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SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

Implementation guidelines to Recommendation ITU-T Y.4409/Y.2070

ITU-T Y-series Recommendations – Supplement 57

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Supplement 57 to ITU-T Y-series Recommendations

Implementation guidelines to Recommendation ITU-T Y.4409/Y.2070

Summary

Supplement 57 to ITU-T Y-series Recommendations provides implementation guidelines to Recommendation ITU-T Y.4409.

This Supplement describes implementation based on the functional architecture for the home energy management system (HEMS) and home network services specified in Recommendation ITU-T Y.4409 with regards to the information models for the devices connected to the home network, the communications protocols and the management for the home network. This Supplement also describes implementation of connecting devices with corresponding information models.

History

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Supplement 57 to ITU-T Y-series Recommendations

Implementation Guidelines to Recommendation ITU-T Y.4409/Y.2070

1 Scope

This Supplement provides implementation guidelines to [ITU-T Y.4409]. It covers the following:

– Overview:

Overview of the architecture for the home energy management system (HEMS) and home network (HN) services specified in [ITU-T Y.4409], the information models for the devices connected to the HN, the communications protocols and the management for the HN.

– Implementation based on functional architecture for HEMS and HN services:

Introduction of the information models of ECHONET Lite, Web of things (WoT) and next generation service interface (NGSI) for the devices connected to the HN, and description of the implementation of the communications protocol stack for the ECHONET Lite devices and implementation of the home-network topology identifying protocol (HTIP), a protocol used to identify the topology of the HN.

– Implementation of connecting devices with corresponding information models:

Description for connecting devices with corresponding information models including ECHONET Lite to the HN and accessible from the applications with WoT, which allows applications to get / set appropriate values from / to the devices via the web interface on the management platform (PF). A case of connecting WoT devices to NGSI is also described.

2 References

[ITU-T G.9973] Recommendation ITU-T G.9973 (2017), *Protocol for identifying home network topology*.

[ITU-T Y.4409] Recommendation ITU-T Y.4409/Y.2070 (2015), *Requirements and architecture of the home energy management system and home network services*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 adapter [ITU-T Y.4409]: An entity used to connect a non-basic device to the home gateway by converting the dedicated communications protocol to the IP based protocol and the dedicated data model to the abstract data model.

3.1.2 device object [b-ECHONET Lite]: A logical model of the information held by equipment devices or home electrical appliances such as sensors, air conditioners and refrigerators, or of control items that can be remotely controlled. The interface form for remote control is standardized. The information and control target of each device is specified as property, and the operating method (setting and browsing) is specified as a service.

3.1.3 home energy management system [ITU-T Y.4409]: A computer system comprising a software platform providing basic support services and a set of applications providing the functionality needed for the effective operation of home equipment, such as home appliances and storage batteries, so as to assure adequate security of energy supply at minimum cost.

3.1.4 home gateway [ITU-T Y.4409]: An always on, always connected device which acts as the central point connecting the devices on the home network to the applications on the wide area network, and monitors and performs actions on data flows within the home network as well as on bi-directional communication flows between the home network and the wide area network.

3.1.5 home network [b-ITU-T J.190]: A short-range communications system designed for the residential environment, in which two or more devices exchange information under some sort of standard control.

3.1.6 information model [b-ITU-T Y.4500.11]: Abstract, formal representation of entities that may include their properties, relationships and the operations that can be performed on them.

3.1.7 IoT area network [b-ITU-T Y.4113]: A network of devices for the IoT and gateways interconnected through local connections.

3.1.8 management platform [ITU-T Y.4409]: A platform which has common functions providing the interface and the management for the home network applications, and the virtual device management and the resource management for the home gateway and the devices.

3.1.9 web of things [b-ITU-T Y.4400]: A way to realize the IoT where (physical and virtual) things are connected and controlled through the world wide web.

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

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

AGW Access Gateway

API Application Programming Interface

CSV Comma-Separated Values

DTLS Datagram Transport Layer Security

HEMS Home Energy Management System

HGW Home Gateway

HN Home Network

HTIP Home-network Topology Identifying Protocol

IoT Internet of Things

IP Internet Protocol

JSON JavaScript Object Notation

LAN Local Area Network

LLDP Link Layer Discovery Protocol

LLDPDU Link Layer Discovery Protocol Data Unit

LM Local Manager

MAC Media Access Control

NGSI Next Generation Service Interface

PAN Personal Area Network

PC Personal Computer

PF	Platform
TCP	Transmission Control Protocol
TD	Thing Description
UDA	Universal Plug and Play Device Architecture
UDP	User Datagram Protocol
UPnP	Universal Plug and Play
UTP	Unshielded Twisted Pair
WoT	Web of Things
XML	Extensible Markup Language

5 Conventions

None.

6 Overview

6.1 General matters for implementation of HEMS and HN services

[ITU-T Y.4409] provides the requirements and architecture of the home energy management system (HEMS) and home network (HN) services.

The HEMS supports energy efficiency and reduction of energy consumption by monitoring and controlling devices such as home appliances, storage batteries and sensors connected to the HN from the HEMS application. While the algorithm for the energy efficiency and reduction of energy consumption runs in the HEMS application, the platform (PF) is the key component which provides common functions to enable the application to access the devices and to support the efficient development of applications. This is not only applied for the HEMS, but also for other HN services such as home security and healthcare.

The HN service architecture applied for the HEMS in [ITU-T Y.4409] is shown in Figure 6-1. Note that the HEMS application is one of the HN applications and therefore the architecture for the HEMS can be the same as that for other HN services. Furthermore, the HN inside the home is part of the Internet of things (IoT) area network. The relationship between the HN and the IoT area network is described in Appendix I.

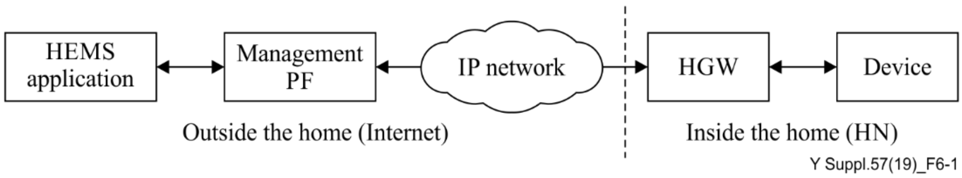

Figure 6-1 – HEMS based on HN service architecture

Devices such as home appliances, storage batteries and power sensors connected to the HN are monitored and controlled from the HEMS application, which in this architecture is located outside of the home (i.e., on the Internet). In order to do so, the home gateway (HGW) bridges the Internet and the HN. The HGW converts the various types of communications protocols used for communication with the devices to the protocol which is used on the Internet for communication with the management PF. The management PF is placed on the Internet and provides a web-based application interface. The HEMS application runs through this interface.

