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SERIES H: AUDIOVISUAL AND MULTIMEDIA SYSTEMS

Broadband, triple-play and advanced multimedia services – Advanced multimedia services and applications

Service capabilities and framework for virtual home networks

Recommendation ITU-T H.622.2

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Recommendation ITU-T H.622.2

Service capabilities and framework for virtual home networks

Summary

Recommendation ITU-T H.622.2 specifies service requirements and framework architecture for virtual home networks (VHNs) to support home network services in ubiquitous networking environments (e.g., fixed and wireless connectivity) allowing extended home network services beyond the service features inside the physical home.

This Recommendation includes multiple use cases of the VHN framework and related service capabilities.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T H.622.2	2015-11-29	16	11.1002/1000/12646

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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1 Scope

This Recommendation identifies service requirements and framework architecture to support virtual home network (VHN) services in fixed and wireless network domains as well as at different network levels including intra-access network, inter-access network and inter-network levels [ITU-T Q.1706]. This includes service requirements, service framework, management functions and service models for VHN.

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 H.622] Recommendation ITU-T H.622 (2008), *A generic home network architecture with support for multimedia services*.

[ITU-T Q.1706] Recommendation ITU-T Q.1706/Y.2801 (2006), *Mobility management requirements for NGN*.

[ITU-T X.1111] Recommendation ITU-T X.1111 (2007), *Framework of security technologies for home network*.

[ITU-T X.1162] Recommendation ITU-T X.1162 (2008), *Security architecture and operations for peer-to-peer networks*.

[ITU-T Y.2291] Recommendation ITU-T Y.2291 (2011), *Architecture overview of next generation home networks*.

[ITU-T Y.2701] Recommendation ITU-T Y.2701 (2007), *Security requirements for NGN release 1*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 access network [b-ITU-T Q.1742.1]: Network that connects access technologies (such as a Radio Access Network) to the core network.

3.1.2 federation [b-ITU-T Y.2720]: Establishing a relationship between two or more entities or an association comprising any number of service providers and identity providers.

3.1.3 home network [ITU-T H.622]: A home network is the collection of elements that process, manage, transport and store information, thus enabling the connection and integration of multiple computing, control, monitoring, communication and entertainment devices in the home.

3.1.4 mobility [ITU-T Q.1706]: The ability for the user or other mobile entities to communicate and access services irrespective of changes of the location or technical environment.

3.1.5 mobility management [ITU-T Q.1706]: The set of functions used to provide mobility. These functions include authentication, authorization, location updating, paging, download of user information and more.

3.1.6 personal mobility [b-ITU-T Y.2201]: This is the mobility for those scenarios where the user changes the terminal used for network access at different locations. The ability of a user to access telecommunication services at any terminal on the basis of a personal identifier, and the capability of the network to provide those services delineated in the user's service profile.

3.1.7 quality of service (QoS) [b-ITU-T G.1000]: The collective effect of service performances, which determine the degree of satisfaction of a user of the service.

3.1.8 service continuity [b-ITU-T Y.2201]: The ability for a moving object to maintain ongoing service over including current states, such as user's network environment and session for a service.

3.1.9 terminal mobility [b-ITU-T Y.2201]: This is the mobility for those scenarios where the same terminal equipment is moving or is used at different locations. The ability of a terminal to access telecommunication services from different locations and while in motion, and the capability of the network to identify and locate that terminal.

3.2 Terms defined in this Recommendation

This Recommendation defines the following term:

3.2.1 virtual home network (VHN): A VHN is a logical home network, built over public and/or private network resources, used to support home network services within a group of home members.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

6LowPAN	IPv6 over Low power Wireless Personal Area Network
ACL	Agent Communication Language
ANI	Application Network Interface
API	Application Programming Interface
ASF	Application Support Function
DAML	DARPA Agent Markup Language
DB	Database
DNG	Delivery Network Gateway
HAVi	Home Audio Visual
IoT	Internet of Things
IP	Internet Protocol
M2M	Machine to Machine
NFC	Near Field Communication
NGN	Next Generation Network
OIL	Ontology Interchange Language
OWL	Web Ontology Language
P2P	Peer-to-Peer

QoS	Quality of Service
RDF	Resource Description Framework
RG	Residential Gateway
SOAP	Simple Object Access Protocol
SON	Service Overlay Network
UNI	User Network Interface
UPnP	Universal Plug and Play
VHN	Virtual Home Network
VHN-RG	Virtual Home Network-Residential Gateway
VHN-SCF	Virtual Home Network-Service Control Function
VHN-TF	Virtual Home Network-Transport Function
VO	Virtual Object
WoT	Web of Things

5 Conventions

The keywords "is required to" indicate a requirement which must be strictly followed and from which no deviation is permitted if conformance to this document is to be claimed.

The keywords "is recommended" indicate a requirement which is recommended but which is not absolutely required. Thus this requirement needs not be present to claim conformance.

The keywords "can optionally" and "may" indicate an optional requirement which is permissible, without implying any sense of being recommended. These terms are 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 Introduction

Ubiquitous networking environments (e.g., fixed and wireless connectivity) enable the service capabilities in a physical home network to be extended anytime, anywhere and to any device. Ubiquitous networking environments allow the service coverage of a home network to expand diverse service features into a virtual group of home network users and resources and to build a virtual home network (VHN).

In accordance with ubiquitous networking, VHN services provide physical home and home-like service features. VHN in this Recommendation is characterized as supporting the following features:

– interface protocols for easy management and control of home appliances and equipment inside/outside the physical home;

– ubiquitous networking in order for outside users to control home network devices;

– cloud computing environment to effortlessly access, view and control the devices on a virtual home network from anywhere, anytime, making it simple to stay connected to everything;

– intelligent service features in accordance with customer-centred, knowledge-driven and collaborating capability.

Figure 6-1 indicates the introduction of VHN in terms of a ubiquitous networking environment.

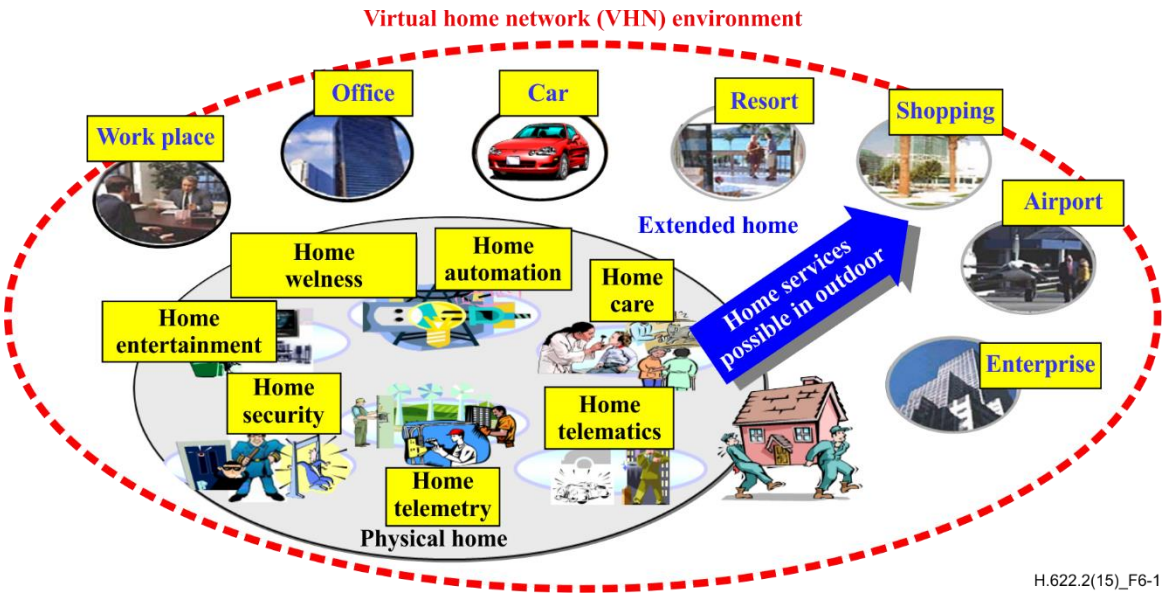

Figure 6-1 – Introduction of VHN environment

Two types of VHN services are provided as shown in Figure 6-1 with:

– site-to-site VHNs that link other home networks, home members and communities of interest;

– access VHNs that accommodate mobile home members and telecommuters allowing them to securely access their home network from outside the home.

