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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

Access networks – In premises networks

**Generic architecture of home networks for
energy management**

Recommendation ITU-T G.9958

ITU-T



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Recommendation ITU-T G.9958

Generic architecture of home networks for energy management

Summary

Recommendation ITU-T G.9958 specifies functional definitions of components and networks to provide energy management services in the home. It also specifies home network configurations and requirements for these services.

History

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Introduction

Standardization of IoT (Internet of Things) has been promoted actively in ITU-T. Q15/15 in ITU-T has discussed the standardization of communication networks for power grids. One of the activities in Q15/15 has been specifications of smart meter networks as one of the promising applications in IoT. This Recommendation specifies generic architecture for home energy management services using smart meter networks and provides an example of real deployment for such services. In these services data protection is an important requirement. This Recommendation mentions security features used to provide secure communication such as isolation of traffic flows. However, the specification of these security features is out of the scope of this Recommendation.

Recommendation ITU-T G.9958

Generic architecture of home networks for energy management

1 Scope

This Recommendation specifies home network configurations and requirements for the provision of energy management services in the home. The proposed set of network configurations is also expected to result in a communication framework suitable for a broader set of other IoT applications.

The relationship between this Recommendation and other Recommendations on IoT and home networks is described as follows. IoT generic architecture and requirements have been specified in [ITU-T Y.4000] and [ITU-T Y.4113]. Architecture and requirements in IP home networks connected to broadband wide area networks have been specified in [ITU-T G.9970] and [ITU-T G.9971]. Home energy management has been described in [ITU-T Y.4409]. This Recommendation is based on the Recommendations mentioned above and does not introduce any conflicts.

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 G.9970] Recommendation ITU-T G.9970 (2009), *Generic home network transport architecture*.
- [ITU-T G.9971] Recommendation ITU-T G.9971 (2010), *Requirements of transport functions in IP home networks*.
- [ITU-T Y.4000] Recommendation ITU-T Y.4000/Y.2600 (2012), *Overview of the Internet of things*.
- [ITU-T Y.4113] Recommendation ITU-T Y.4113 (2016), *Requirements of the network for the Internet of things*.
- [ITU-T Y.4409] Recommendation ITU-T Y.4409 (2015), *Requirements and architecture of the home energy management system and home network services*.

3 Definitions

The following definitions specify the functionality of various components and networks with regard to home energy management services and do not include implementation details.

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 Components

3.2.1.1 HEMS controller: A home energy management system (HEMS) controller is a networking device used to connect home appliances to the home network through a variety of IP and/or non-IP network interfaces. It provides intelligent functions, such as the monitoring of real-time and/or cumulative power consumption, feedback to users for ecology, etc., for energy management services in conjunction with a home gateway and/or smart meter.

3.2.1.2 HEMS-managed home appliances: HEMS-managed home appliances are devices associated with a HEMS controller by IP or non-IP interface. They are managed and controlled by the HEMS controller. Examples of such managed appliances include energy management facilities in the home, such as power conditioners for a photovoltaic (PV) power system, fuel cells, storage batteries, electric vehicles (EV) / plug-in hybrid vehicles (PHV), air conditioners, lighting equipment, water heaters etc.

3.2.1.3 home gateway: A home gateway is a networking device designated for use in a home which associates a general-purpose network and one or more general-purpose home networks and is responsible for the transfer of information between these networks. A home gateway may provide other user-oriented services such as video-on-demand, in addition to generic communication functionality.

3.2.1.4 non-HEMS appliance: A non-HEMS appliance is a device connected to the home network which is not managed by a HEMS controller.

3.2.1.5 smart meter: A smart meter is an electronic device that records consumption of electric energy in periodic intervals of an hour (or less) and reports this information to the electric utility for monitoring and billing. A smart meter enables two-way communication between the meter and the utility company. In addition to the function of automated meter reading it also can receive and handle control information regarding energy management from the utility, and report power quality monitoring information. The smart meter does not provide open access to its functionality to the users, regardless of its physical installation location (outdoor plant, in-building, in-home etc.).

3.2.2 Networks

3.2.2.1 dedicated home network: A dedicated home network is a local area network deployed in a home in order to connect specific managed home appliances. It is deployed as either a physical network or a logical network and it is independent of the general purpose home network.

3.2.2.2 general purpose home network: A general purpose home network is a local area network deployed in a home. This network provides wired and/or wireless connectivity to any device in the home, utilizing mainly IP technologies. This network is positioned as a backbone network in a home for general purpose use.

3.2.2.3 general purpose network: A general purpose network is a wide area network (WAN) which can be used for any legitimate purpose and does not impose any restrictions regarding its usage. A general purpose network must provide Internet access and may provide additional services such as telephony and video distribution services.