With the HGW and the management PF, it is possible for the HEMS application to discover and identify devices connected to the HN and to access them using their identifiers. In this way, the HEMS application monitors and controls the individual devices and thus is able to provide HEMS.

By making use of a standardized communications protocol between the HGW and the management PF, the HEMS application does not need to take into consideration the interfaces of the devices or the communications protocols used between the HGW and the devices. The devices are represented as web resources by the management PF. Therefore, this architecture supports application developers by allowing them to develop applications without deep knowledge about multiple device interfaces and communications protocols.

Figure 6-2 shows the functional architecture for the HN services (with the Internet protocol (IP) based basic device) shown in [ITU-T Y.4409]. Each part in Figure 6-2 is introduced in the following clauses 6.2 to 6.4 and its implementation is described in clauses 7.1 to 7.3.

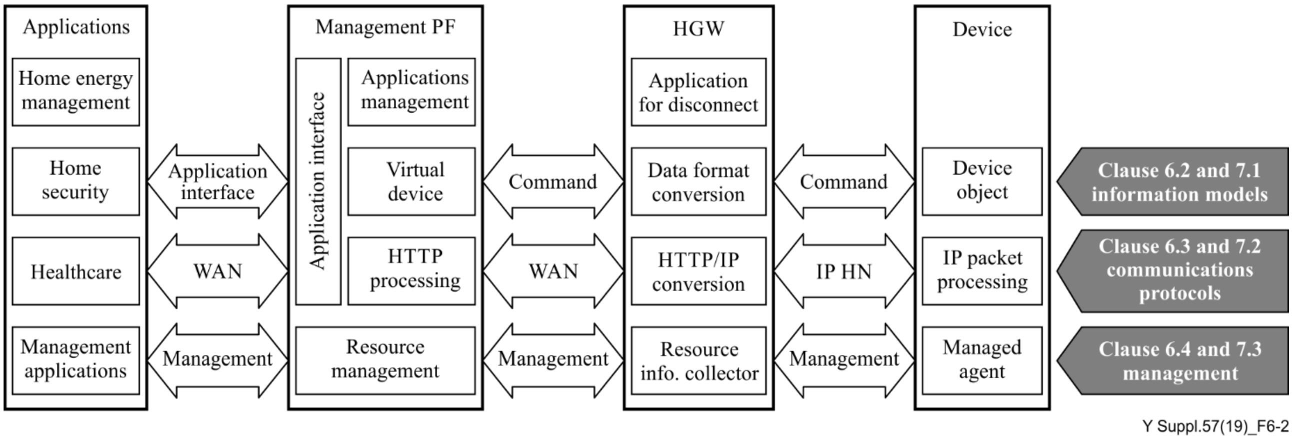

Figure 6-2 – This Supplement's clause structure based on functional architecture for HN services

6.2 Information models

The basic device specified in [ITU-T Y.4409] has the device object. It is composed of properties that specify the device functions which are independent of the implementation of the manufacturers. The properties are logical internal items to get the device status and to control the device functions, which can be remotely accessed and controlled from the application. The data form is basically specified as the tuple of <property, value>. Since the device object is specified for each type of device (e.g., home appliance, storage battery), existing home appliances made by different manufacturers would be remotely controlled in exactly the same way. As introduced in clause 9.1.1 of [ITU-T Y.4409], ECHONET Lite is one of the frequently used standards which has the feature of compatibility with more than 100 types of devices and with their device objects.

The information model for the device is an abstract, formal representation of the device that may include their properties and the operations that can be performed on them. Table 6-1 shows frequently used information models for the devices connected to the HN. As shown in Table 6-1, each standard has its own information model. Therefore, there is a difficulty for applications to make use of data combined from multiple devices each of which supports a corresponding standard. On the other hand, each information model basically has the tuple of <property, value>, so there is a possibility of interconversion.

Table 6-1 – Frequently used information models for devices connected to HN

Organization	Standard	Reference for information model
Broadband Forum	TR-181	TR-181 (Device Data Model for TR-069) [b-BBF TR-181]
ECHONET Consortium	ECHONET Lite	Detailed Requirements for ECHONET Device Objects Appendix in [b-ECHONET Lite]
ETSI	NGSI-LD	NGSI-LD Information model [b-ETSI NGSI-LD]
IEC	IEC 61970 series	IEC61970 CIM (Common Information Model) / Energy Management [b-IEC 61970]
ITU-T	ITU-T Y.4500 series	ITU-T Y.4500.23 (Home Appliances Information model and Mapping) [b-ITU-T Y.4500.23]
KNX	KNX	Application Description [b-KNX AD]
Open Connectivity Foundation	OIC Core	OIC Core Smart Home [b-OCF OIC Core]
OMA SpecWorks	LwM2M	Smart Objects [b-OMA SO]
OMA SpecWorks	NGSI	NGSI Information model [b-OMA NGSI]
W3C	WoT	WoT Thing Description [b-W3C WoT TD]
ZigBee Alliance	ZigBee PRO, ZigBee IP	ZigBee Cluster Library [b-ZigBee CL]

For creating various HN services, devices with various standards and information models are desired to be connected to the HN and accessible from the applications. The WoT allows applications to access various standardized device objects via the web interface on the management PF. As shown in Figure 6-2, the management PF provides an application interface. It is a web-based interface and the devices are represented as web resources by the management PF. WoT is an appropriate technology for this purpose. The WoT thing description (TD) specified in [b-W3C WoT TD] provides a generic horizontal information model for describing various information models and protocols in a single common model.

Clause 7.1 describes information models of ECHONET Lite, WoT and next generation service interface (NGSI). Clause 8 describes the implementation that enables to connect devices with corresponding information models including ECHONET Lite, to WoT.

6.3 Communications protocols for HN

The HN serves a function of connecting devices to the HGW.

The devices' properties are transmitted with communications protocols to the application via the HGW and the management PF for the application to monitor and control the devices. The commands transmitted between the HGW and the devices provide control methods for the HGW to the devices such as "GET" to get their status, "SET" to specify their properties and/or set the value and "INFORM" to request notification about their status and the events that have occurred in them.