This Recommendation builds upon the framework for the VHN services environment with support for multimedia services in [ITU-T H.622] as shown in Figure 6-2.

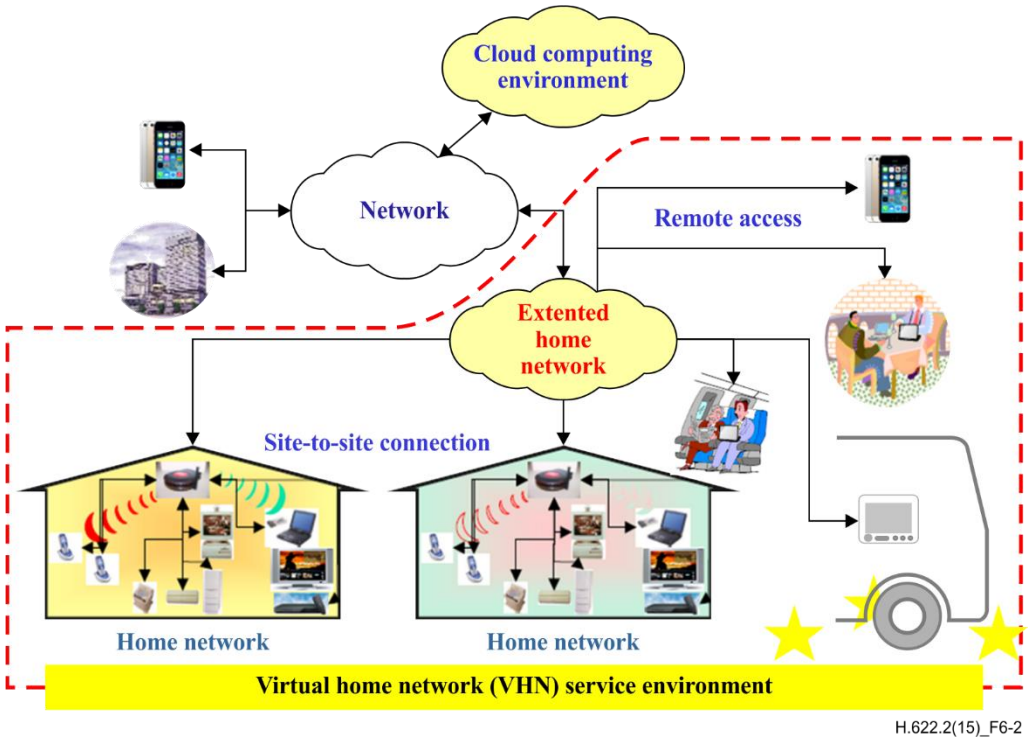

Figure 6.2 – Provision environments of virtual home network services

7 VHN service requirements

This clause addresses the requirements for VHN services when provided site-to-site and access types including a mobile environment.

7.1 General requirements

For the support of VHN services, a VHN in accordance with [ITU-T H.622], as for example in a delivery network gateway (DNG) at a home network, is required to provide:

– interfaces for fixed and mobile access;
– means for a home network user to specify VHN membership;
– accommodation of user-defined VHN addressing schemes (e.g., IP or non-IP addressing);
– transparency to VHN user data;
– means for a single customer site to belong concurrently to more than one VHN;
– multi-protocol support for home network services;
– standards-based interfaces (independent of user's device supplier);
– means to meet user's security requirements (e.g., in terms of different security levels);
– secure dynamic access to a VHN;
– the interface function to promote Internet of things (IoT) services in a VHN.

7.2 Service configuration management

The service configuration function at the DNG of a home network is required to provide:

– configuration capability for VHN service members at service level (e.g., dynamic creation and modification of VHN members in accordance with specific application requirements and/or user requirements);
– consistency and coherence verification of the configuration information for VHN users;
– ability to easily change topology;
– ability to easily add, remove or modify VHN service related devices, sites, etc.;
– ability to accommodate growth requirements for VHN service related devices, sites, etc.

7.3 Security

A VHN service is required to support mechanisms for:

– controlling (fixed or mobile) user access to the VHN service via access control mechanisms (identification, authentication and authorization of (fixed or mobile) users accessing the VHN);
– ensuring the privacy of data being transported by the VHN.

7.4 Fault management

VHN service management is recommended to provide:

– information to the VHN customers in the event of service disruption and restoration;
– dynamic VHN service recovery, non-disruptive and not perceived by the VHN users;
– provision of relevant VHN service incident reports and summaries.

7.5 Mobility

A VHN is recommended to support:

– nomadism for personal (i.e., VHN user) and terminal (i.e., VHN user terminal) mobility [ITU-T Q.1706];
– service continuity for terminal mobility [ITU-T Q.1706].

7.6 Multicast

A VHN is recommended to support:

– multicast capability within a VHN service group, e.g., provision of specific applications such as linear TV within a VHN service community;
– creation, operation and release of multicast members/groups within a VHN service group;
– a mechanism to manage multicast connections within a VHN (i.e., management of multicast trees within a VHN);
– a mechanism to allow VHN service members to join and leave multicast groups within a VHN.

7.7 Intelligent service features

A VHN is recommended to support:

– context awareness functions in accordance with the VHN environment;
– a service composition function to promote VHN application and user adaptability;
– automatic representation to be used by VHN applications;
– knowledge enabled learning and processing in VHN applications and users;
– ability to adaptively perform service discovery rather than requiring an external trigger to the current context;
– object virtualization functions for the VHN service control function (VHN-SCF).

8 Framework architecture for VHN

This clause identifies the framework architecture for new functions and extensions/modifications to support VHN services in a home network.

Figure 8-1 shows the VHN service control function and transport function based on the home functional architecture [ITU-T H.622] to support VHN service requirements.

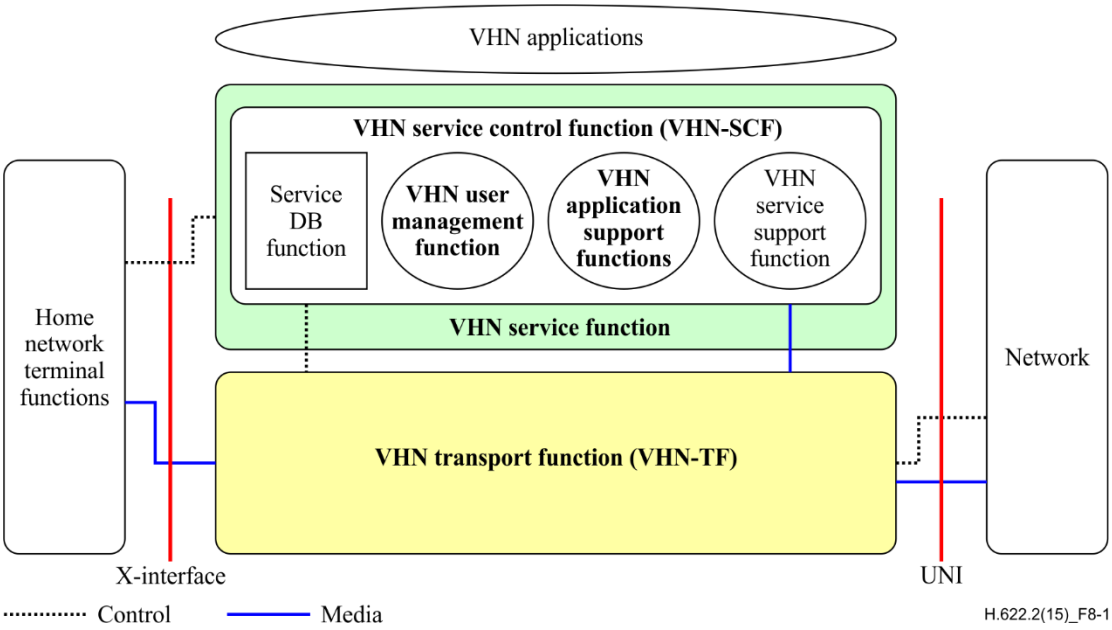

Figure 8-1 – Framework architecture for VHN services based on [ITU-T H.622]