3.2.2.4 utility network: In this Recommendation, a utility network is deployed and managed by an electric utility company for the purposes of electric energy management, monitoring and billing.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AEM	Advanced Energy Management
EV	Electric Vehicle
FTTH	Fibre To The Home
HEMS	Home Energy Management System
HES	Head End System
HGW	Home Gateway
IoT	Internet of Things
MDMS	Meter Data Management System
PHV	Plug-in Hybrid Vehicle
PV	Photo-Voltaic
WAN	Wide Area Network

5 Conventions

In clause 6, the scopes of the descriptions on "Physical configuration" and "Communication path" are defined as follows.

"Physical configuration": physical connections between the components defined in clause 3. These connections can be categorized by a combination of the networks described in clause 3.

"Communication path": communication flows of data between components across networks. A communication path is a logical configuration provided by a combination of physical configurations. Various services for home energy management can be provided over communication paths.

6 Network configurations

Home energy management services are provided using the following network configurations. These configurations are the most representative network configurations used to offer home energy management services. Home energy management services must utilize secure communications. This Recommendation mentions the isolation of communication paths as a means to achieve secure communications among various components and assumes that all networks and components provide adequate security features. For example, communication for home energy management services is physically separated from other communications by person, devices and application software for cybersecurity reasons. These configuration is to prevent hackers from injecting harmful data and/or programs into the utility network through home network. However, secure communication protocols, their implementation, as well as the set of security features that must be provided by components and networks, are outside the scope of this Recommendation.

6.1 Summary

The relationship between components and networks are described in Table 1. This table indicates physical configuration. Each row and column in Table 1 denote "network" and "component", respectively. An "x" mark denotes "connection". Grey rows denote the home network parts.

Table 1 – Physical configuration of components and networks

	Smart meter	HEMS C	HEMS AP	HGW	Descriptions	Purpose
Utility Net	X				6.2	Electric power companies measure electric supply and/or electricity sales with the use of one smart meter per contractor. No HEMS controller is present.
Gen Net						
G HNW						
D HNW						
Utility Net	X				6.3.1	Intelligent energy management services, such as a demand-response service, are provided by an installed HEMS controller.
Gen Net						
G HNW	X	X				
D HNW		X	X			
Utility Net	X				6.3.2	
Gen Net						
G HNW						
D HNW	X	X	X			
Utility Net	X				6.4.1	In addition to electric power companies, other service providers can supply intelligent energy management services. In this case, these providers can access HEMS controllers through HGW.
Gen Net				X		
G HNW	X	X	X	X		
D HNW						
Utility Net	X				6.4.2	
Gen Net				X		
G HNW	X	X				
D HNW		X	X			
Utility Net	X				6.4.3	
Gen Net				X		
G HNW		X		X		
D HNW	X	X	X			

HEMS C: HEMS Controller, HEMS AP: HEMS-managed home appliances

Utility Net: Utility network, Gen Net: General purpose network, G HNW: General purpose home network, D HNW: Dedicated home network

6.2 Monitor of power consumption

The network configuration shown in Figure 1 represents the simplest configuration used to offer home energy management services. In this configuration, electric power companies provide measurement services of electric supply and/or electricity sales with the use of one smart meter per contractor.

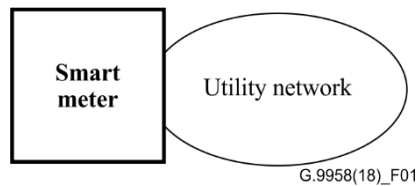


Figure 1 – Network configuration for metering using a smart meter

(1) Physical configuration

A smart meter shall be connected to a utility network. A smart meter shall not be connected to other components in the home from a communications point of view.

(2) Communication path

A smart meter supports communication protocols designated by the connected utility network. A smart meter connects to the utility network as a client. Although the utility network may provide support for various communication protocols, specifying the protocol to be used by the utility network is out of the scope of this Recommendation. This communication path shall be secured. Any data shall not be leaked to other communication paths.

6.3 Monitor and control of power consumption through a utility network

In these configurations, a HEMS controller is installed in the home. It can provide intelligent home energy management services in conjunction with a smart meter. These services are provided by an electric power company through a utility network. These configurations can be categorized into the following two types (clauses 6.3.1 and 6.3.2). In these configurations, a smart meter and a utility network shall be protected from threats by using some secure protocols which are out of the scope of this Recommendation.

6.3.1 General purpose home network oriented configuration

In the home, home energy management information between a smart meter and a HEMS controller is transferred across a general purpose home network as shown in Figure 2.

