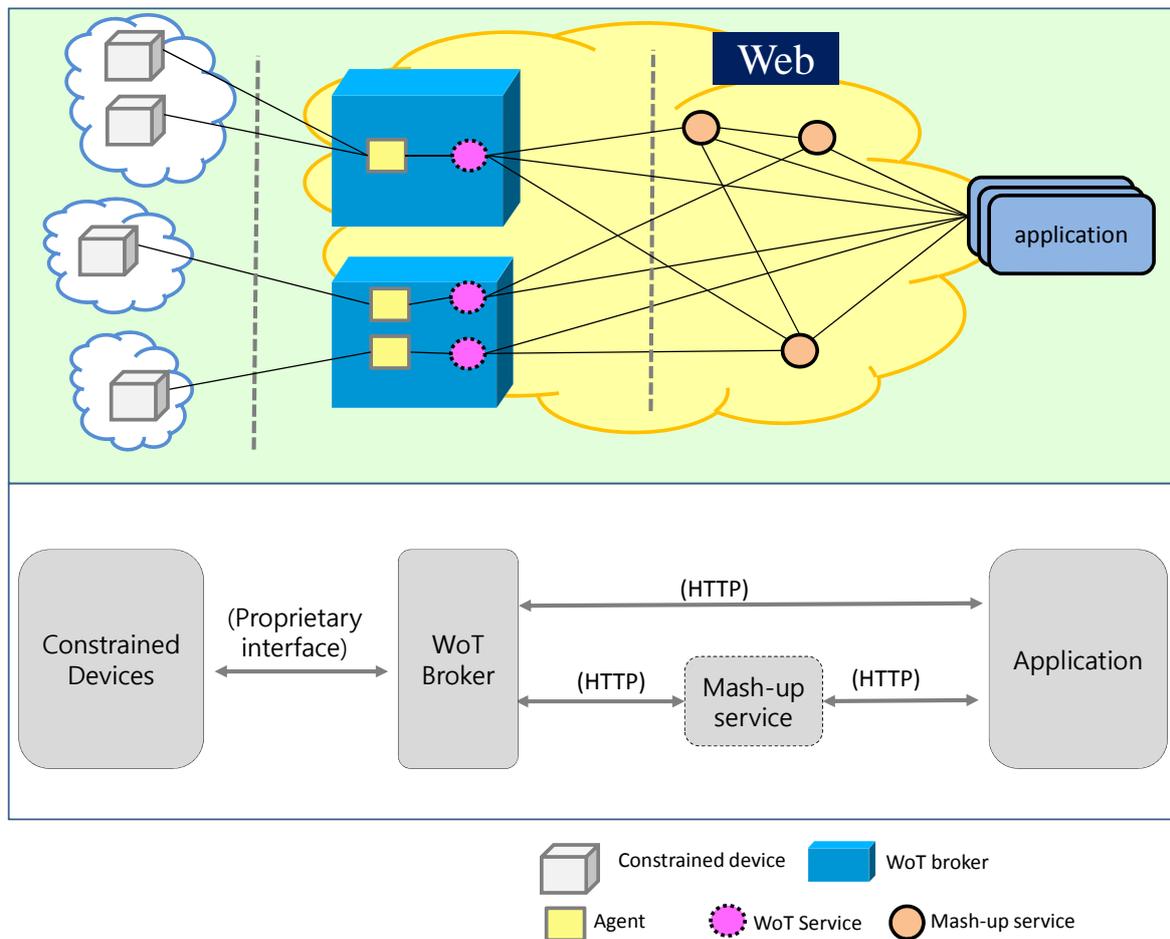


Figure 8-2 – WoT deployment model for fully-fledged devices

### 8.2.2 WoT deployment model for constrained devices

The key factor of this model is how applications can use constrained devices. This deployment model is implemented by the WoT broker, which performs as an intermediation between physical devices and applications. The resources of devices can be exposed on the web through the WoT broker.

In Figure 8-3, there are also four parts according to their communicating methods like the model for fully-fledged devices. However each device communicates with the WoT broker using their proprietary interface. Applications can access mash-up services in a similar way to the model for fully-fledged devices.



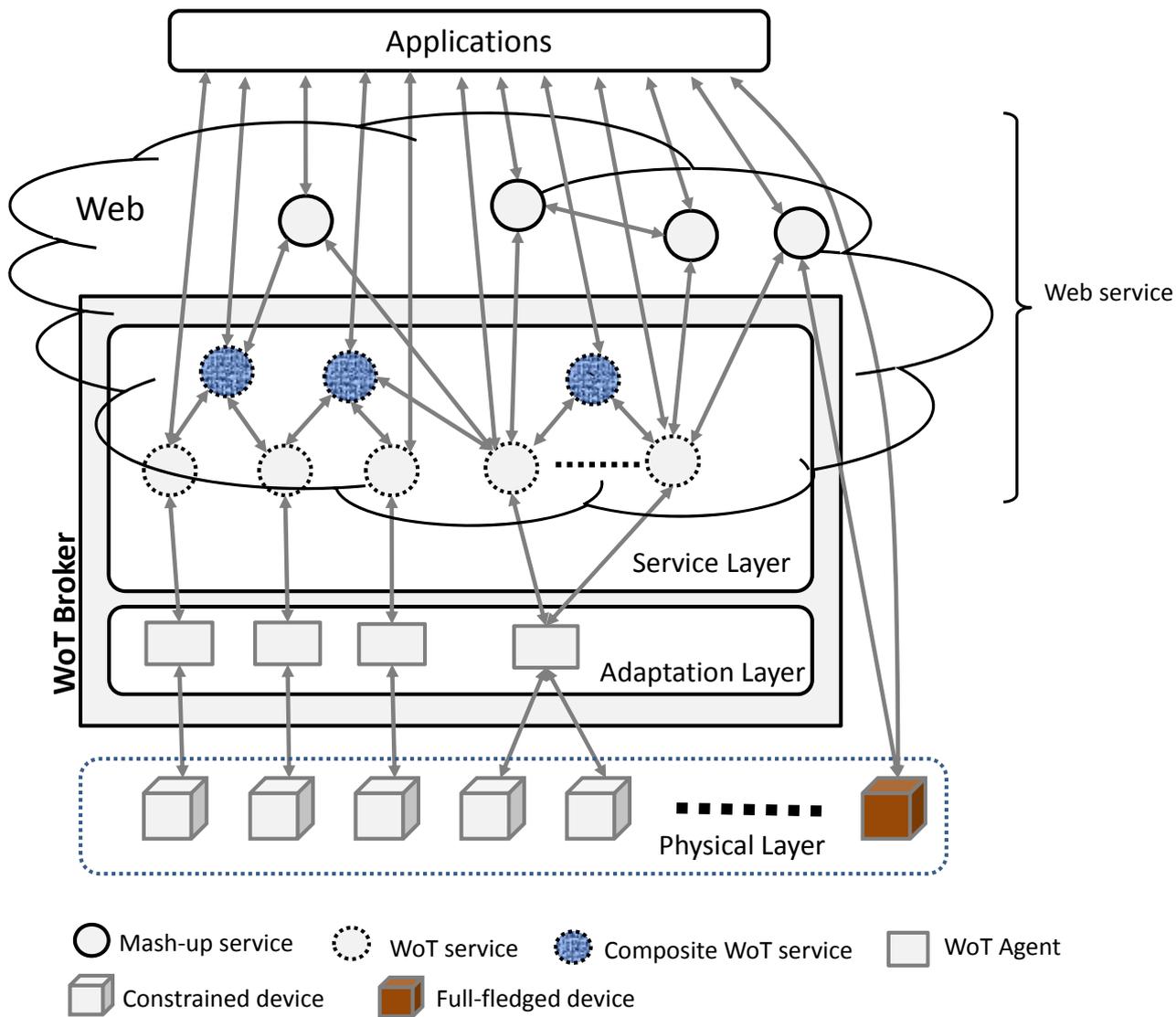
**Figure 8-3 – WoT deployment model for constrained devices**