8.1 VHN service control function

The VHN-SCF (including VHN membership management and VHN multicast service control functions) support service control functions for VHN applications including interaction with service user profiles. VHN service control functions provide the capabilities to perform:

– VHN service registration and membership management;

– VHN multicast service control within a VHN;

– VHN service support functions.

8.1.1 VHN user management function

The VHN user management functions provide support for:

– creation, maintenance and release of VHN service users;

– joining and leaving VHN service users;

– partitioning of a VHN service group into multiple VHN service groups (including VHN service multicast groups).

The VHN user management functions interact with the management function of multicast service group membership for VHN multicast group membership management.

8.1.2 VHN application support function

The VHN application support function allows enhanced utilization of home network device capabilities and service characteristics and provides users with a consistent virtual home environment which spans multiple home environments and multiple devices (PC, laptop, PDA, cell phone, etc.). VHN application support includes the following interactions:

– (application) server-to-server;

– server-to-terminal;

– terminal-to-server;

– terminal-to-terminal (or peer-to-peer);

– terminal-to-devices.

It is required to provide VHN application support satisfying the following:

– secure access to applications;
– consistent user experience across VHN transports;
– support of service composition techniques;
– scalability of VHN applications.

8.1.3 VHN service support function

The VHN service support function enables application developers and providers to develop VHN applications. It includes functions such as registration, authentication and authorization functions at application level within the VHN. These functions are available to the VHN applications and terminal functional groups. This works in conjunction with the VHN-SCF to provide end-users and applications with the services within the VHN.

8.1.4 Service DB function

A service profile is a set of stored information, which is related to a VHN service. In a VHN environment, the management of the service profile attributes is especially important since the service information is required to implement a number of capabilities, including authentication, authorization, VHN features, etc. Service profiles include service-related information and can be stored in separate databases (DBs) in the service stratum. These DBs can optionally have data exchange functions between them.

A device profile is a set of stored information related to a user equipment. In a VHN environment, the management of the device profile attributes is also important since the device information is required in conjunction with a "user profile" by a number of capabilities, including authentication, authorization, mobility and location, etc.

Device profiles may be used for the following purposes:

– to track stolen or misappropriated devices;
– to determine the type and level of service that may be provided to the user (based on device capabilities);
– to determine the required quality of service (QoS) for a connection between terminals (based on device capabilities).

8.2 VHN transport function

The VHN transport functions (VHN-TFs) provide home network resource and transport control functions and home network connection functions as indicated in [ITU-T H.622].

In VHN transport there are basically two methods to connect things to the network, namely wired networking and the wireless networking. For static elements VHN transport does not need to take mobility into account so the connection could be by wired access lines as with a home Internet connection. This wired connection uses an Internet protocol (IPv4 or IPv6) to communicate with other devices around the world. The other possibility to connect things to the network is wireless networking. Figure 8-2 shows various types of network topologies to connect objects.

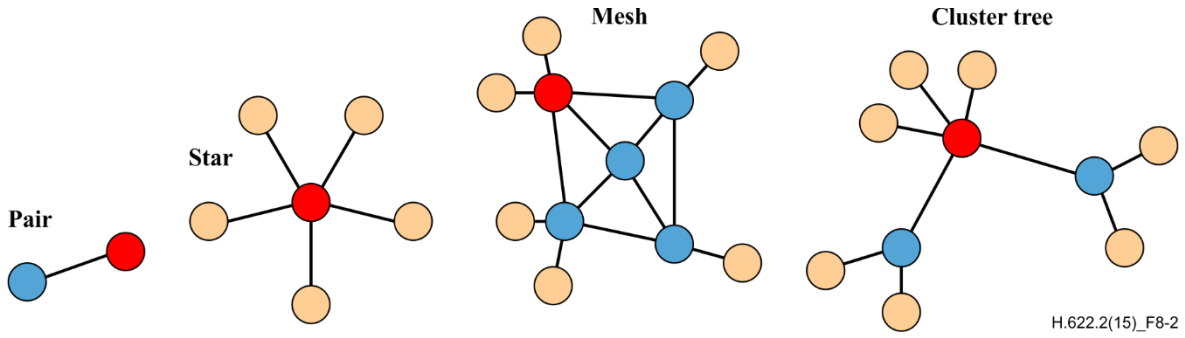

Figure 8-2 – Various types of networking topologies in VHN transport

VHN transport will create a connection through wired or wireless networking capabilities to create a wireless sensor network, which enables mobile data to be transferred safely and with low energy consumption. Depending on the type of device, a VHN transport environment will apply different kinds of networking:

– Internet protocol (IPv4 or IPv6); IPv6 over low power wireless personal area network (6LowPAN);
– Bluetooth;
– Near field communication (NFC);
– Wi-Fi;
– ZigBee;
– Z-Wave.

8.3 VHN service provisioning architecture

VHN service resources and components, which are indicated in clause 7, clause 8.1 and Figure 8-3, support dynamic service creation, maintenance and deactivation of resource objects. Their service features will be used to support a provisioning architecture that supports the dynamicity of service orchestration in VHN cloud environments.

In a VHN, applications collaborating with a home cloud computing environment, will be orchestrated to enrich the conventional home network service provisioning with novel capabilities. The VHN service provisioning architecture depicted in Figure 8-3 will support intelligent virtual home services to provide an adaptive reaction in terms of user, network and service environments.

A more detailed modular structure of each subsystem will be designed to present versatile adaptation capabilities of VHN services based on the service provision architecture shown in Figure 8-3.