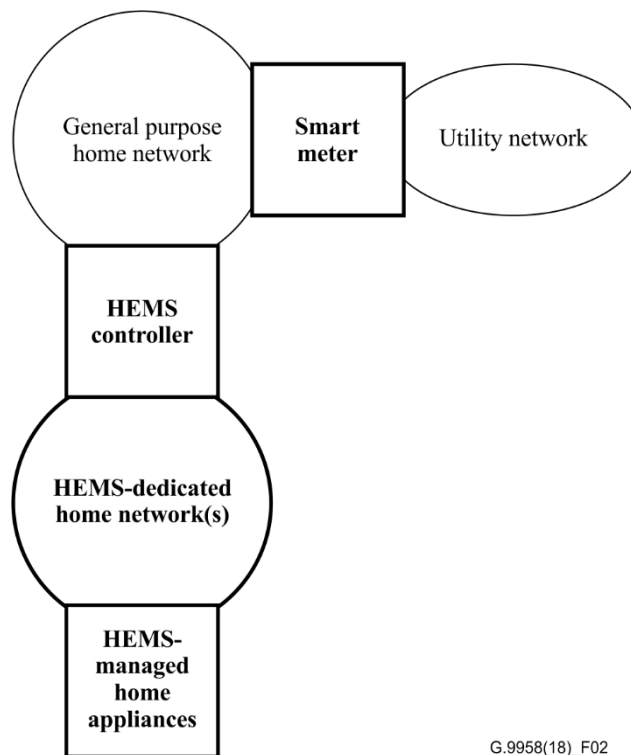


Figure 2 – General purpose home network oriented configuration

(1) Physical configuration

A smart meter shall be connected to a utility network as in clause 6.2. Furthermore, a smart meter and a HEMS controller shall be connected to a general purpose home network. A HEMS controller and HEMS-managed home appliances shall be connected to a HEMS-dedicated home network. A HEMS-dedicated home network may comprise of one or more networks depending on the type of HEMS-managed home appliance.

(2) Communication path

A smart meter shall communicate with a utility network as described in clause 6.2. In the home, a smart meter and a HEMS controller shall communicate directly with each other over the general purpose home network. The HEMS controller and HEMS-managed home appliances shall communicate directly with each other over a HEMS-dedicated home network. A smart meter shall not directly communicate with a HEMS-managed home appliance, thus allowing the independent operation of the general purpose home network and the HEMS-dedicated home network.

A HEMS controller can aggregate information from HEMS-managed home appliances and transfer aggregated information to a smart meter. Therefore, services over a general purpose home network and services over HEMS-dedicated home networks must be isolated. Moreover, on a general purpose home network, the communication path between a smart meter and a HEMS controller shall be secured and isolated logically from other communication paths by appropriate security technologies which are out of the scope of this Recommendation.

6.3.2 Dedicated home network oriented configuration

In this configuration, all of the components for a home energy management service in the home are connected to a HEMS, a dedicated home network as shown in Figure 3. To facilitate other services, a general purpose home network may be present, but it is not involved in the operation of HEMS services.

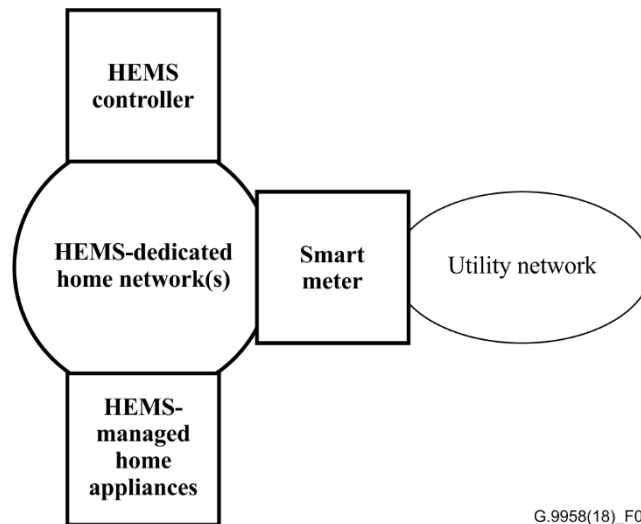


Figure 3 – Dedicated home network oriented configuration

(1) Physical configuration

A smart meter shall be connected to a utility network as described in clause 6.2. In the home, a smart meter, a HEMS controller and HEMS-managed home appliances shall be connected to a HEMS-dedicated home network. A HEMS-dedicated home network may comprise of one or more networks depending on the type of HEMS-managed home appliance.