[ITU-T Y.4409] lists [b-ECHONET Lite], [b-SEP 2.0] and [b-ISO/IEC 14543-3-x] as the communications protocols in the HN. This Supplement takes ECHONET Lite by making use of the existing comprehensive study results such as [b-TTC TR-1043] and [b-TTC TR-1064] for the implementation of the devices and communications of the device properties.

Clause 7.2 describes the protocol stack based on each layer of the communications protocols for the implementation of the ECHONET Lite compliant device.

6.4 Management for HN

As described in [ITU-T Y.4409], the HN is sometimes very complex and could have a complicated topology composed of various HN resources (e.g., devices). It could be difficult to manage and maintain the HN for end users. Therefore, it is important that the management function to support a variety of fault determination processes and fault recovery processes by remote administrators is provided.

The implementation of the home-network topology identifying protocol (HTIP) which is a protocol used to identify the topology of the HN is described in clause 7.3.

7 Implementation based on functional architecture for HEMS and HN services

In this clause, information models of ECHONET Lite, WoT and NGSI are introduced in clause 7.1, the implementation of protocol stack for ECHONET Lite devices is described in clause 7.2 and the implementation of the HTIP is described in clause 7.3.

7.1 Information models

Clause 7.1 describes the information models of ECHONET Lite, WoT and NGSI respectively in clause 7.1.1 to clause 7.1.3.

7.1.1 ECHONET Lite

ECHONET Lite is a light version of the conventional ECHONET which was developed by ECHONET Consortium and is a network communications protocol designed for the HN services. ECHONET Lite is reduced in protocol stack configuration, designed to be easier to implement for HN system builders and service system developers. [b-ECHONET Lite] is the ECHONET Lite specification. It is also standardized as [b-IEC 62394] and [b-ISO/IEC14543-4-3].

ECHONET Lite is characterized by reducing the amount of implementation of the communication part of the conventional ECHONET. It specifies the communication middleware layer which is shown hatched in Figure 7-1, taken from [b-ECHONET Lite]. By excluding layers 1 to 4 from its specification, it allows any standardized communications protocols. This enables multi-vendor interconnection for the HN services.

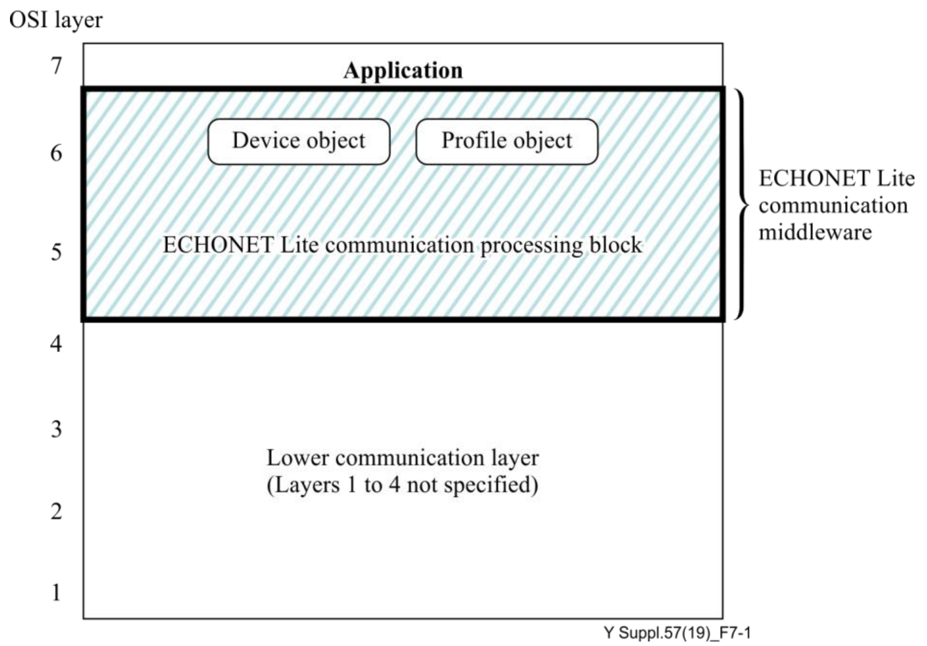

Figure 7-1 – ECHONET Lite communication layer configuration

Devices used at home, such as air conditioners, lighting equipment and sensors are defined as device objects. They are monitored and controlled through the ECHONET Lite communications protocol. Since the device object is specified for each type of device, products of different manufacturers can be remotely controlled in exactly the same way if they are of the same device type.

In a single ECHONET device, one or more device objects may be defined. Each device object defines the properties to be used in each class and the services corresponding to the properties. Figure 7-2 taken from [b-ECHONET Lite] illustrates this relationship by specific examples. [b-ECHONET Lite] describes property configurations of the device objects of more than 100 types of devices.

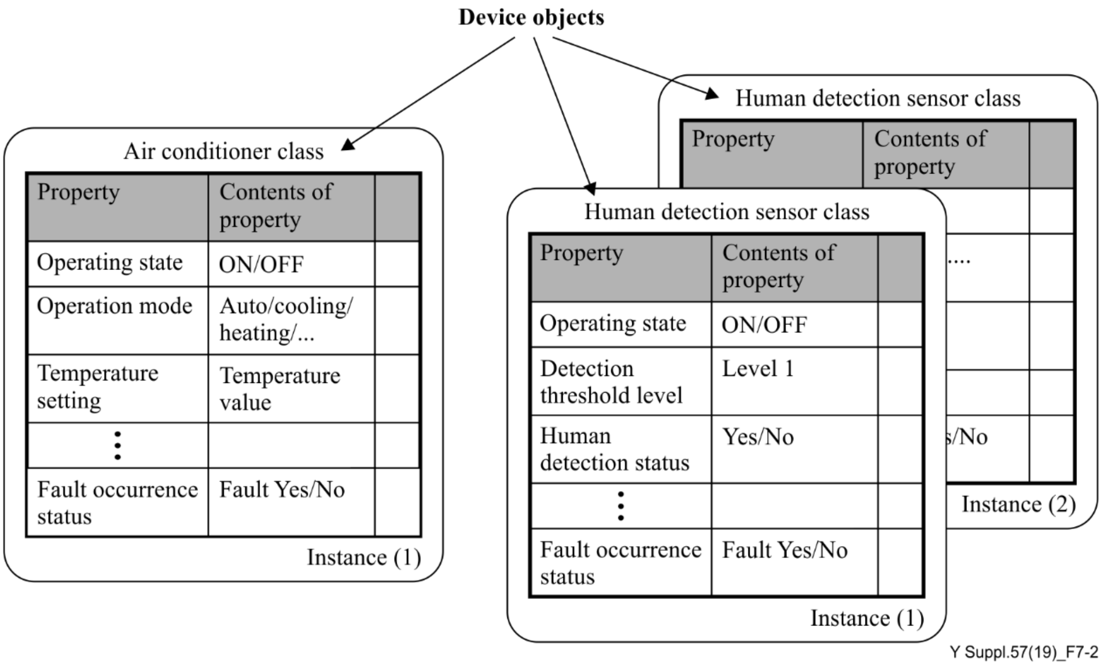

Figure 7-2 – Device object example

For the concrete implementation method, [b-ECHONET Lite] includes in its Appendix "Detailed Requirements for ECHONET Device objects" for the property configurations of the device objects.