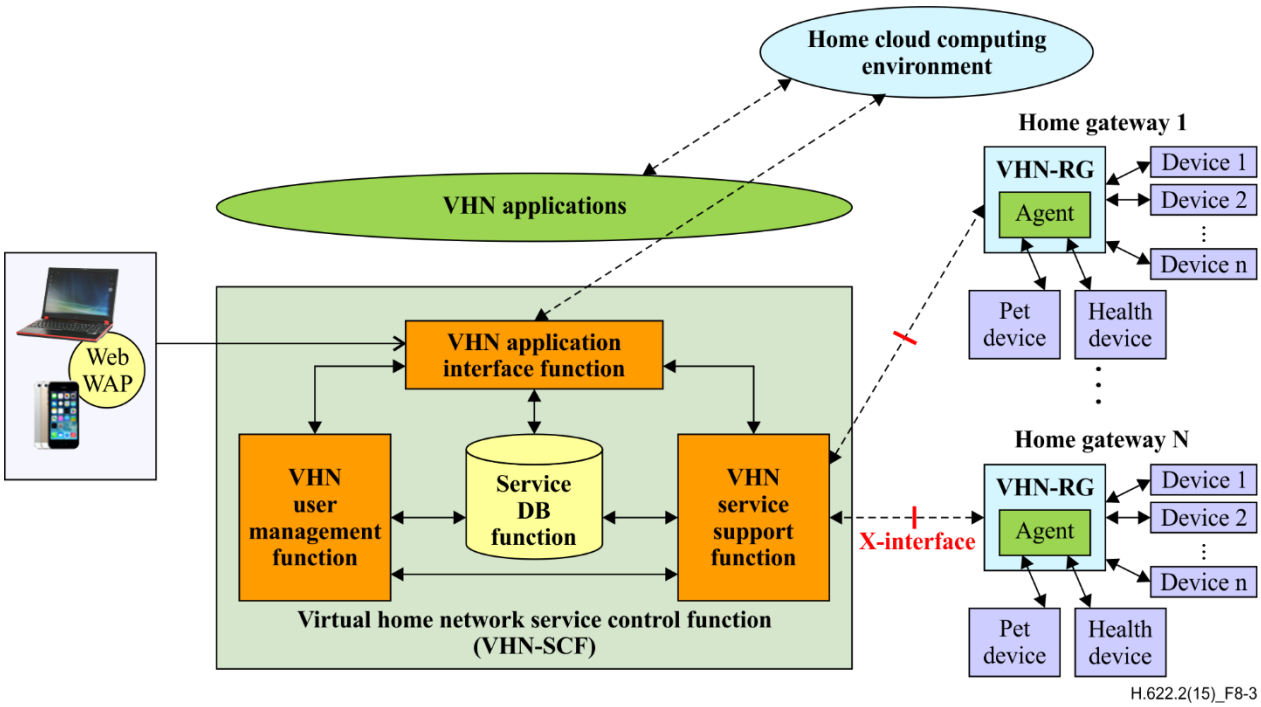

Figure 8-3 – Illustration of VHN service provisioning model

8.4 Application-level home gateway function in VHN service provisioning

A VHN supports a functional architecture to create and interwork with other virtual service groups through application-level home gateways. A VHN service group is created through its required interworking function of an application-level home gateway and each user will be able to join multiple VHN service groups in accordance with their favourite application features. Application-level home gateway functions provide route data and convert into different protocols according to the user environment using some interworking protocols. The application-level home gateway function supports the service capabilities and features of the VHN.

Figure 8-4 shows VHN architecture supporting application-level home gateway functions. An example of an application-level home gateway function is described in Appendix II.

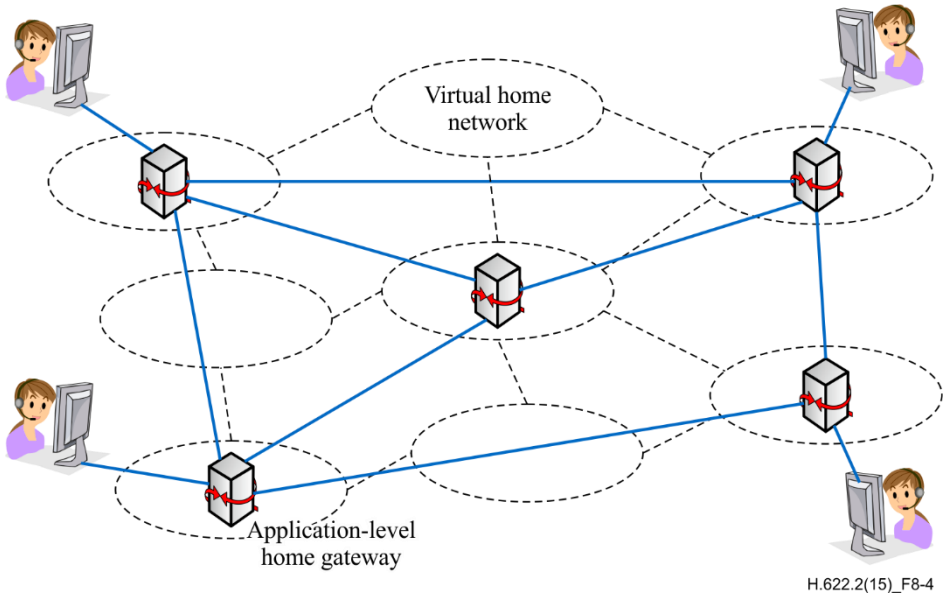

Figure 8-4 – VHN architecture which supports application-level home gateway functions

8.5 Federation capability

A VHN provides a federation capability among all home environments to support virtual extended home network services and also supports a federation capability among distributed service resources in several physically separated domains. The federation capability in VHN services is provided in conjunction with user and service nomadism, for example to support the interactive set-up of "extended home networks" that go beyond the borders of the physical house. Therefore, VHN services enable the user to have an application experience similar to the experience of accessing services from the primary home.

The federation capability in VHN service supports:

– self-managing environments as well networked intelligent objects to allow novel applications beyond home automation (e.g., health care, smart social service);

– an integrated environment which will federate many challenges, at network, service and application level in order to ensure service nomadism;

– benefits from user interactivity and creativity (e.g., tools for intuitive creation, distribution, consumption, storage and retrieval, personalisation and context awareness);

– service capability that will emerge from the availability of the Internet of things;

– a change in patterns between the home network and public networks (e.g., flexible modification of a service features in terms of user's demand).

8.6 Security for VHN

VHN is necessary to support service capabilities such as remote services, multiple device control services, health care services, education services and entertainment services, these services comprise a significant need for security. A VHN supports the security requirements in accordance with [ITU-T X.1111].

The security requirements for VHN are:

– authentication of the communication entities for policy requests in a VHN;

– availability and accessibility in a VHN service domain, upon demand by an authorized entity;

– availability of non-repudiation mechanisms to prevent one of the entities or parties in a communication from denying participation in the whole or part of the communication falsely.

The security considerations in the VHN services should be in accordance with the security requirements in [ITU-T X.1111] and [ITU-T Y.2701].

8.7 Intelligent service capabilities in VHN

In the provision of VHN intelligence, knowledge is created to represent the information related to understanding and awareness acquired through learning, investigation, observation or experience over some duration of time. VHN knowledge is also created through the individual's interpretation based on personal situation, skill and capabilities.

VHN-SCF supports the capability to create knowledge through composition, orchestration, collaboration and harmonization among objects, which are the virtual entities of the captured data, procedure, policy and existing information in VHN environments. In VHN-SCF, five functional entities, as indicated in the Figure 8-5, cooperate to support intelligent features in VHN.

In order to capture context-awareness information from a VHN environment, the VHN service support function provides the functions such as context reasoning, context sensing and context modelling.