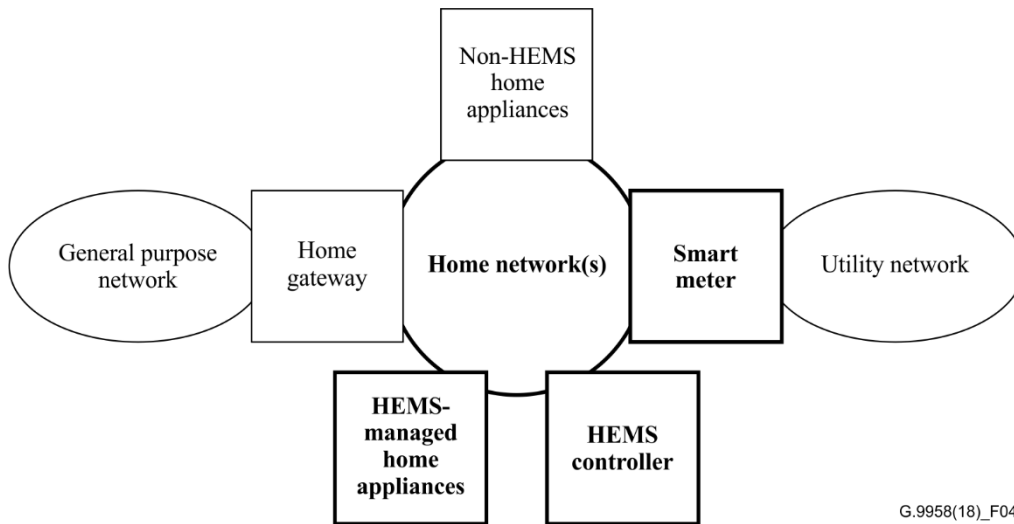
(2) Communication paths

A smart meter shall communicate with the utility network as described in clause 6.2. In the home, a smart meter and a HEMS controller shall communicate directly with each other over the HEMS-dedicated home network. A HEMS controller and HEMS-managed home appliances shall communicate directly with each other over the HEMS-dedicated home network. However, it is not necessary that a smart meter and HEMS-managed home appliances communicate directly with each other. A communication flow between a smart meter and a HEMS controller shall be secured and isolated logically from other communication flows, even if this flow and other flows are overlaid on the same HEMS-dedicated home network.

A HEMS controller can aggregate information from HEMS-managed home appliances and transfer aggregated information to a smart meter. Therefore, services over a general purpose home network and services over HEMS-dedicated home networks must be isolated.

6.4 Monitor and control of power consumption using a general purpose network

In this configuration, other services are provided in addition to the intelligent home energy management service provided by electric power companies. Figure 4 shows an example of this configuration. When other service providers deploy these services, the home gateway shall be installed at the edge of a home network and is connected to a general purpose network, such as fibre to the home (FTTH). Several variations of this configuration are explained in the following parts. In each part, a smart meter and a utility network shall be protected from threats by using some secure protocols which are out of the scope of this Recommendation.

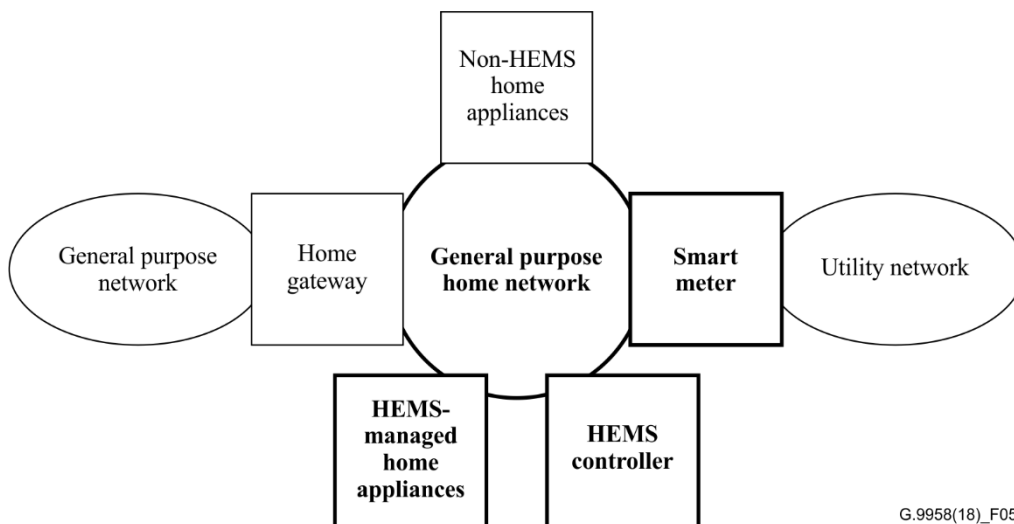


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Figure 4 – A generic home network configuration using a general purpose network

6.4.1 Integration by general purpose home network

All components with communication interfaces in the home are connected to the general purpose home network, as shown in Figure 5.