## 9 Functional architecture for the web of things

### 9.1 Overview of the WoT architecture

The WoT architecture is divided into three layers: service layer, adaptation layer and physical layer.

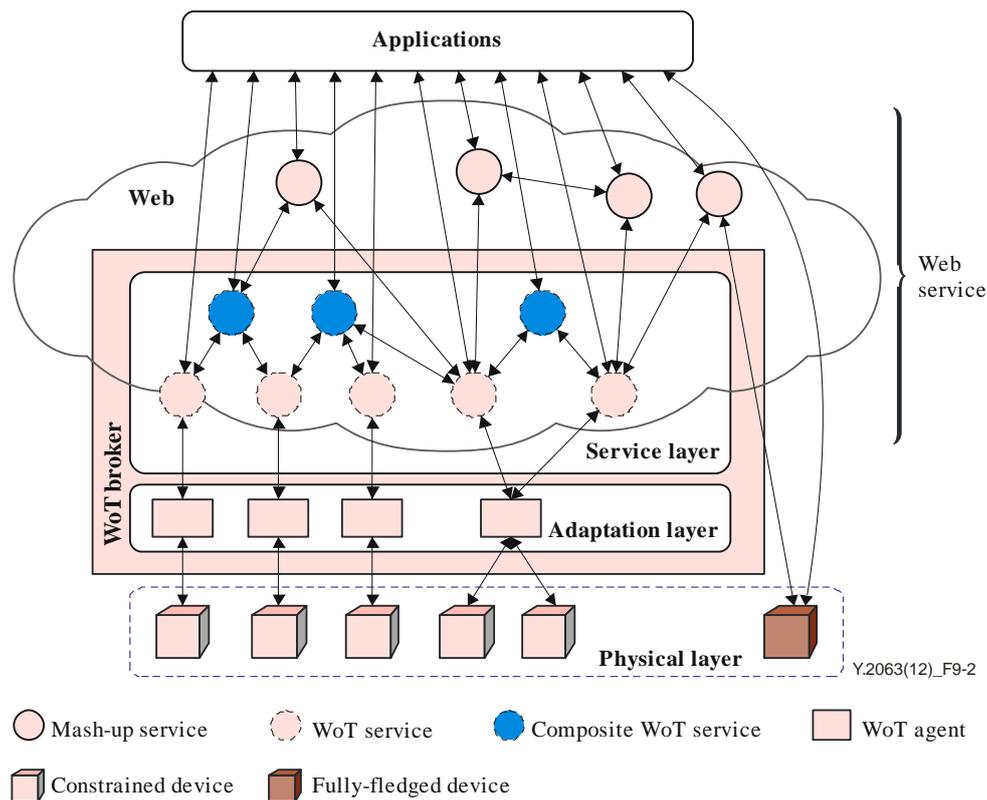
- Service layer
  - ✓ The service layer provides a common function for service capabilities. It is the entity responsible for making a service available and for managing it.
- Adaption layer
  - ✓ The adaption layer is where agents reside. In this layer, each agent interacts with physical devices for the translation of different protocols and message formats. According to the type of physical device (e.g., Bluetooth, Zigbee) the correspondence agent in the adaptation layer can be connected. Also, all the resource management on the agent is conducted in this layer.
- Physical layer
  - ✓ The physical devices are in the physical layer. All constrained devices can be accessed by an agent in the adaptation layer. Also, it is possible that a fully-fledged device in the physical layer can be directly accessed by the mash-up service or applications.



**Figure 9-1 – Overview of the web of things architecture**

## 9.2 Functional architecture of the WoT broker

Figure 9-2 shows the functional architecture of the WoT broker. The WoT broker functional architecture is divided into the service layer and adaptation layer and it consists of six functional entities (FEs) and several WoT agents. The service layer consists of the service profile management FE, service control FE, service composition FE and service access control FE. The adaptation layer consists of the resource ID management FE, resource management FE and WoT agents.



**Figure 9-2 – Functional architecture of the WoT broker**

Based on the functional architecture of the WoT broker, it is possible to describe five service information flows: service discovery, service registration, service execution, service composition and agent registration. These information flows are described in Appendix II.

### 9.2.1 Service profile management functional entity

The service profile management FE contains service information which is supported by the WoT broker and this FE is responsible for registering WoT services. This FE interworks with the service control FE for the discovery of services. It also interworks with the service composition FE which has the ability to composite new services using registered services.

This FE has the following information:

- type of service (e.g., power control service, monitoring service, sensing service, printing service);
- service category name (e.g., personal WoT service, public WoT service, company WoT service);
- service name;
- service provider information.

The service profile is updated by requests from the service control FE and service composition FE.

### **9.2.2 Service control functional entity**

The service control FE is responsible for the access, execution and management between resources and applications. The service control FE interworks with the service profile management FE to discover registered services and it interworks with a service access control FE to check whether the service requester has the right authentication and authorization or not.

In addition, the service control FE has responsibility for service registration/deregistration with the service profile management FE. In order to provide a service, the service should be registered with the service profile management FE. When a new service is created or deleted, the service control FE sends a service registration/deregistration request to the service profile management FE. The service control FE also helps the service composition FE to find services which are using new composite services.