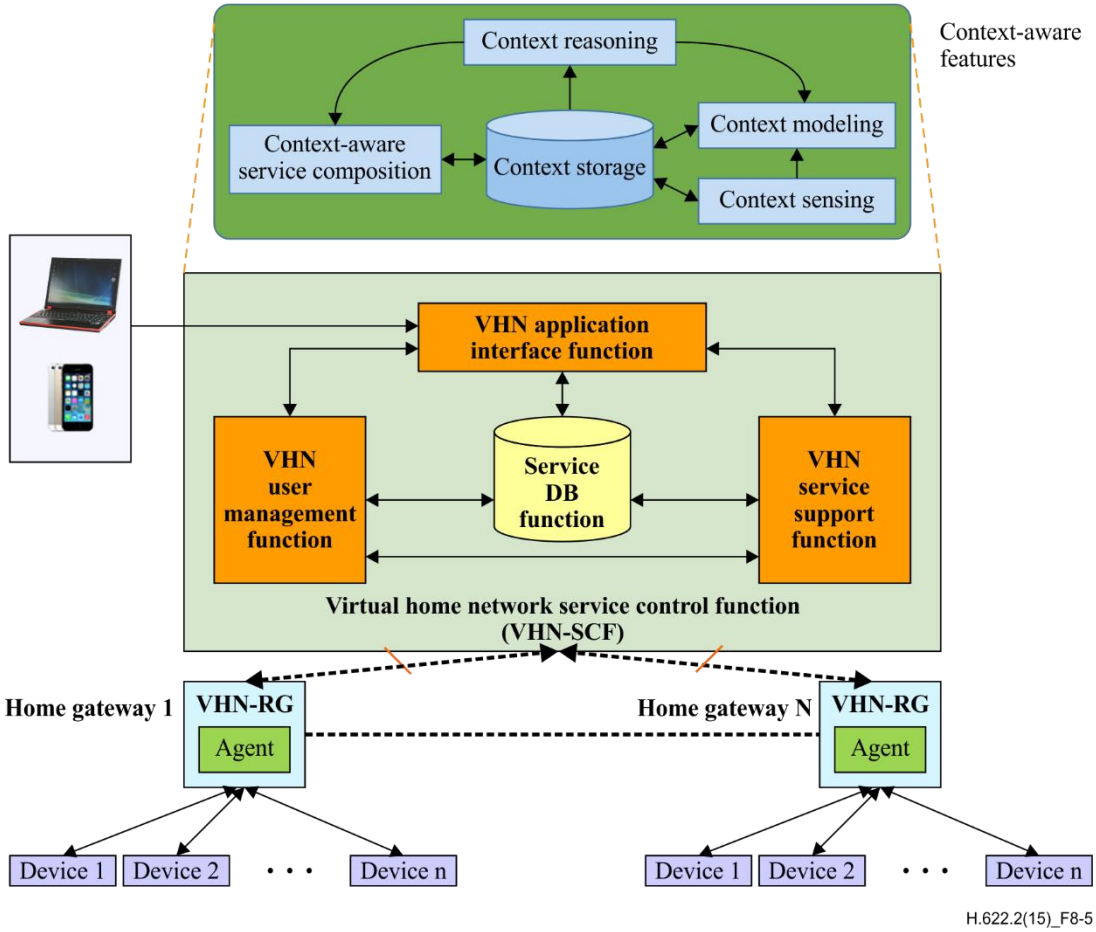

Figure 8-5 – A general overview architecture for context-awareness feature in VHN

Figure 8-5 shows that VHN-SCF captures context information from VHN environments and adjusts this information to the expected environment. The context information is requested to be reliable and available when it is needed by applications. VHN context-awareness is used to provide additional service features in terms of the following:

– automatic identification of actual VHN user and local environment upon approach;

– automatic recording of the events coming to and leaving the actual VHN user;

– automatic presentation of the orders or service due on the current location.

Appendix III shows a use case of an intelligent service provisioning model in VHN and Appendix IV shows an example of context awareness features in smart energy-aware management in VHN.

9 Management functions for VHN

The VHN management functions support the following functions to manage VHN featured services such as:

– terminal device management;

– access control;

– service session control;

– resource control;

– traffic management (e.g., unicast and multicast);

– fault management;

– performance management.

10 VHN service model

10.1 P2P based VHN service model

Another virtual group of VHN members can be created through peer-to-peer (P2P) based connection. The connection types between the entities in VHN can be categorized into two cases as follows:

– connection between a residence gateway (RG) in a home network and peers in other home networks;

– connection between an RG in a home network and peers in public networks.

Peers communicate with a home network by searching, sharing, etc. In the categorization, the role of the DNG in a home network may be treated as the role of the super-peer. For a detailed description of overlay networks refer to clause 6 of [ITU-T X.1162].

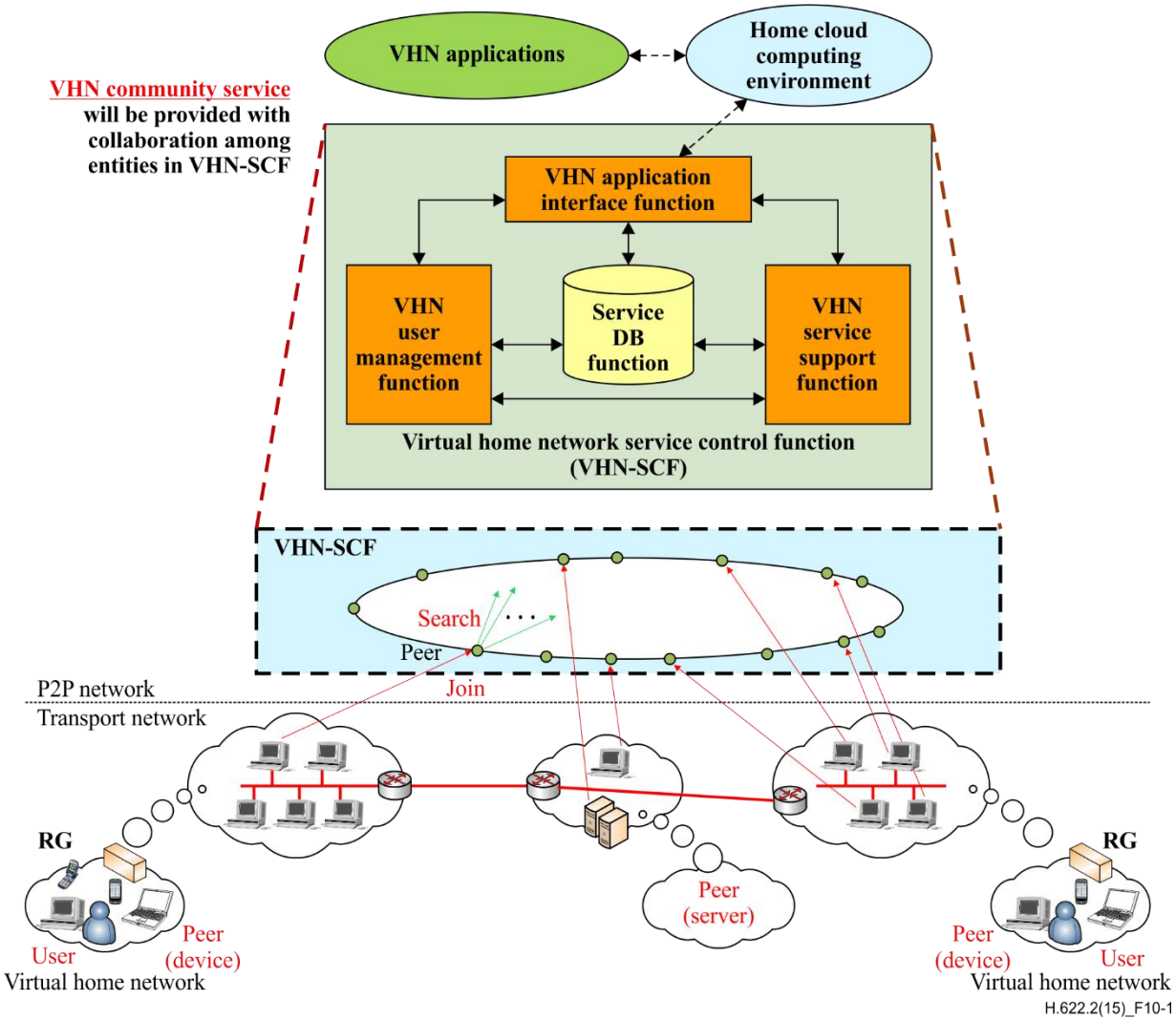

Figure 10-1 – A model for P2P based VHN

Figure 10-1 shows a P2P based VHN. The operation of each peer is assumed not to be limited by the physical network architecture and a peer can communicate with other peers regardless of location. In order to provide the P2P based VHN services, VHN-SCF consists of the following characteristics:

– each peer (terminal device in a virtual home network) switches its role as a server and a client depending on the situation;
– a peer that acts as a server can know its communication status, such as traffic, accessed client, accessed files, etc.;
– a peer that acts as a server can control its traffic by changing the access control policy.