G.9958(18)_F05

Figure 5 – An integrated general purpose home network configuration

(1) Physical configuration

All components with communication interfaces in the home shall be connected to the general purpose home network. A smart meter and a home gateway must also be connected to a utility network and a general purpose network, respectively.

(2) Communication paths

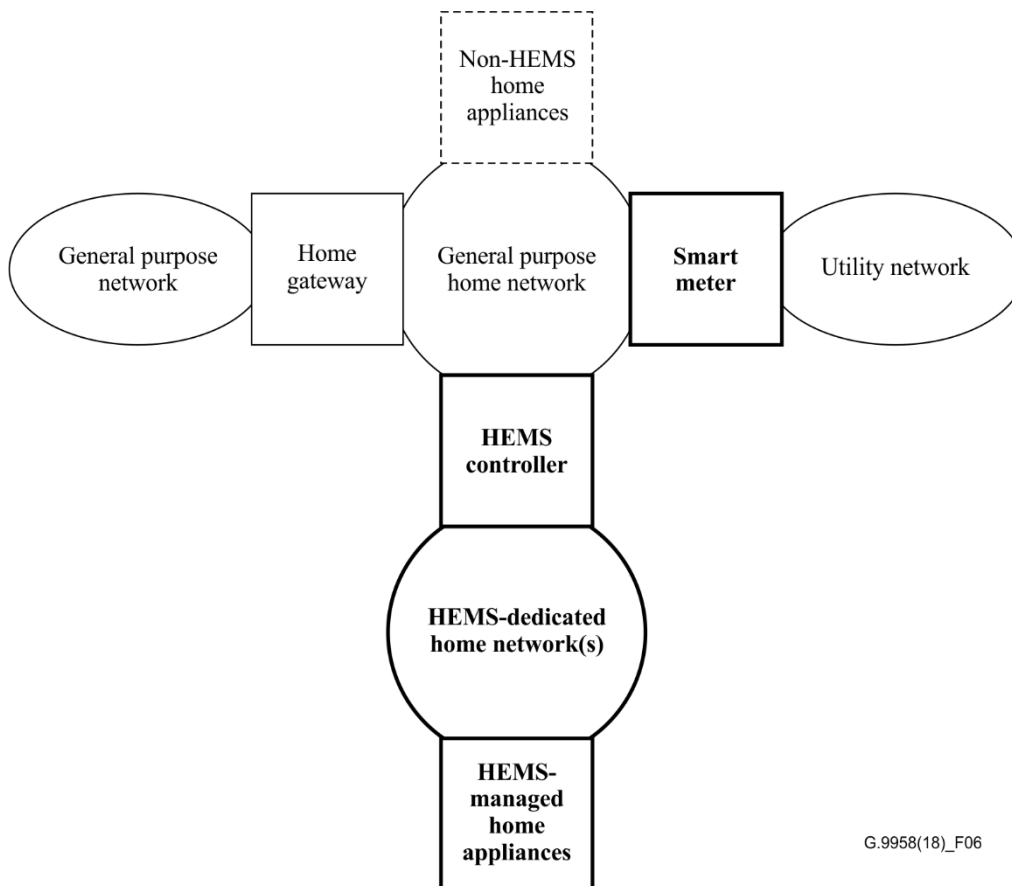
All components with communication interfaces in the home can communicate directly with each other. However, some communication paths can be limited depending on the services they relate to. In a general purpose home network, IP-based protocols are applied as a common communication method. Although a home gateway is connected to the general purpose network, protocols and operations in the general purpose home network and the general purpose network shall be independent. The home gateway shall perform routing between the general purpose network and the general purpose home network, thus allowing components to connect to the Internet as necessary. A communication flow between a smart meter and a HEMS controller shall be secured and isolated

logically from other communication flows, even if this flow and other flows are overlaid on the same HEMS-dedicated home network.

Various home energy management services can be provided via the home gateway by some service operators. However, home energy management services provided by electric power companies shall be provided through the use of a smart meter and must not be provided through the home gateway.

6.4.2 Dedicated home networks to accommodate HEMS-managed home appliances

In this configuration, HEMS-managed home appliances are connected to a HEMS-dedicated home network and are isolated from the general purpose home network as shown in Figure 6.



G.9958(18)_F06

Figure 6 – Configuration using a HEMS-dedicated home network

(1) Physical configuration

HEMS-managed home appliances are not connected to a general purpose home network. The HEMS controller shall connect to HEMS-managed appliances by one or more HEMS-dedicated home network(s). A home gateway shall be connected to the general purpose network.