### **9.2.3 Service composition functional entity**

The service composition FE provides the capabilities to compose existing services to create new services. Service composition is accomplished by service providers. New composition services are registered at the service profile management FE.

NOTE – The service logic of a composite service is not defined in this Recommendation because it depends on the implementation.

### **9.2.4 Service access control functional entity**

The service access control FE is responsible for access control of the user (e.g., application provider, service provider). It checks and controls user authentication, authorization, accounting and user-related information. For example, if an unauthorized user requests to access/use services, this FE rejects to access the services. This FE interworks with the service control FE to support access control.

### **9.2.5 Resource management functional entity**

There are many agents in the WoT broker to support physical devices belonging to heterogeneous networks. The resource management FE is able to control each agent and it can register/deregister agents and maintain the information of each agent.

#### **1) Agent control function**

This function is responsible for controlling each agent. It can identify resources (device/service) and execute the requested service by interworking with the resource ID management FE.

#### **2) Agent registration function**

The agent registration function is responsible for the registration and deregistration of agents. When a new agent appears, the service provider can register the new agent using the agent registration function. Information related to the new agent is registered through the agent profile management function.

#### **3) Agent profile management function**

The agent profile management function is responsible for checking and storing agents with agent-related information. It checks the agent's authentication, authorization and types of agent.

The agent profile management function has the following information:

- types of agent (e.g., Wi-Fi agent, Bluetooth agent)
- location of agent.

### 9.2.6 Resource ID management functional entity

The resource ID management FE is responsible for storing the identifiers of resources (e.g., resource ID, agent ID) and maintaining mapping information between the resource ID and agent ID. This FE can optionally maintain mapping information using the mapping table. When a service requester wants to use a resource, this FE can provide related information (e.g., agent ID, resource ID). The resource ID management FE is also recommended to maintain the latest mapping information. This FE has the following additional information:

- physical information related to the service (e.g., subnetwork ID, subnetwork type and service location).

### 9.2.7 WoT agent

A WoT agent is a bridge between the WoT service and the physical devices residing in a subnetwork. The WoT agent has the role of communicating and translating between the adaptation layer of the WoT broker and the physical devices in a subnetwork. If a WoT agent receives a request from a resource management FE in the WoT adaptation layer, the WoT agent translates the request for the proprietary interface of the device and sends the translated request to a device in the subnetwork using the communication protocol so that the device can recognize the request and execute it. If the WoT agent receives results from the device in the subnetwork using its communication protocol, the WoT agent also translates the results in order to understand on the web and send the translated results using the web interface and web protocol.

NOTE – There are different subnetworks. Therefore, the WoT broker may have many agents to support those subnetworks because an agent is dedicated only one subnetwork.

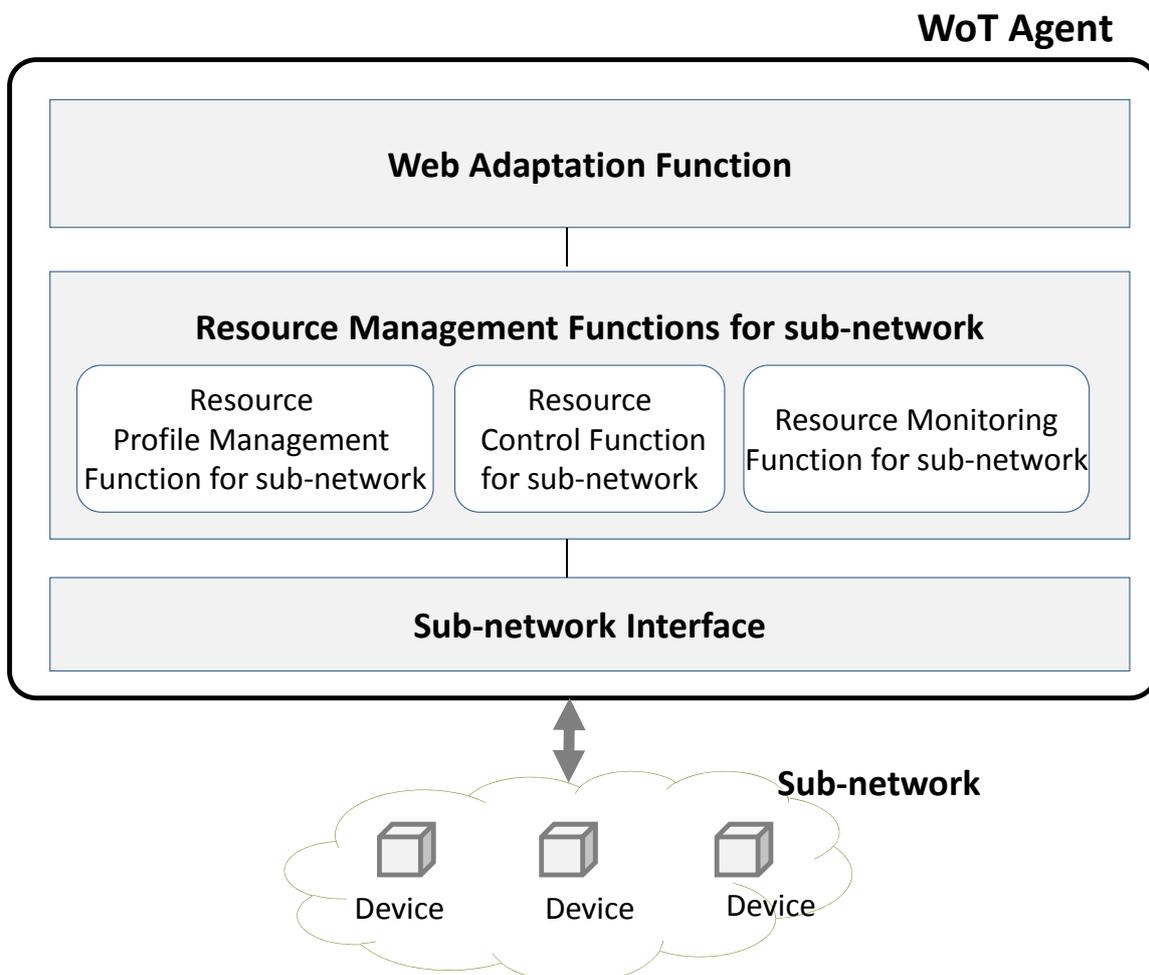


Figure 9-3 – Functional architecture of WoT agent

### **9.2.7.1 Web adaptation function**

The web adaptation function is responsible for adapting the dedicated device interface to the web interface which can be accessed and used by the WoT service. It has two main capabilities as follows:

- adaptation of a subnetwork protocol to the web protocol in order to communicate between the physical device and the WoT service;
- supporting the description method and status of resources status based on the web.