10.2 Overlay network based VHN service model

An overlay network is a type of P2P network that is logically formed on top of a physical communication network. An overlay network can exploit diverse connectivity to form a virtual home network between nodes and a home gateway (e.g., an RG) in a home network. To enrich the service features of VHN, an overlay network based VHN has the following VHN-SCF characteristics:

– user based VHN service customization can be performed on users' demand despite different locations of the users;
– scalability can be provided even though the number of subscribers to a VHN is large;
– reliable connections are guaranteed as long as the physical network connections exist;
– routing paths can be dynamically changed according to the network's condition.

A model for an overlay network based virtual home network is shown in Figure 10-2.

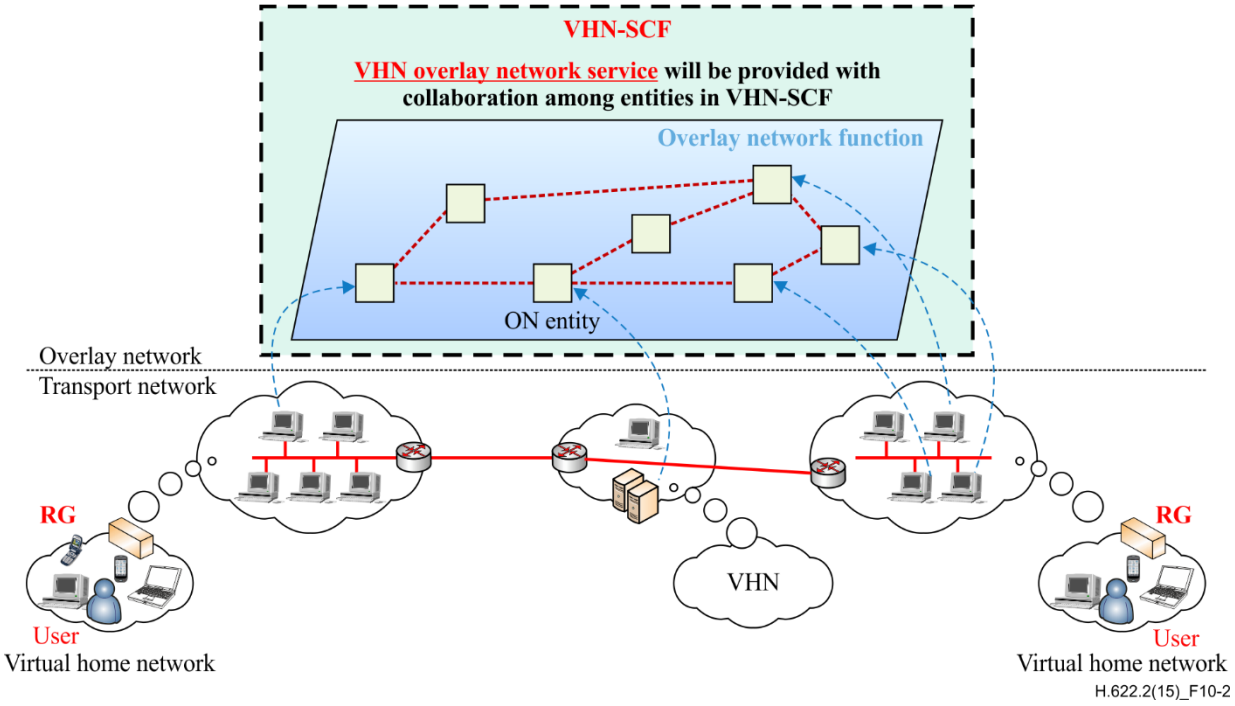

Figure 10-2 – A model for overlay network based virtual home network

10.3 VHN community service model

The VHN is able to support multiple heterogeneous capabilities in accordance with the needs of users and a federated configuration for a home community, which is created among multiple entities in the physical home network and multiple entities in VHN-SCF. The community federation among multiple entities in VHN is performed to create virtual service or user groups.

Various terminal devices such as desktop PCs, laptop PCs, tablet computers and smart phones connect to a VHN service community under the permission of the orchestration entity (e.g., a service overlay network (SON) or P2P server). Service features in the VHN community will be shared amongst virtual home community users and new users. The community members can

discover and get access to these shared services. In addition, communication among home networks is required to be protected through a virtual community protection system and mechanism.

A model for a community service based virtual home network is shown in Figure 10-3.

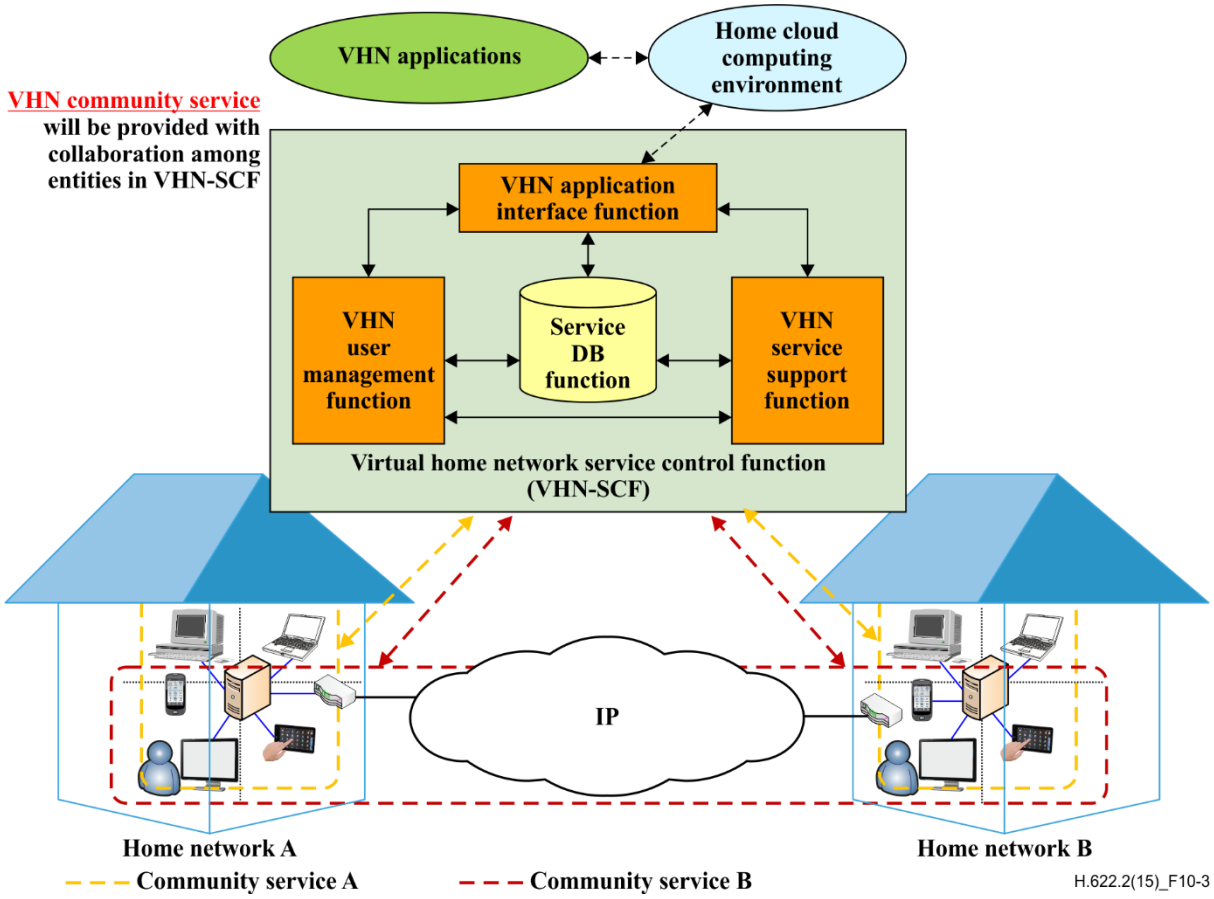

Figure 10-3 – A model for community service based virtual home network

10.4 Web-based VHN service model

Many kinds of VHN services will be deployed on the web and will be required to support a web portal platform to diversify VHN application features. A VHN-SCF will be required to support multiple types of services in a virtualized environment of VHN as shown in Figure 10-4.