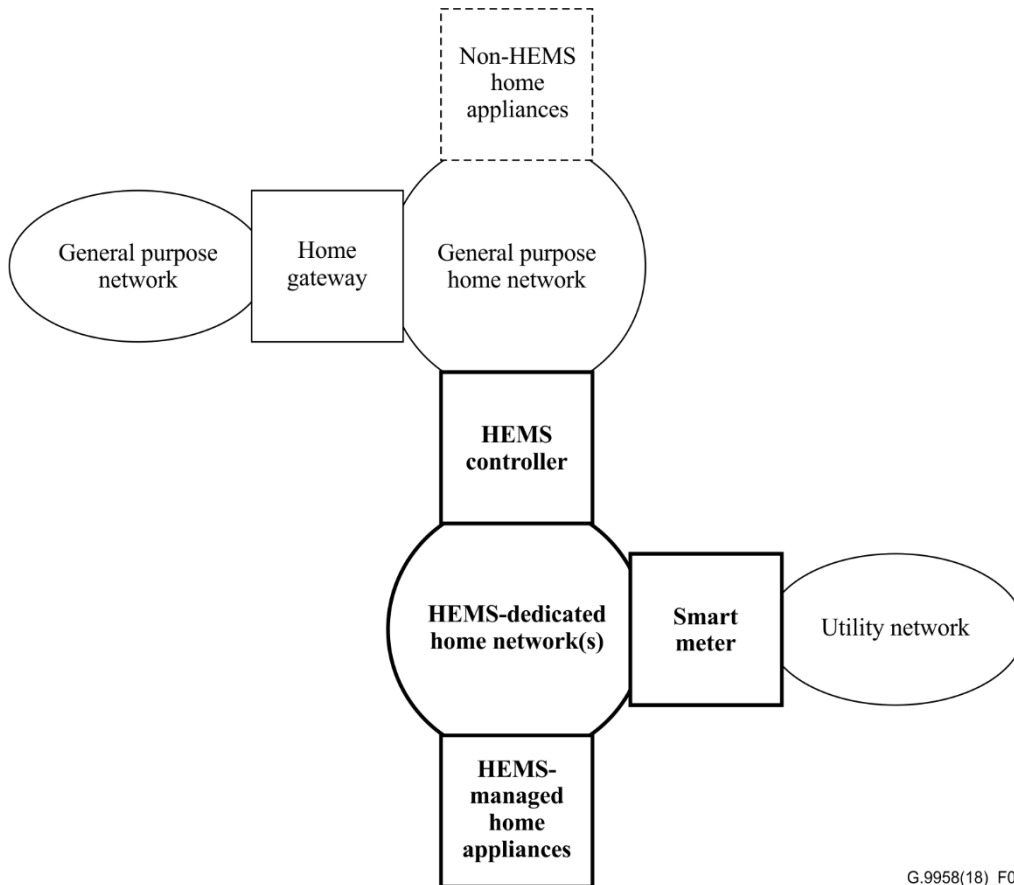
(2) Communication paths

In this configuration, the general purpose home network and the HEMS-dedicated home network(s) are heterogeneous. HEMS-managed home appliances shall communicate directly with the HEMS controller. The HEMS controller in turn communicates with a smart meter and the Home gateway. HEMS-managed home appliances shall not communicate with a smart meter and a Home gateway directly. If multiple HEMS-dedicated home networks are deployed, each network is operated independently. A communication flow between a smart meter and a HEMS controller shall be secured and isolated logically from other communication flows, even if this flow and other flows are overlaid on the same HEMS-dedicated home network.

Various home energy management services can be provided by communication via the home gateway. However, home energy management services provided by electric power companies shall be provided through the use of a smart meter and must not be provided through the home gateway.

6.4.3 Exclusive dedicated home networks configuration

This configuration exclusively utilizes HEMS-dedicated home networks for home energy management purposes. A smart meter is connected to a HEMS-dedicated home network but not connected to the general purpose home network, as shown in Figure 7. An example of real deployment using this configuration is described in Appendix I.



G.9958(18)_F07

Figure 7 – Exclusive dedicated home network configuration

(1) Physical configuration

A smart meter shall be connected to the HEMS-dedicated home network. If multiple HEMS-dedicated home networks are deployed, a smart meter shall be connected to one HEMS-dedicated home network. The physical configurations for the rest of the components are the same as the configurations described in clause 6.4.2.