### **9.2.7.2 Resource management functions for the subnetwork**

Resource management functions for the subnetwork have responsibility for controlling and managing physical devices. The functions consist of the resource profile management function, resource control function and resource monitoring function for the subnetwork.

#### 1) Resource profile management function for the subnetwork

The resource profile management function for the subnetwork keeps and maintains information of the physical devices which are located in the subnetwork. This function interworks with the resource monitoring function for the subnetwork to maintain the latest status of the physical devices.

The resource profile management function for the subnetwork has the following information:

- physical devices status (e.g., availability, capability)
- sub-network ID
- physical devices ID.

#### 2) Resource control function for the subnetwork

This function is responsible for controlling the physical devices in the subnetwork. It can directly control and manage the physical devices in the subnetwork and provide registration/deregistration of devices in the subnetwork through interworking with the resource profile management function.

#### 3) Resource monitoring function for the subnetwork

The resource monitoring function for the subnetwork checks and monitors the status of the physical devices (e.g., physical devices' availability, response time). If the status of the physical devices has changed, this function informs the resource profile management function for the subnetwork about it so that it can update the information of the physical device.

### **9.2.7.3 Subnetwork interface**

Each subnetwork has a dedicated communication interface which is used for the interconnection of network elements (e.g., physical devices, agents).

## **10 Security considerations**

Security is an important issue for WoT services because WoT services are built upon various kinds of physical devices. Some physical devices can provide strong security features themselves but others cannot provide all security features because they have many limitations (e.g., bandwidth, computing power). Thus, the WoT service provider should support the security of the physical devices, especially constrained devices (e.g., sensor). Additionally WoT service providers should verify the identification of users which access physical devices and WoT services, to protect against the unauthorized use of WoT services/physical devices and unauthorized access to applications.

## Appendix I

### Use cases and scenarios of the web of things

(This appendix does not form an integral part of this Recommendation.)

#### I.1 Home control services using WoT

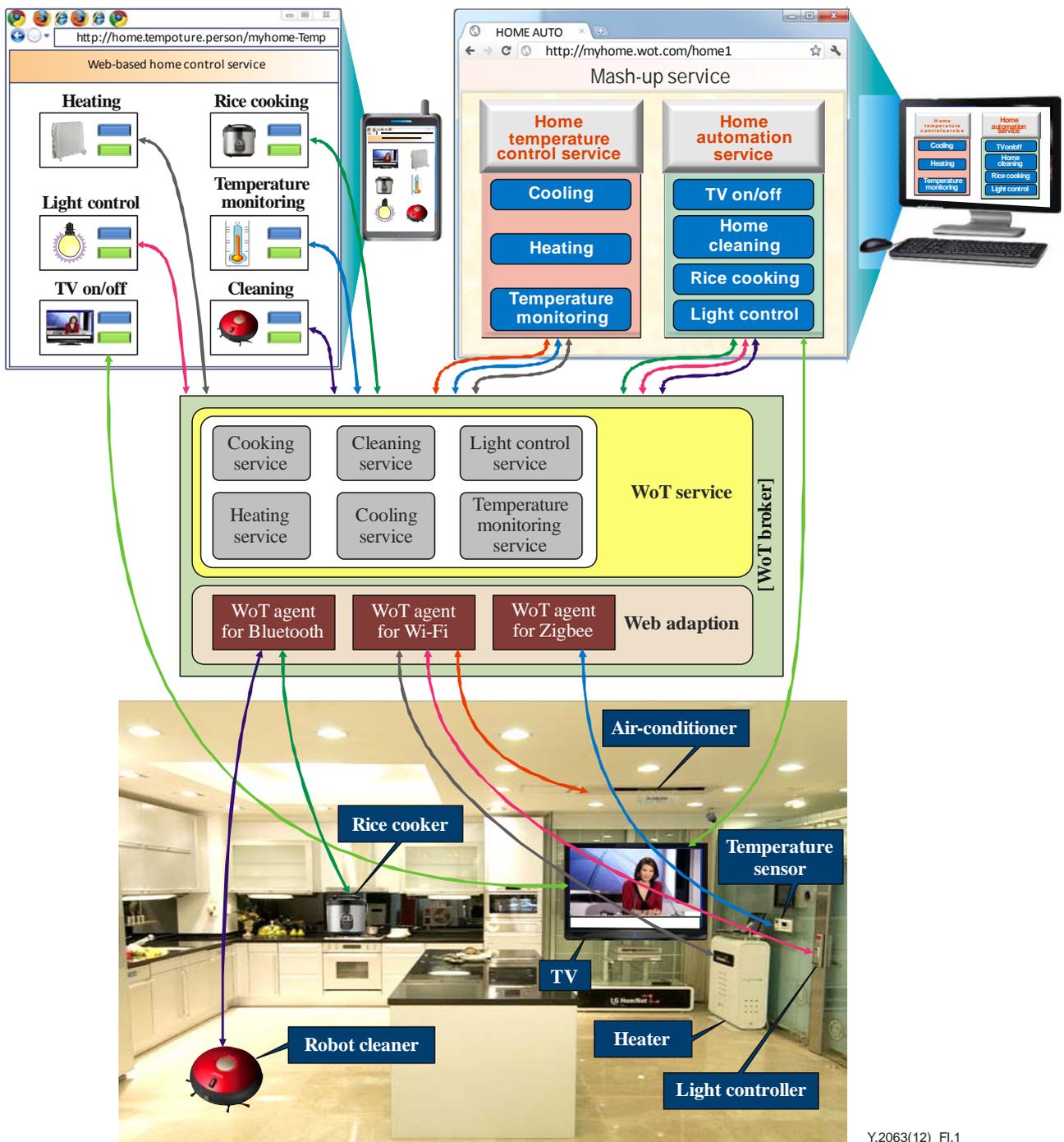
This appendix describes a use case of how an owner of a home can control devices in his home on the web using the WoT. The scenario is outlined in Figure I.1. In this scenario, we can see seven physical devices (a rice cooker, an air-conditioner, a robot cleaner, a heater, a light controller, a temperature sensor, a TV) and we can see nine services which can be accessed by the web user. These services are classified as follows:

- WoT services: cooking service, home-cleaning service, home-light control service, home-heating service, home-cooling service, home-temperature-monitoring service;
- pure web service: TV control service;
- mash-up services: home temperature control service, home automation service.