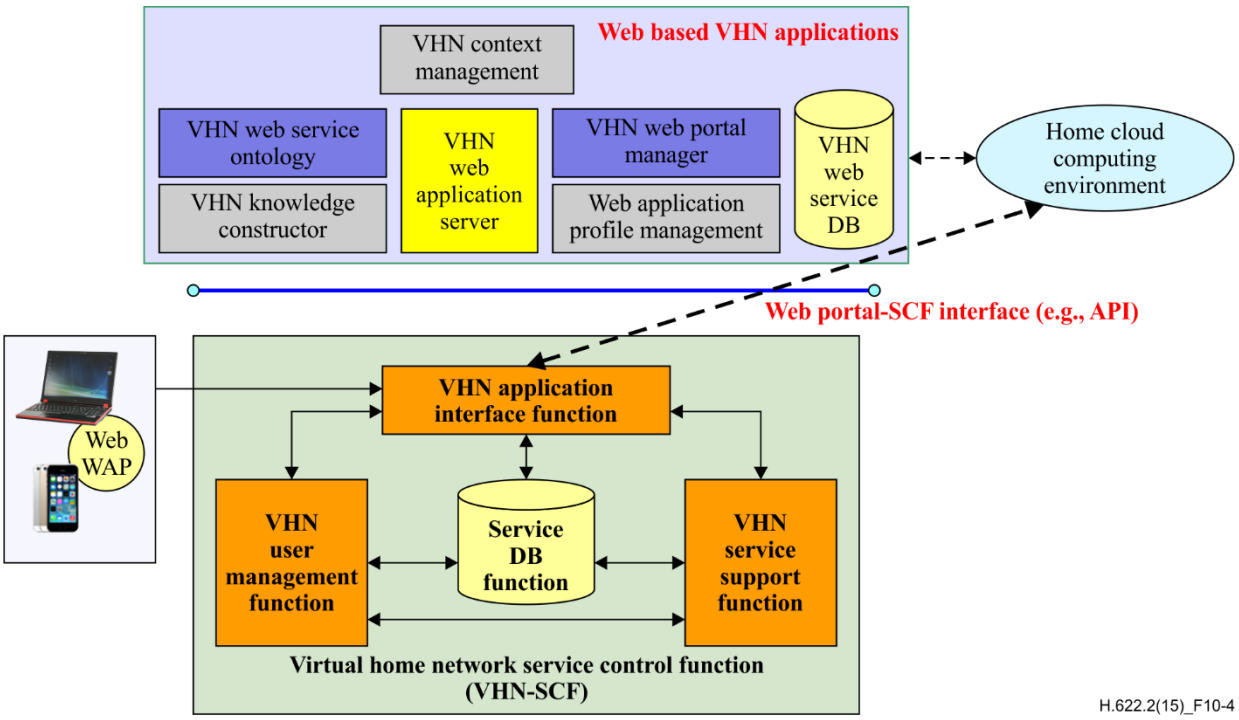

Figure 10-4 – Web-based VHN portal

The service interface between VHN-SCF and web-based VHN applications is required to support the following interworking capability:

– user profile management;
– web service ontology;
– context awareness management;
– web service application server;
– web portal manager;
– home cloud computing environment;
– context management function.

The interfaces between web services and VHN-SCF are divided into four functional features to support an open application programming interface (API):

– interface for actions on actuators;
– interface for precise location information;
– interface for predicted VHN object behaviours;
– interface with other IoT service platforms.

Appendix I

Virtual home networking capability over NGN service overlay network

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

One of the solutions to provide a VHN environment is to use SON functions. SON utilizes DNG information of each home network and controls home networks with information from the DNGs. SON functions also exist above the service stratum in next generation networks (NGNs) and exchange service control information with the DNGs via application network interfaces (ANIs). For these reasons, VHN services can be widely applied in different network environments such as NGN, etc.

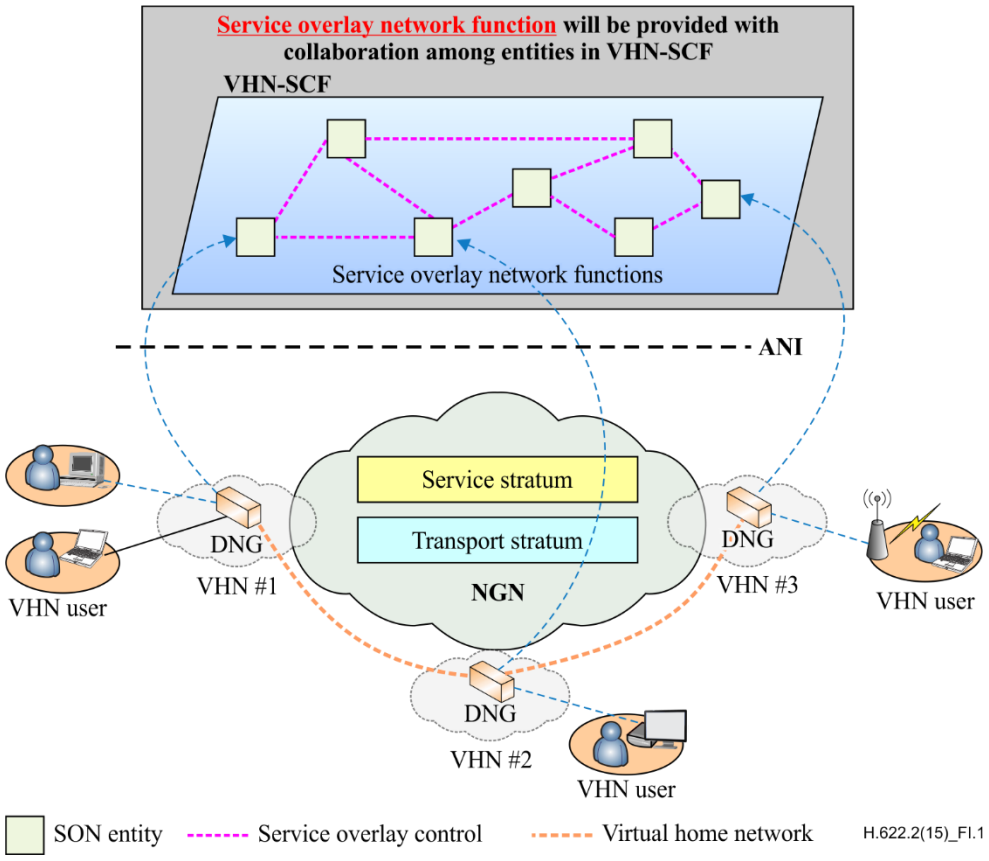

Figure I.1 – VHN service over SON

Figure I.1 shows an example of a SON enabled VHN service. Users in a home network request a VHN service from a SON entity via a DNG. The SON entity provides the requested VHN service by confirming the home network information and user profiles.

The SON entity has the geographical distributed structure of a service provider. The VHN service capabilities of each SON provide the following functions:

– easy composition of dynamic VHN;
– SON service interaction between VHNs;
– network level QoS and application level QoS guarantee between VHNs;
– application security guarantee between VHNs.

Appendix II

Example of an application-level home gateway function

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

Generally, most of the service entities in VHNs are low computing powered devices of special-purpose embedded computers. The devices do not have enough computing power to process all of the information carried on general-purpose protocols. Consequently, information should be processed by the VHN functions before it (the information) reaches the terminal devices. The following conditions are to be satisfied:

– verify the features or location of devices without hardcoded hostnames to addresses;
– use http for application-level home gateway communication for universal usages; or
– interwork with application support function (ASF) in NGN;
– provide unified management method to application and existing systems;
– convert data for devices with limited computational resources.