7.1.2 WoT

A typical WoT interaction is shown as "consumer-thing interaction" in Figure 7-3. A thing is the abstraction of a physical or virtual entity (e.g., a device or a room) and is described by standardized data. The structured data describing a thing is called the TD. A TD comprises general metadata, domain-specific metadata, interaction affordances, security configuration, and links to related things among other things. TD is the central building block of WoT, and consumer is an entity that can process TDs (including its JavaScript object notation (JSON)-based representation format) then interact with things by activating interaction affordances provided by the things. Interaction affordance, based on web technologies such as hypermedia controls (i.e. links and forms), media types and JSON schema, is metadata of a thing that shows and describes the possible choices to consumers, thereby suggesting how consumers may interact with the thing.

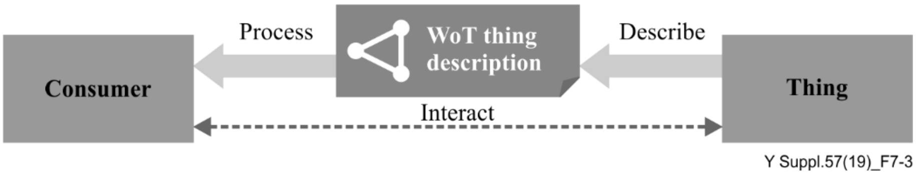

Figure 7-3 – WoT consumer-thing interaction

Figure 7-4 shows an example of the WoT consumer-thing interaction. The application of consumer (e.g., smart phone) can handle the physical device (e.g., air conditioner) by operating its properties. To bring the physical device into this WoT framework, a virtual device is created as TD. TD has properties and their values. In this example, properties of the air conditioner are status, mode, and temperature. The commands transmitted between the application and the device provide control methods for the applications to the device such as "READ" to get its status, "WRITE" to specify its properties and/or set the value and "NOTIFY" to request notification about its status and the events that have occurred in the device. [b-W3C WoT Arch] contains the concrete implementation method.

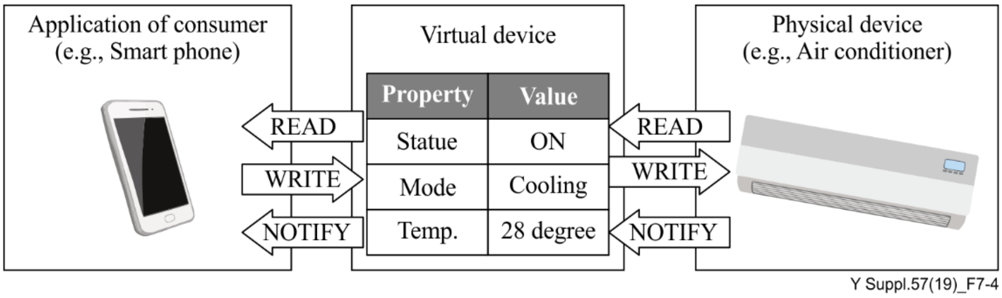

Figure 7-4 – Example of WoT consumer-thing interaction

7.1.3 NGSI

Next generation service interface (NGSI) is a set of common application programming interfaces (APIs) for the information exchange. The NGSI information model has "entity" and "context element".

The entity is a virtual representation of all kinds of physical objects in the real world such as tables, rooms, and persons. The virtual entities have an identifier and a type.

NOTE – For example, a virtual entity representing a person named "John" could have the identifier "John" and the type "person".

The context element is used for exchanging information about entities. A context element contains information about multiple attributes of one entity. It may have an entity id and a list of triplets <attribute name, attribute type, attribute value> etc.

7.2 Communications protocols for HN with ECHONET Lite

This clause refers to [b-TTC TR-1043] which describes the protocol stack based on each layer of the communications protocols for the implementation of ECHONET Lite. This clause also refers to [b-TTC TR-1064] for the brief description of the communications protocols.

7.2.1 UDP/IPv4

When User Datagram Protocol (UDP)/IPv4 is implemented with ECHONET Lite, the protocol stack is shown in Table 7-1 and the specifications are described below the table. The details are described in [b-ECHONET Lite].

Table 7-1 – Protocol stack with UDP/IPv4

OSI model layer	Protocol type
Session to Application	ECHONET Lite
Transport	UDP
Network	IPv4
Data link	Anything that can implement IPv4
Physical	Anything that can implement IPv4 with the data link layer protocol
Media	Depends on the physical layer protocol

(1) Specifications for network layer:

- Address of each node: IP address
- Range of the address: Not specified
- Acquisition of the address: Not specified

(2) Specifications for transport layer:

- UDP port number: 3610 (destination port number; source port is not specified)
- Broadcasting method: IP multicast (multicast address: 224.0.23.0)
- Security: RFC5191 (node authentication), Datagram Transport Layer Security (DTLS) or IPSec (network layer security) may be used.

7.2.2 UDP/IPv6

When UDP/IPv6 is implemented with ECHONET Lite, the protocol stack is shown in Table 7-2 and the specifications are described below the table. The details are described in [b-ECHONET Lite].

Table 7-2 – Protocol stack with UDP/ IPv6

OSI model layer	Protocol type
Session to Application	ECHONET Lite
Transport	UDP
Network	IPv6
Data link	Anything that can implement IPv6
Physical	Anything that can implement IPv6 with the data link layer protocol
Media	Depends on the physical layer protocol

(1) Specifications for network layer:

- Address of each node: IPv6 address
- Range of the address: Not specified
- Acquisition of the address: Not specified

(2) Specifications for transport layer:

- UDP port number: 3610 (destination port number; source port is not specified)
- Broadcasting method: IP multicast (ff02::1 all nodes multicast address)
- Security: RFC5191 (node authentication), DTLS or IPSec (network layer security) may be used.