Most of the devices (e.g., a cooker, an air-conditioner, a robot cleaner, a heater and a light controller) can be accessed and used on the web through the WoT broker. However the TV contains an embedded web server. Therefore it can be exposed and used on the web directly without the help of a WoT broker. In this scenario the WoT broker has three agents (i.e., a WoT agent for Bluetooth, WoT agent for Wi-Fi, WoT agent for Zigbee). Each agent can communicate with each device using its own dedicated interface and it performs adaptation roles to make each device accessible to web services. The WoT services can be used to make new composite services, i.e., mash-up services. In this scenario two mash-up services are shown. The home temperature control service is composed of a home-temperature-monitoring service, a home-heating service, and a home-cooling service. The owner of the home can easily maintain the desired temperature using this service on the web. The home automation service is composed of a home-cleaning service, a cooking service, a home-light control service and a TV control service.

If the owner of the home has devices connected to the web with a web agent (e.g., web browser), he can control and manage devices which are located in his home remotely. Based on these capabilities, we can consider the following scenarios:

- Scenario 1: If the owner wants to clean his home when he goes out, he simply commands the robot cleaner located at home to clean his home using a web browser. He can do it from his office or even while walking on the street using devices with web capabilities.
- Scenario 2: When an owner is about to leave his office on a very hot summer's day, he wants to return to a cool house. He can set the temperature through the web before he leaves his office.



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**Figure I.1 – Home control service using the WoT**

## Appendix II

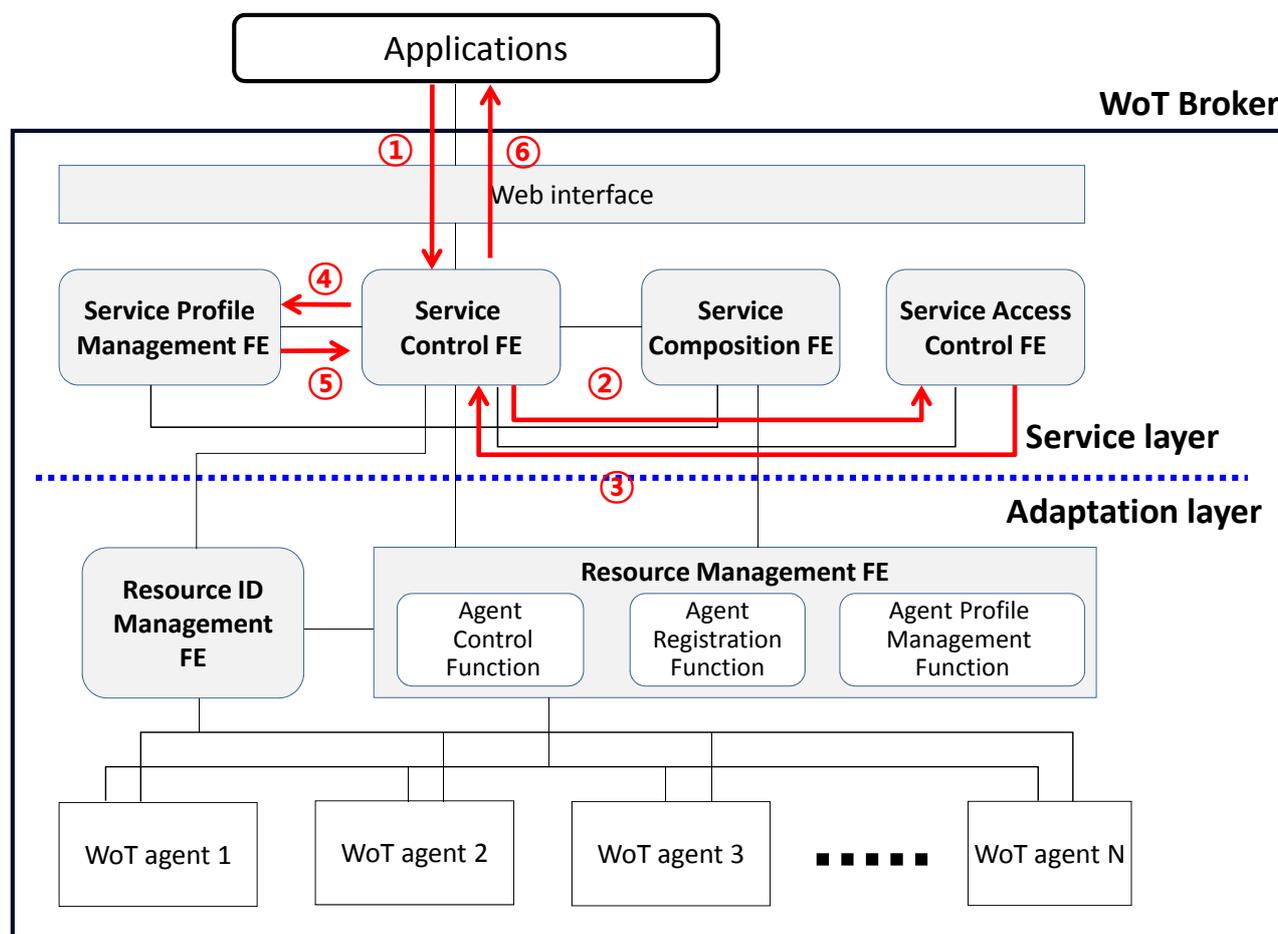
### WoT broker service information flows

(This appendix does not form an integral part of this Recommendation.)

This appendix describes information flows related to the operation of a WoT broker which includes service discovery, service registration, service execution, service composition and agent registration. This appendix is helpful for understanding how applications can use WoT services.

#### II.1 Service discovery

Figure II.1 shows the information flows describing how the applications can discover WoT services.