(2) Communication paths

In this configuration, the general purpose home network and the HEMS-dedicated home network(s) are heterogeneous. HEMS-managed home appliances shall communicate directly with the HEMS controller. Then, the HEMS controller communicates with a smart meter and a home gateway. HEMS-managed home appliances shall not communicate with a smart meter and a home gateway directly. If multiple HEMS-dedicated home networks are deployed, each network is operated independently. A smart meter shall be connected to a single HEMS-dedicated home network and shall only communicate with a HEMS controller. A communication flow between a smart meter and a HEMS controller shall be secured and isolated logically from other communication flows, even if this flow and other flows are overlaid on the same HEMS-dedicated home network.

Various home energy management services can be provided by communication via the home gateway. However, home energy management services provided by electric power companies shall be provided through the use of a smart meter and must not be provided through the home gateway.

Appendix I

A use case of real deployment in Japan

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

I.1 Definitions of service routes

An example of a real deployment case is shown in Figure I.1. This case is aligned to the logical configuration described in clause 6.4.3.

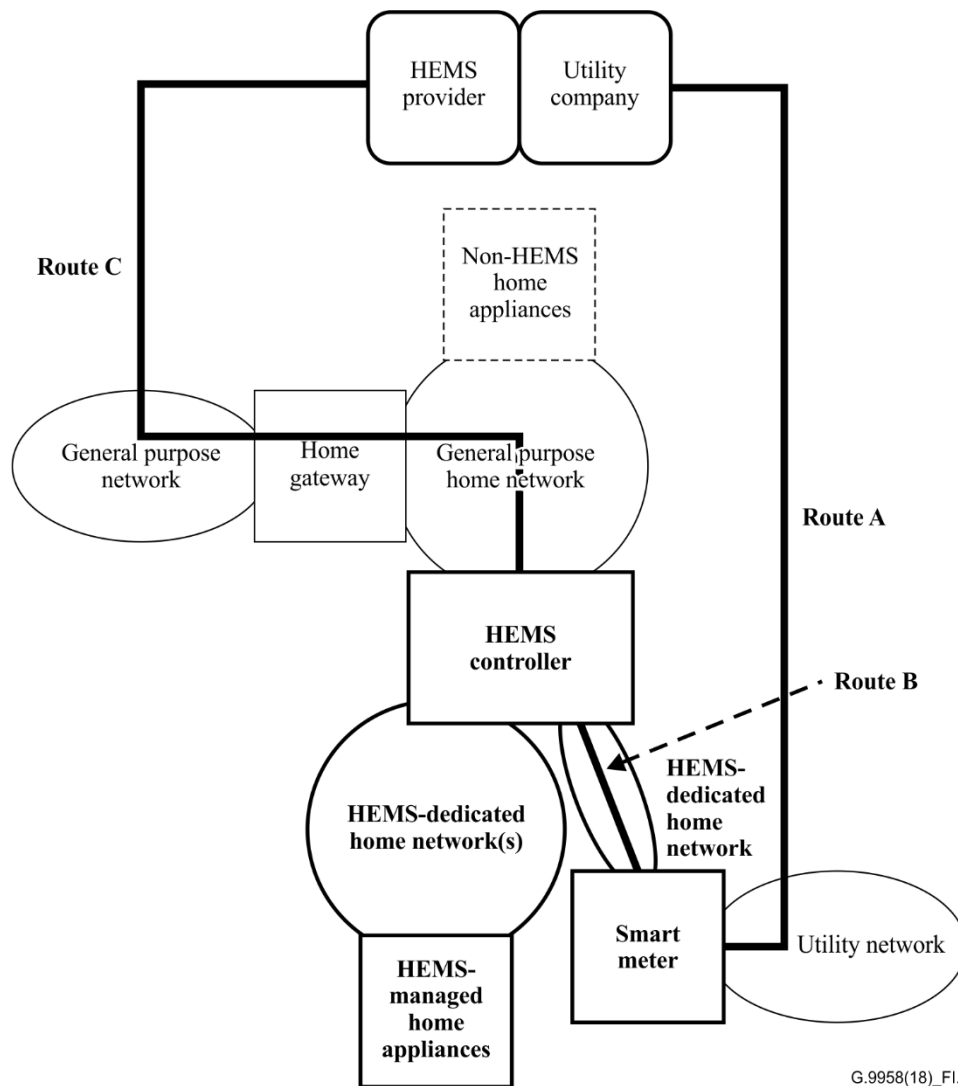


Figure I.1 – Network configuration in Japan

In this example, three service routes are specified, referred to as "Route A", "Route B" and "Route C". Detailed operations and features are described in [b-Report] (in Japanese).