7.2.3 TCP/IPv4

When Transmission Control Protocol (TCP)/IPv4 is implemented with ECHONET Lite, the protocol stack is shown in Table 7-3 and the specifications are described below the table. The details are described in [b-ECHONET Lite].

Table 7-3 – Protocol stack with TCP/IPv4

OSI model layer	Protocol type
Session to Application	ECHONET Lite
Transport	TCP
Network	IPv4
Data link	Anything that can implement IPv4
Physical	Anything that can implement IPv4 with the data link layer protocol
Media	Depends on the physical layer protocol

(1) Specifications for network layer:

- Address of each node: IP address
- Range of the address: Not specified
- Acquisition of the address: Not specified

(2) Specifications for transport layer:

- TCP port number: 3610 (destination port after establishing connection is not specified; source port number is not specified; response message corresponding to the request message is transmitted over the same connection)

(3) Guidelines on TCP:

- A node that transmits the response message to other nodes is implementation-dependent (it may not respond to) if the connection is already disconnected during the transmission process.
- A node that transmits the request message to other nodes is desired to re-transmit with UDP unicast in case that the TCP connection fails, with assuming the possibility that they do not support the TCP connection.
- Broadcasting method: IP multicast with UDP (multicast address: 224.0.23.0)
- An ECHONET Lite node is desired to listen on UDP port 3610 for UDP unicast and UDP multicast packets, and process the message.

7.2.4 TCP/IPv6

When TCP/IPv6 is implemented with ECHONET Lite, the protocol stack is shown in Table 7-4 and the specifications are described below the table. The details are described in [b-ECHONET Lite].

Table 7-4 – Protocol stack with TCP/IPv6

OSI model layer	Protocol type
Session to Application	ECHONET Lite
Transport	TCP
Network	IPv6
Data link	Anything that can implement IPv6
Physical	Anything that can implement IPv6 with the data link layer protocol
Media	Depends on the physical layer protocol

(1) Specifications for network layer:

- Address of each node: IPv6 address
- Range of the address: Not specified
- Acquisition of the address: Not specified

(2) Specifications for transport layer:

- TCP port number: 3610 (destination port after establishing connection is not specified; source port number is not specified; response message corresponding to the request message is transmitted over the same connection)

(3) Guidelines on TCP:

- A node that transmits the response message to other nodes is implementation-dependent (it may not respond to) if the connection is already disconnected during the transmission process.
- A node that transmits the request message to other nodes is desired to re-transmit with UDP unicast in case that the TCP connection fails, with assuming the possibility that they do not support the TCP connection.
- Broadcasting method: IP multicast with UDP (ff02:1 all nodes multicast address)
- An ECHONET Lite node is desired to listen on UDP port 3610 for UDP unicast and UDP multicast packets, and process the message.

7.2.5 IEEE 802.3 family (Ethernet)

Implementing HEMS with the local area network (LAN) cable is one option. It enables 100Mbit/s or 1Gbit/s data transmission with the transmission range up to around 100m.

When IEEE 802.3 family (Ethernet ([b-IEEE 802.3])) is implemented with ECHONET Lite with the LAN cable, there are the following options and the protocol stack is shown in Table 7-5.

a. IPv4 is used for the protocol type of the network layer

  a1. UDP is used for the protocol type of the transport layer

  a2. TCP is used for the protocol type of the transport layer

b. IPv6 is used for the protocol type of the network layer

  b1. UDP is used for the protocol type of the transport layer

  b2. TCP is used for the protocol type of the transport layer

Table 7-5 – Protocol stack with IEEE 802.3 family (Ethernet)

OSI model layer	Protocol type			
Session to Application	ECHONET Lite			
Transport	a1. UDP	a2. TCP	b1. UDP	b2.TCP
Network	a. IPv4		b. IPv6	
Data link	IEEE 802.3 family			
Physical	IEEE 802.3 family			
Media	Copper cable (Unshielded Twisted Pair (UTP)), Optical cable			

Refer to 7.2.1 UDP/IPv4 for the details of a1.

Refer to 7.2.3 TCP/IPv4 for the details of a2.

Refer to 7.2.2 UDP/IPv6 for the details of b1.

Refer to 7.2.4 TCP/IPv6 for the details of b2.

7.2.6 IEEE 802.11 family (Wi-Fi)

Wi-Fi (wireless fidelity) is the brand name of Wi-Fi Alliance. The wireless LAN products certified for the Wi-Fi signal transmission based on the IEEE 802.11 technology family (802.11a, 802.11b, 802.11g, 802.11n and so on [b-IEEE 802.11]) would be given the right to use the Wi-Fi logo by Wi-Fi Alliance.

When IEEE 802.11 family (Wi-Fi) is implemented with ECHONET Lite with the wireless LAN, there are the following options and the protocol stack is shown in Table 7-6.

a. IPv4 is used for the protocol type of the network layer
   - a1. UDP is used for the protocol type of the transport layer
   - a2. TCP is used for the protocol type of the transport layer

b. IPv6 is used for the protocol type of the network layer
   - b1. UDP is used for the protocol type of the transport layer
   - b2. TCP is used for the protocol type of the transport layer

Table 7-6 – Protocol stack with IEEE 802.11 family (Wi-Fi)

OSI model layer	Protocol type			
Session to Application	ECHONET Lite			
Transport	a1. UDP	a2. TCP	b1. UDP	b2.TCP
Network	a. IPv4		b. IPv6	
Data link	IEEE 802.11 family			
Physical	IEEE 802.11 family			
Media	Radio wave (2.4GHz band, 5GHz band)			

Refer to 7.2.1 UDP/IPv4 for the details of a1.

Refer to 7.2.3 TCP/IPv4 for the details of a2.

Refer to 7.2.2 UDP/IPv6 for the details of b1.

Refer to 7.2.4 TCP/IPv6 for the details of b2.

7.2.7 IEEE 802.15.1 family (Bluetooth)

Bluetooth is standardized as [b-IEEE 802.15.1] and used in the data transmission range between a few to around 100m based on its transmission power. It is used for the low rate wireless data transmission for example for controlling the mouse and the keyboard of the notebook or personal computer (PC) and the voice data of the cellular / smart phone. It is specified by Bluetooth SIG. It uses the frequency hopping spread spectrum modulation technique with the 2.4 GHz frequency range.