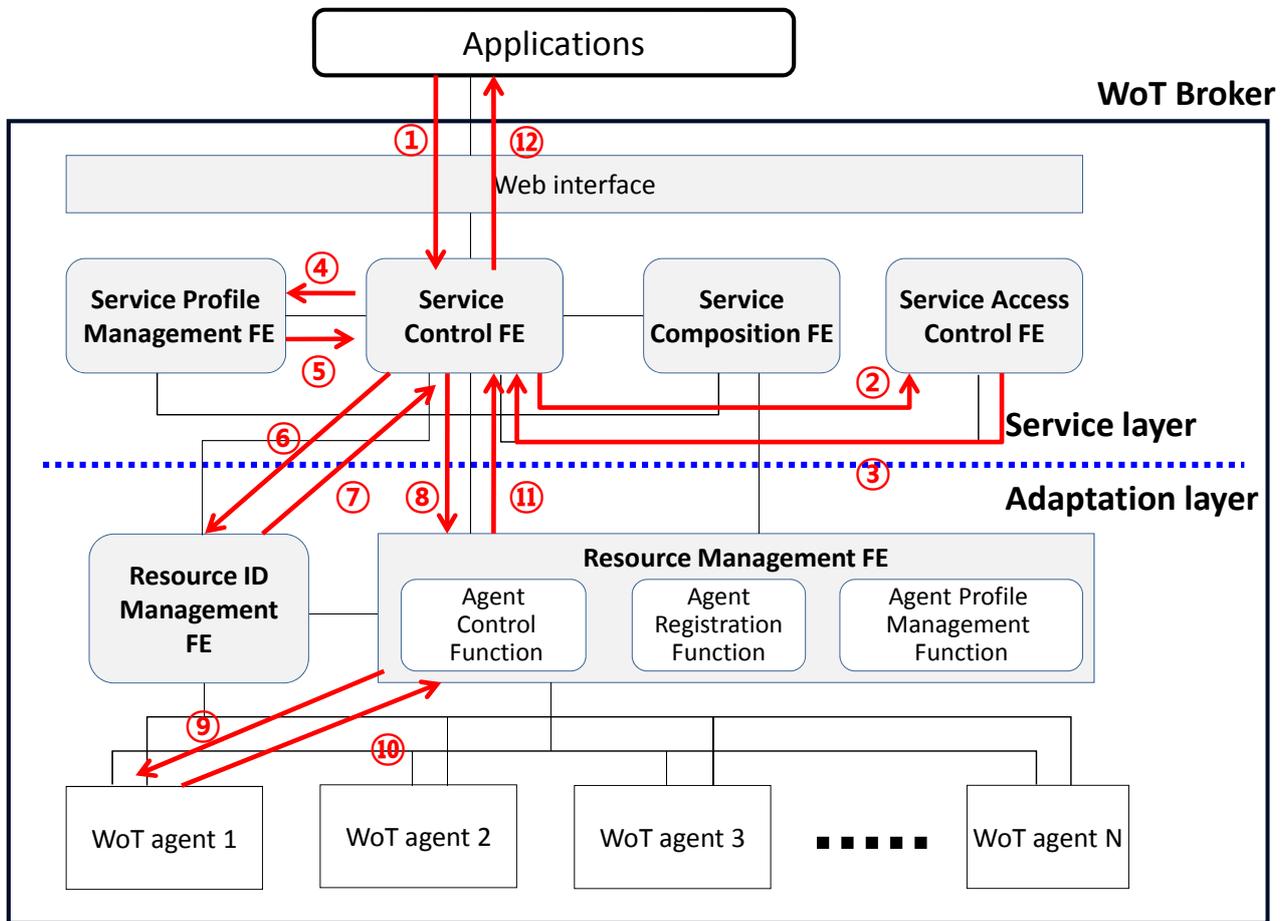
**Figure II.1 – Information flow of service discovery in a WoT broker**

- (1) The application requests a WoT service using a web interface to a service control FE.
- (2) The service control FE sends a request message to a service access control FE to check whether the application has authentication and authorization for the requested service.
- (3) The service access control FE checks the authentication and authorization for the application. It sends a result to the service control FE.
- (4) If the application has the right authentication and authorization, the service control FE sends a discovery message to a service profile management FE.
- (5) The service profile management FE returns the search results of the service to the service control FE.

- (6) The service control FE returns the information about the service to the application.

## II.2 Service execution

Figure II.2 shows the information flows describing how to execute services in the WoT.



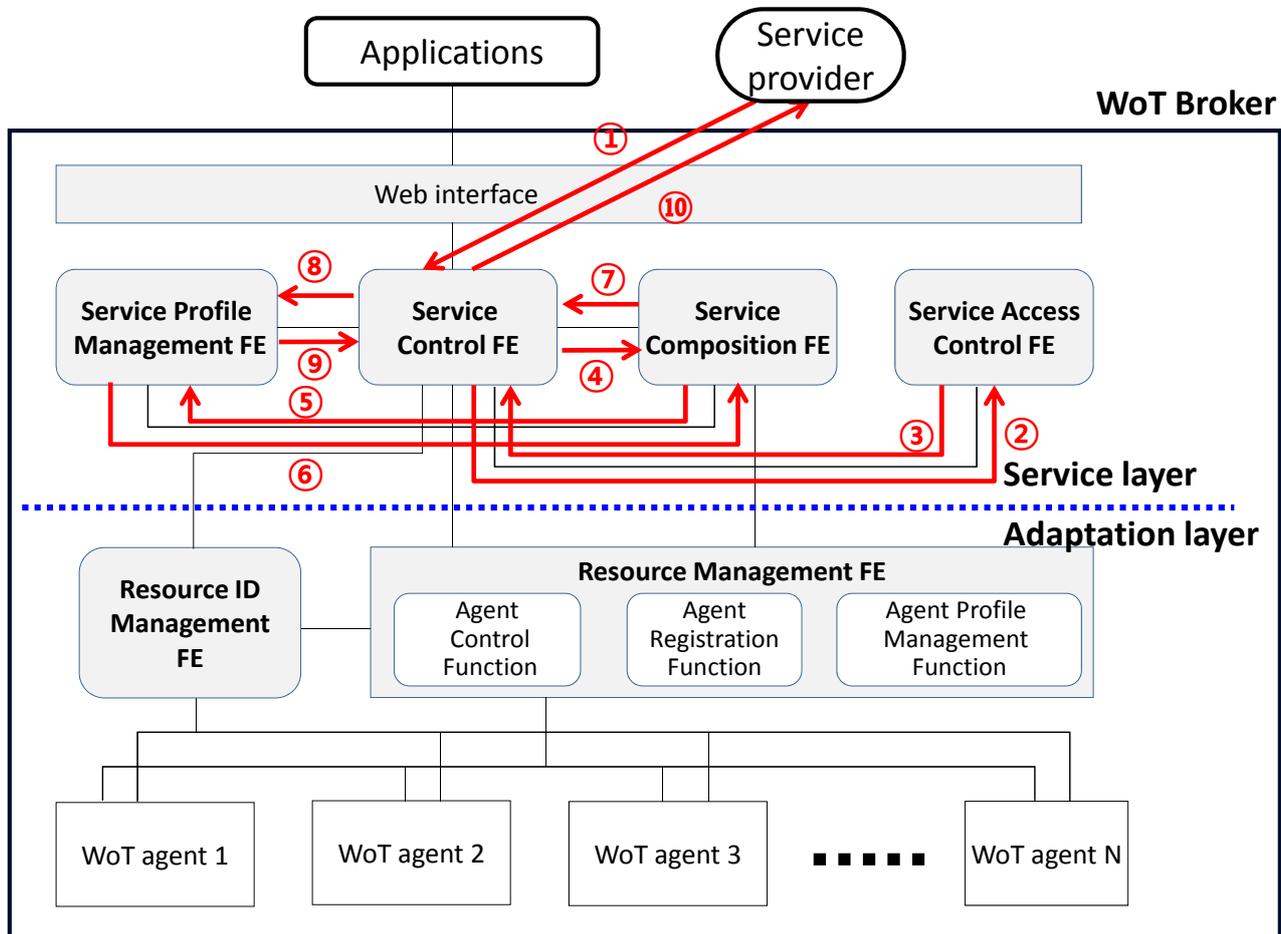
**Figure II.2 – Information flow of service execution in a WoT broker**