Japan

The data from smart meters can be communicated to the energy utility through two mechanisms. These mechanisms are referred to as 'Route A' and 'Route B'. Another mechanism is referred to as 'Route C'.

(1) Route A

Smart meter data is transferred to the head end system (HES) and then to the meter data management system (MDMS), both of which are owned and operated by the utility. The utility can share this data with the HEMS provider with the customer's consent. This is typically referred to as 'Route A'.

(2) Route B

The second architecture entails the transfer of smart meter data to a home energy management system (HEMS) which then transmits it to a third party over the Internet. This third party then shares the consumer data with the utility according to predefined agreements. The communication between the meter and the HEMS controller is referred to as 'Route B'.

(3) Route C

The route between the utility or HEMS in the home and the HEMS provider is referred to as 'Route C'. Route C provides intercommunication between a HEMS controller and HEMS provider through a home gateway and general purpose network.

In the home, these routes are isolated logically and/or physically from other generic communication. Currently, in this deployment case, encryption is not used in routes A and B due to the low processing capabilities of the smart meter. In the future, encryption for routes A and B shall be considered.

I.2 Feature requirements of Route B

Route B is a fundamental route for providing various home energy management services. Therefore, this route has the following specific feature requirements. Detailed operations are specified in [b-JSCA HEMS Task force].

(1) Support IPv6 on communication between HEMS controller and smart meter

In the future, it is expected that IP technologies will converge to IPv6. Therefore, to mitigate IP processing power by dual stack implementation in the smart meter and HEMS controller, it is recommended that smart meters implement only IPv6 support. Because Route B requires local communication only between a smart meter and a HEMS controller through a HEMS-dedicated home network, IPv6 link local addresses are utilized.

(2) Isolation of communication on Route B

For security reasons, in this deployment case, HEMS-dedicated home networks are isolated physically in each domain because the requirements of communications, especially security requirements, are different for every domain. For this reason, communication on Route B should be isolated physically from other communications. Communication on this route shall not be routed to other routes or unrelated networks.

(3) Point-to-point connection between smart meter and HEMS controller

As described in (2), although IPv6-based communication is applied on Route B, a smart meter and a HEMS controller are connected directly. This connection is isolated physically as described in (2). A HEMS controller shall only communicate with the smart meter over Route B and shall not route any other type of traffic over Route B. Multiple HEMS controllers shall not be connected to a single smart meter.

Other communication between a HEMS controller and HEMS-managed appliances and communications on Route B is achieved with ECHONET Lite based protocol stacks ([b-TTC TR-1043] and [b-TTC JJ-300.10]), described in clause I.3.

I.3 Example of communication protocols

A general purpose home network supports IP and provides seamless connections with the general purpose network via a home network according to [ITU-T 9970] and [ITU-T 9971].

In this deployment case, the HEMS-managed appliances communicate with the HEMS controller only via HEMS-dedicated home networks. The smart meter and HEMS controller communicate via a different, separate HEMS-dedicated home network. The smart meter is directly connected exclusively to the HEMS controller. The HEMS controller and the smart meter on Route B support the protocol stack shown in Figure I.2. The application layer protocol currently in use is ECHONET Lite. In ECHONET Lite, various data models have been specified. Some of them will be supported on Route B; see [b-TTC TR-1043] [b-TTC JJ-300.10].

5-7	ECHONET Lite							ECHONET Lite over Layer 2 frame
4	UDP / TCP							
3	IPv4 IPv6		IPv6 6LoWPAN	IPv4 IPv6		IPv6 6LoWPAN		
2	IEEE802.3 family	ITU-T G.9961 ITU-T G.9972	IEEE1901	ITU-T G.9903	IEEE802.11 family	IEEE802.15.1 family PAN profile	IEEE802.15.4 IEEE802.15.4e	
1	IEEE802.3 family	ITU-T G.9960 ITU-T G.9963 ITU-T G.9964 ITU-T G.9972	IEEE1901	ITU-T G.9903	IEEE802.11 family	IEEE802.15.1 family	IEEE802.15.4 IEEE802.15.4g	
Phy. Media	UTP/ optical fibre	Power line			Radio wave (2.4/5G)	Radio wave (2.4G)	Radio wave (2.4G/920M)*	
	Ethernet	ITU-T G.hn	IEEE1901 JJ-300.20 JJ-300.21 HD-PLC	ITU-TG.hnem JJ-300.11 G3-PLC	Wi-Fi	Bluetooth	IEEE802.15.4/4e/4g JJ.300-10 Wi-SUN ZigBee IP, 9201P	

*Only ZigBee IP supports 2.4G G.9958(18)_Fl.2

Figure I.2 – Protocol stack between a HEMS controller and a smart meter (Route B)

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