When IEEE 802.15.1 family (Bluetooth) is implemented with ECHONET Lite, there are the following options and the protocol stack is shown in Table 7-7.

a. IPv4 is used for the protocol type of the network layer with the Bluetooth personal area network (PAN) profile
   - a1. UDP is used for the protocol type of the transport layer
   - a2. TCP is used for the protocol type of the transport layer

b. IPv6 is used for the protocol type of the network layer with the Bluetooth PAN profile
   - b1. UDP is used for the protocol type of the transport layer
   - b2. TCP is used for the protocol type of the transport layer

Table 7-7 – Protocol stack with IEEE 802.15.1 family (Bluetooth)

OSI model layer	Protocol type			
Session to Application	ECHONET Lite			
Transport	a1. UDP	a2. TCP	b1. UDP	b2.TCP
Network	a. IPv4		b. IPv6	
Data link	IEEE 802.15.1 family, PAN profile			
Physical	IEEE 802.15.1 family			
Media	Radio wave (2.4GHz band)			

Refer to 7.2.1 UDP/IPv4 for the details of a1.

Refer to 7.2.3 TCP/IPv4 for the details of a2.

Refer to 7.2.2 UDP/IPv6 for the details of b1.

Refer to 7.2.4 TCP/IPv6 for the details of b2.

Although there are other methods to transmit the ECHONET Lite message directly with a Bluetooth profile other than the PAN profile or to handle the IP packet without the PAN profile, there is no activity for the standardization.

7.3 Management for HN with HTIP

The HTIP is a protocol used to identify the topology of a HN and is specified in [ITU-T G.9973] and [b-TTC JJ-300.00]. Figure 7-5 is taken from [ITU-T G.9973] which shows the protocol.

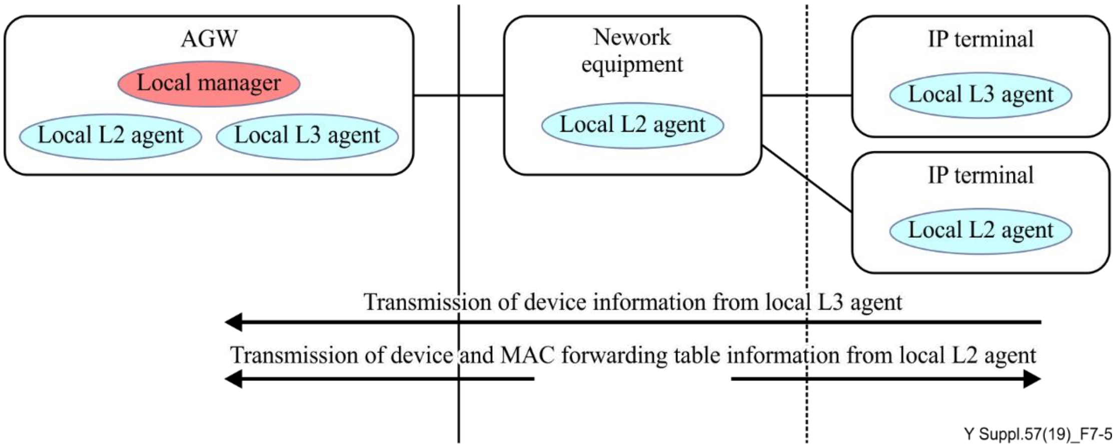

Figure 7-5 – Protocol for identifying HN topology

Figure 7-5 is composed of the IP terminal, the network equipment and the access gateway (AGW). The IP terminal corresponds to the device which supports the IP based communications protocols in [ITU-T Y.4409]. The network equipment is a hardware device that has two or more ports and a function to transfer frames and packets received at one port to the other by using a media access control (MAC) forwarding table (e.g., Ethernet bridge). The AGW corresponds to the HGW in [ITU-T Y.4409].

Management information can be retrieved by the local manager (LM), which can reside in any device in the IP HN. Figure 7-5 shows a typical case where the LM resides in the AGW. The AGW has both the local L2 and L3 agents. The network equipment has the local L2 agent, and there are two types of the IP terminal which has the local L2 agent and the local L3 agent, respectively. Processing load on the network equipment can be reduced by implementing the local L2 agent in transmit-only mode which uses only the L2 protocol stack because they don't need to constantly monitor the packets and frames to be received but perform one-way transmission of information.

The local L3 agent of the IP terminal sends device information by using the Universal Plug and Play (UPnP) device architecture (UDA), while the local L2 agent of the network equipment sends both device information and MAC forwarding table information by using the link layer discovery protocol (LLDP). Note that the management information to identify the IP HN topology consists of these two types information. The device information consists of at least the following four kinds of information: the device category, the manufacturer code, the model name and the model number. Fault management information may be added to the device information as described in clause 6.1 of [b-TTC JJ-300.00]. The LM can identify the HN topology by analysing the collection of this management information. By utilizing this HN topology information, some applications can perform fault localization in response to the failure of network services.

This protocol configures the link layer discovery protocol data unit (LLDPDU) frame destination MAC addresses as basically broadcast addresses. This design enables LM to collect information from arbitrary network equipment and estimate the topology of a HN even if devices, which do not implement LLDP, are connected to the HN.
Connectivity check between the LM and the L2/L3 agent is also executed.

[b-TTC JJ-300.00] contains the details of the implementation of the protocol.

8 Implementation of connecting devices with corresponding information models

As described in clause 6.2, WoT allows applications to get / set appropriate values from/to the devices supporting corresponding standards and information models via the web interface.

In this clause, the implementations that enable devices supporting corresponding information models to be connected are described. The implementation of connecting devices to WoT is described in clause 8.1. The implementation of connecting ECHONET Lite device to WoT is described in clause 8.2 and the implementation of connecting WoT device to NGSI is described in clause 8.3.

8.1 Connecting devices to WoT

Most of the information models shown in Table 6-1 have data corresponding to the TD's properties and the value of properties. WoT takes advantage of the fact that many devices have a structure similar to that of the TD to ensure interoperability.

Functional architecture for connecting devices with the corresponding information model to WoT is shown in Figure 8-1. The devices with any standards' information model such as those listed in Table 6-1 are connected to WoT by converting the information model to the WoT information model. In this way, they are connected to the applications.