- (1) The application requests a WoT service through a web interface to a service control FE.
- (2) The service control FE sends a request message to a service access control FE to check whether the application has authentication and authorization for the requested service.
- (3) The service access control FE checks authentication and authorization for the application. It sends the result to the service control FE.
- (4) If the application has the right authentication and authorization, the service control FE sends a discovery message to a service profile management FE.
- (5) The service profile management FE returns the search result of the service to the service control FE.
- (6) The service control FE sends a message to the resource ID management FE to find which agent manages and controls the requested services.
- (7) The resource ID management FE returns the search result of the service to the service control FE.
- (8) The service control FE requests to execute the service to the resource management FE with a resource ID and an agent ID.
- (9) The resource management FE checks the requested service and command the agent to execute the services.

- (10) The agent returns the results of the service execution to the resource management FE.
- (11) The resource management FE sends the results to the service control FE.
- (12) The service control FE sends the results to the application.

### II.3 Service composition

Figure II.3 shows the information flows describing how to composite services in the WoT broker.



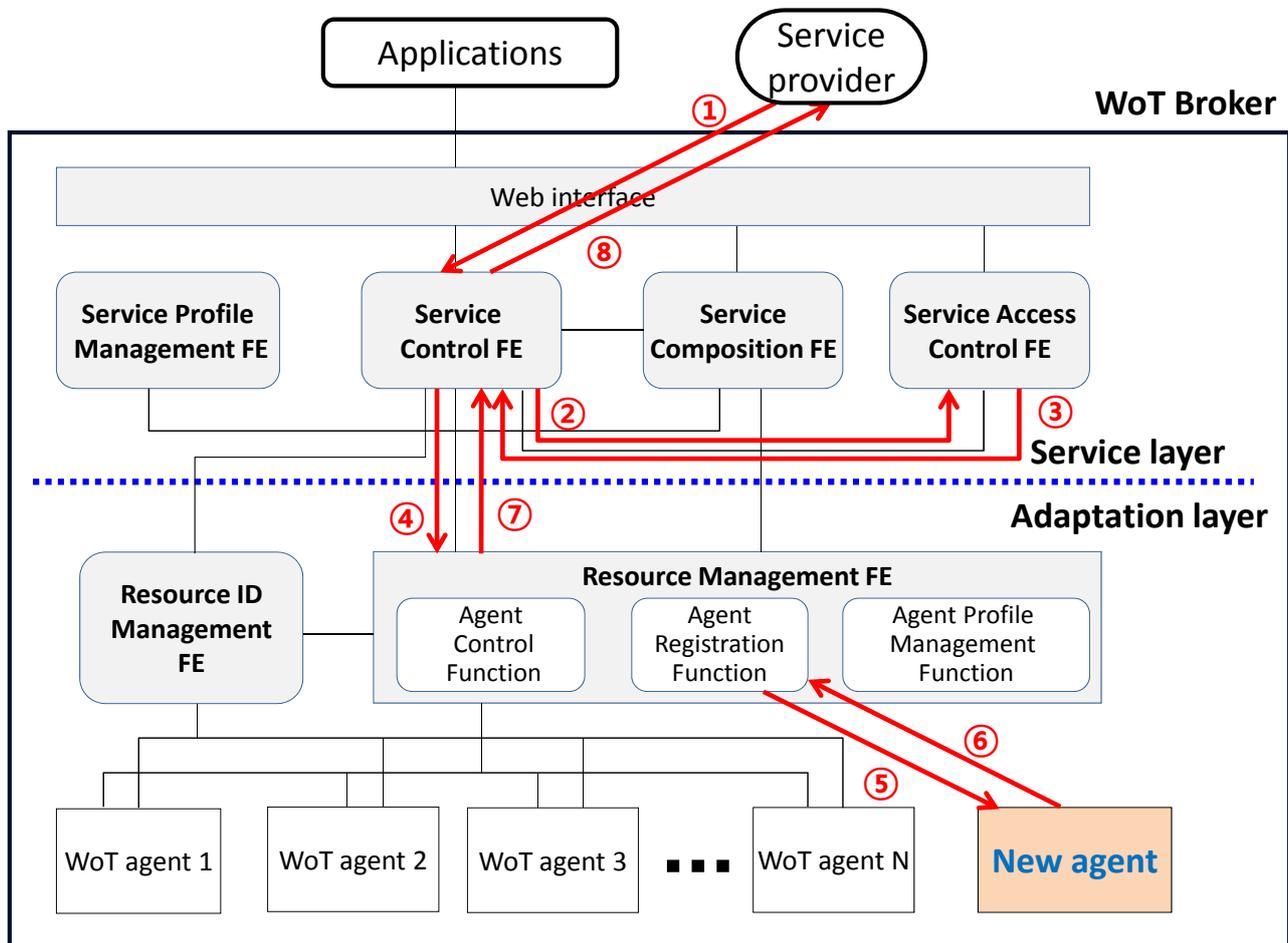
**Figure II.3 – Information flow of service composition in a WoT broker**

- (1) A service provider requests service composition to a service control FE.
- (2) The service control FE sends a request to a service access control FE regarding whether the service provider has authentication and authorization for the request.
- (3) The service access control FE checks authentication and authorization for the application. It sends the result to the service control FE.
- (4) The service control FE requests service composition to a service composition FE.
- (5) The service composition FE sends a discovery message to the service profile management FE to find related services which will use the service composition process according to the request.
- (6) The service profile management FE returns the results to the service composition FE.
- (7) The service composition FE performs a composition process and it sends the result to the service control FE.
- (8) The service control FE requests to register the new service to the service profile management FE.