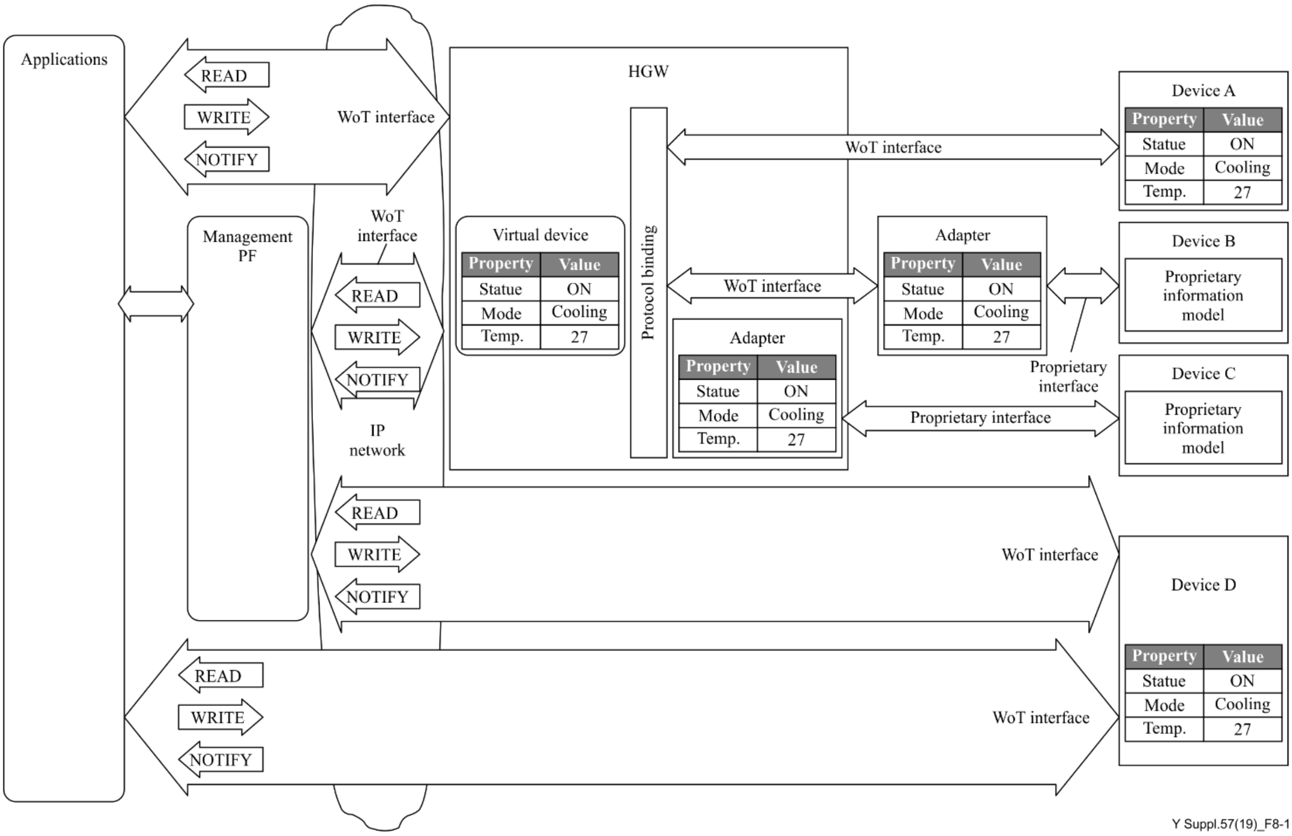

Figure 8-1 – Functional architecture for connecting devices with corresponding information model to WoT

Figure 8-1 shows an example of the properties and values of four air conditioners as the Devices A to D, in each of which the operation state is ON, the operation mode is set to cooling, and the temperature setting value is 27 degrees. The network topology of Device A, B, and C can be identified by the HGW with HTIP described in clause 7.3.

In Figure 8-1, the information model for Device A and Device D is TD of WoT. Device B and Device C have an information model of any standards such as those listed in Table 6-1. Most of the information models for devices such as those listed in Table 6-1 have a structure similar to TD, and properties are described in many ways, such as JSON, extensible markup language (XML), comma-separated values (CSV), etc. The adapter converts description formats and operation protocols.

By implementing WoT this way, devices with corresponding standards, information models, and interfaces which may include some other than WoT can be connected to the network, can be accessible from the applications and can exchange their data.

8.2 Connecting ECHONET Lite devices to WoT

Figure 8-2 shows a functional architecture for an ECHONET Lite device connecting to WoT. The ECHONET Lite device and the HGW can be connected by various protocol stacks as described in clause 7.2. As described in clause 7.1.1, ECHONET Lite has the device objects, and the property and contents of property of the device objects correspond to the property and value of WoT as shown in Figure 8-2. WoT absorbs differences from ECHONET Lite and allows applications to monitor and control the ECHONET Lite device using the WoT interface.

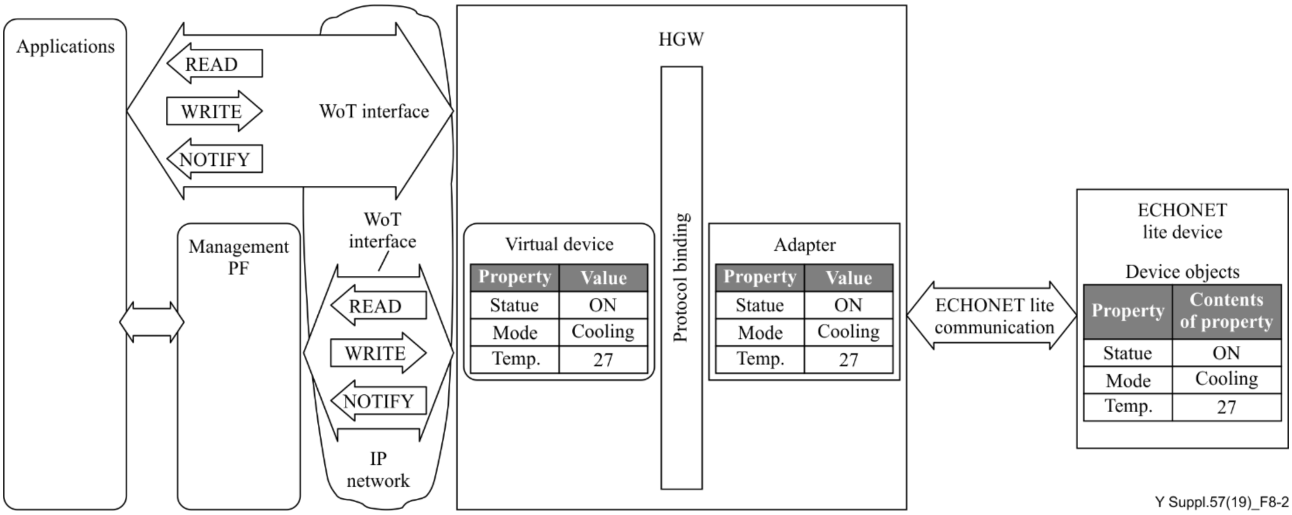

Figure 8-2 – Functional architecture for ECHONET Lite device connecting to WoT

8.3 Connecting WoT devices to NGSI

NGSI described in clause 7.1.3 is one of the Open Mobile Alliance (OMA) standard networking APIs. Figure 8-3 shows the functional architecture in which the application and the management PF communicate to the HGW with NGSI. A WoT device is connected to the HGW in the same way as the Device A in Figure 8-1. On the other hand, the HGW also has a protocol binding on the IP network side. This protocol binding converts the information model and protocol to NGSI for the applications and the management PF.

As described above, it is possible to ensure interoperability between the HGW and the application with a various APIs such as NGSI by implementing a protocol binding on the IP network side of the HGW.

Although it is not limited to the case of connecting the WoT device to NGSI, the connection often becomes across different domains or different companies. Each domain and company may have corresponding terms for the same meaning and that may make interoperability difficult. In such cases, if a common vocabulary exists, it can be used in converting the information model to ensure interoperability.

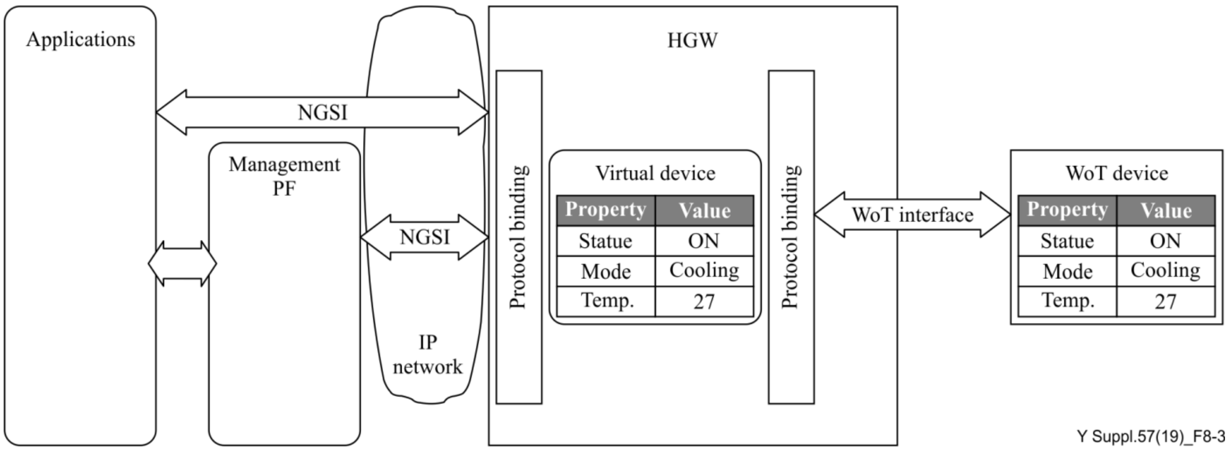

Figure 8-3 – Functional architecture for WoT device connecting to NGSI

Appendix I

IoT area network

[b-ITU-T Y.4113] defines the IoT area network as a network of devices for the IoT and gateways interconnected through local connections, and depicts it in the basic model of the network for the IoT which is shown in Figure I.1.

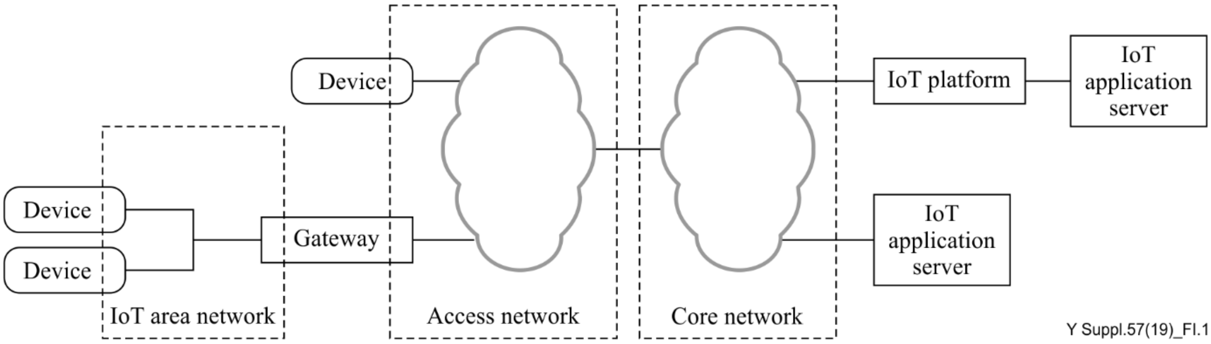

Figure I.1 – Basic model of the network for the IoT

Figure 6-1 in this Supplement shows the HEMS based on HN service architecture. Comparing Figure 6-1 and Figure I.1, it can be seen that the HN service architecture is a part of Figure 6-1. Therefore, the architecture of [ITU-T Y.4409] can also be applied to the IoT related services.

The correspondence between each part of Figure I.1 and Figure 6-1 is described below.

The device in Figure I.1 is a piece of equipment with mandatory capabilities of communication, and optional capabilities of sensing, actuation, data capture, data storage and data processing with regard to the IoT. It can also be directly connected to the access network by including the function of the gateway. The device of Figure I.1 corresponds to the device of Figure 6-1.

The gateway in Figure I.1 is a unit with regard to the IoT which interconnects the devices with the core network. It performs the necessary translation between the protocols used in the core network and those used by devices. The gateway of Figure I.1 corresponds to the HGW of Figure 6-1.

The core network is a portion of the delivery system composed of networks, equipment and infrastructures. The access network connects the devices for the IoT and gateways to the core network. The core network and access network of Figure I.1 correspond to the IP network in Figure 6-1.

The IoT area network is a network of devices for the IoT and gateways that are interconnected. Connectivity is realized through local connections, typically using short-range communication technologies. The IoT area network in Figure I.1 corresponds to the HN in Figure 6-1.

The IoT platform is a technical infrastructure that provides integration of generic and specific capabilities in [b-ITU-T Y.4000]. The IoT platform in Figure I.1 corresponds to the management PF in Figure 6-1.

The IoT application server runs applications, and communicates with devices, gateways and the IoT platform in order to deliver application services. It can also be directly connected to the core network by including the function of the IoT platform. The IoT application server in Figure I.1 corresponds to the HEMS application in Figure 6-1.

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