- (9) The service profile management FE returns the result to the service control FE.
- (10) The service control FE sends the result to the service provider.

## II.4 Agent registration

When there is a new agent, the new agent should be registered to the resource management FE to access and be used through the WoT broker. Figure II.4 shows the process of how to register an agent.



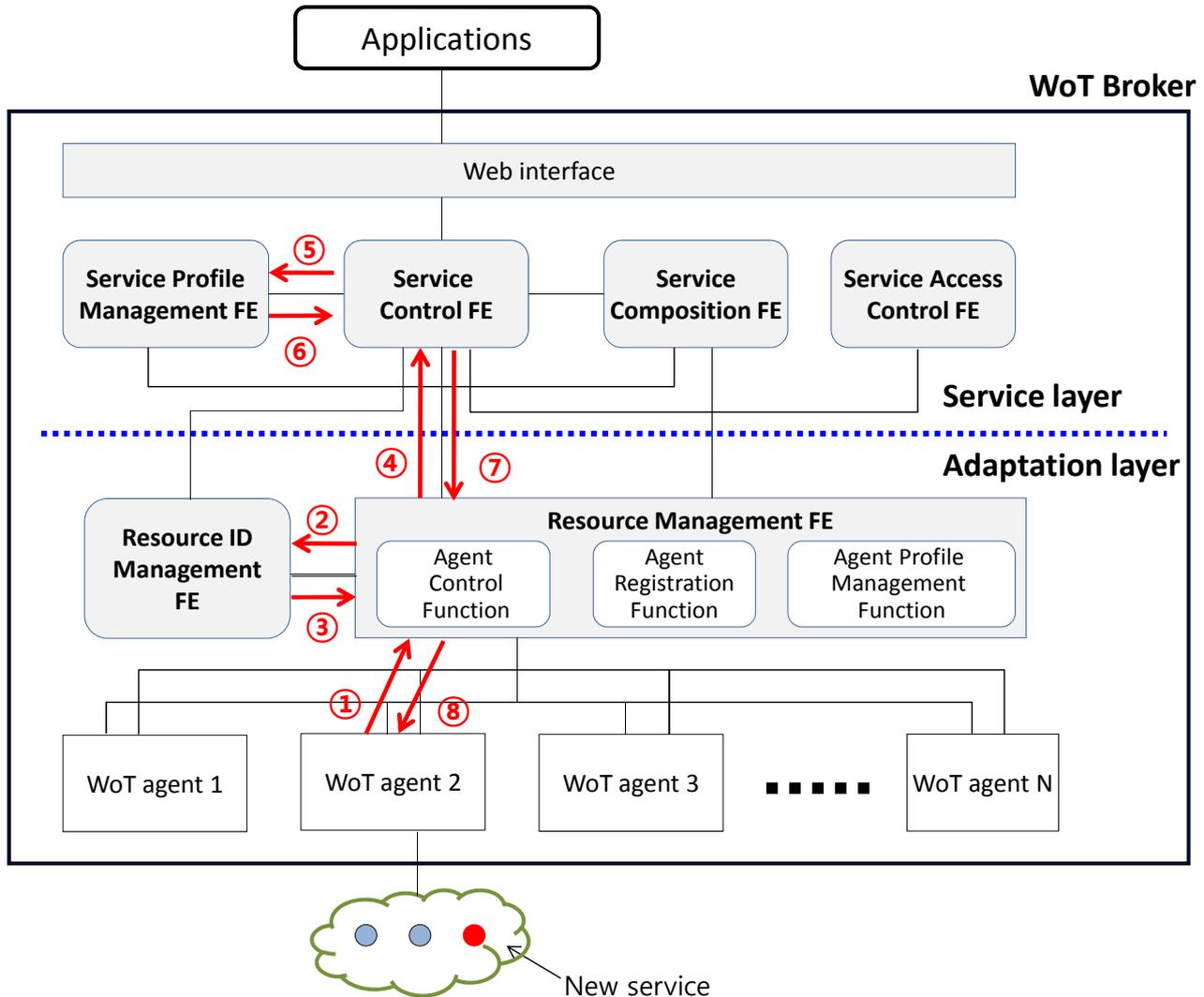
**Figure II.4 – Information flow of agent registration in a WoT broker**

- (1) A service provider is responsible for registering an agent. The service provider requests that the service control FE registers a new agent.
- (2) The service control FE sends a request to a service access control FE regarding whether the service provider and the new agent have authentication and authorization for the request.
- (3) The service access control FE checks authentication and authorization about the service provider and the new agent. It sends the result of the request to the service control FE.
- (4) The service control FE instructs the resource management FE to register the new agent.
- (5) The resource management FE interworks with the new agent to register the agent. It requests information related to the agent (e.g., service category, network characteristics, number of services belonging to the new agent).
- (6) The new agent sends the requested information.
- (7) The resource management FE registers the new agent and sends the result to the service control FE.
- (8) The service control FE informs the service provider of the result.

## II.5 Service registration

A new service is registered through an agent that the service belongs to. An agent recognizes a new service in the subnetwork. The agent tries to register the service in the WoT broker.

Figure II.5 shows the process for how to register a service.



**Figure II.5 – Information flow of service registration in the WoT broker**

- (1) An agent requests that the resource management FE registers a new service.
- (2) The resource management FE checks the request and it sends a message to register the new service with information to the resource ID management FE.
- (3) The resource ID management FE registers the new service with the resource ID and agent ID, and it returns the result to the resource management FE.
- (4) The resource management FE tries to register the new service to the upper layer (service layer). It sends a message to register the new service to the resource control FE.
- (5) The service control FE checks and requests to register the new service to the service profile management FE.

- (6) The service profile management FE registers the new service and it returns the result to the service control FE.
- (7) The service control FE returns the result to the resource management FE.
- (8) The resource management FE informs the result to the agent.

## Bibliography

- [b-W3C dig loss] W3C (2005), *Glossary of Terms for Device Independence*  
<<http://www.w3.org/TR/di-gloss/>>
- [b-W3C WACterms] W3C (1999), *Web Characterization Terminology & Definitions Sheet*  
<<http://www.w3.org/1999/05/WCA-terms/>>
- [b-IETF RFC 3986] IETF RFC 3986 (2005), *IETF Uniform Resource Identifiers (URI):  
Generic Syntax*  
<[http://datatracker.ietf.org/doc/rfc3986/?include\\_text=1](http://datatracker.ietf.org/doc/rfc3986/?include_text=1)>
- [b-W3C web arch] W3C (2004), *Architecture of the World Wide Web, Volume One*  
<<http://www.w3.org/TR/webarch/>>



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