Application-level home gateway functions of a home gateway form a bridge between http-based control methods and various middleware-application control methods. Many devices can generate http-based control protocol such as PCs, PDAs, cellular phones, digital TV sets with web browsing capabilities.

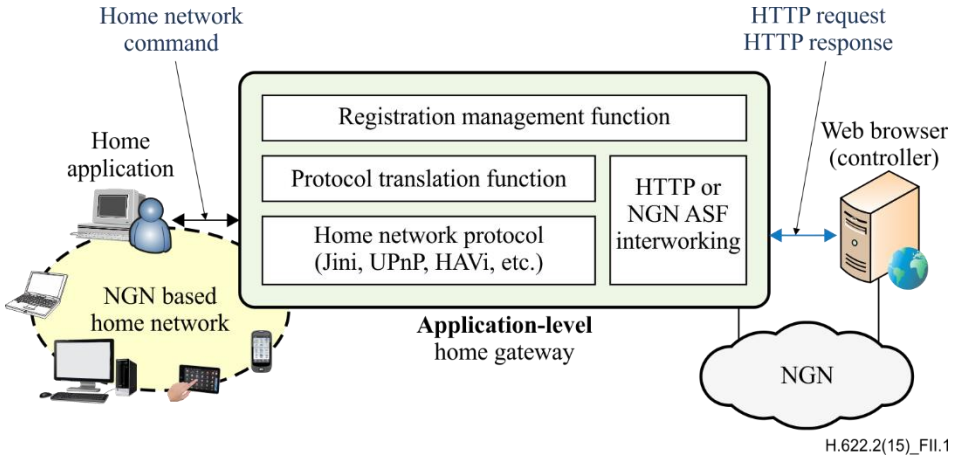

Figure II.1 – Example of an application-level home gateway function

Figure II.1 shows application-level home gateway functions. An application-level home gateway consists of four functional components:

– registration management function;
– protocol translation function;
– home network protocol;
– interworking and http protocol or ASF in NGN.

If an application-level home gateway function receives a http-based control message, it parses the message, applies the necessary protocol translation and sends out to the corresponding middleware application. The terminal devices see the gateway as that which provides the functions or services that are actually provided by devices on the Internet.

Appendix III

Intelligent service provisioning model in VHN: knowledge-driven model

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

Intelligent services in VHN are designed to support the intelligent features generated in VHN-SCF through a few additional service processing functions, e.g., service composition, collaboration and harmonization among virtual objects with reasoning and service policing.

Knowledge for services in VHN is also created through the proper training of sensed data. For instance VHN home appliances, resident's behaviour and demand provide efficient and optimized user centric services virtually. Such user centric services include security, home care, health care, energy management, ventilation, appliance management, pet care, fire alarm, suspect person tracking and plant water supply services, etc. This knowledge creation for VHN will promote the VHNs intelligence to provide much better control and management functions in accordance with users, situations and environments. Figure III.1 shows the step-by-step process to create knowledge in the VHN.

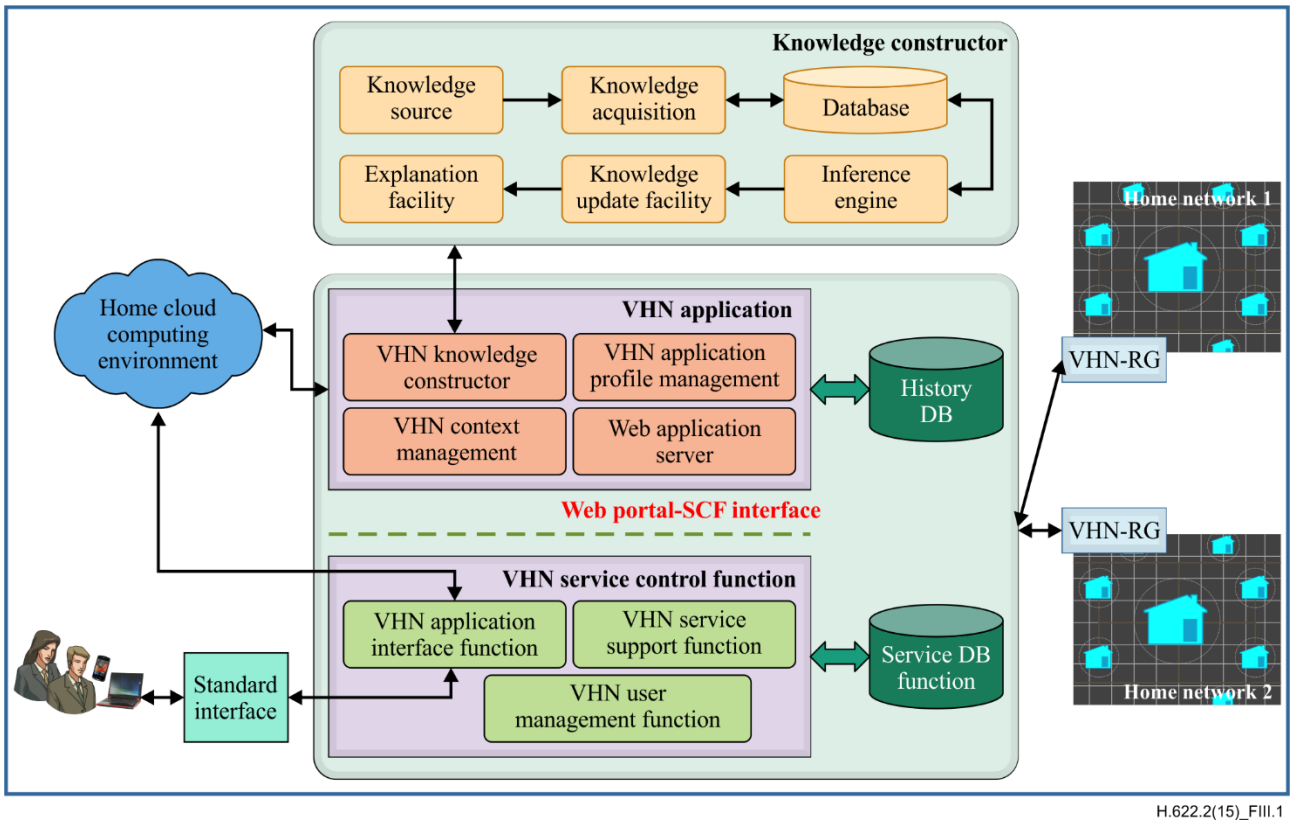

Figure III.1 – Knowledge construction process in VHN

Semantic ontology represents physical devices, resources and services of VHN in terms of virtual objects and composite virtual objects. Virtualizing the physical devices and resources forms virtual objects, whereas composing them from the interrelated virtual objects provides detailed information and services. VHNs combine multiple home networks and residents as social media.

III.1 VHN knowledge construction process

Knowledge represents information in a structured way in VHN. Knowledge is created from the individual members, social environment, indoor and outdoor activities and experiences based on

schedule. Raw data are collected, stored and maintained to create knowledge. Knowledge creation elements are shown in Figure III.1.

The core components of intelligent systems are the knowledge and the reasoning (inference) engine. The knowledge acquisition component accumulates, transfers and transforms problem-solving expertise and/or documented knowledge sources to a computer program to construct or expand the knowledge base. The inference engine takes the data as input and processes the output based on defined rules like a human intellect. The inference engine uses the control structure and provides a methodology for reasoning via data analysis and rule processing.

III.2 Knowledge-based service features

Different attributes of physical objects are combined to create a virtual object, packaging the virtual object with added intelligence in the virtual domain leads to knowledge by reasoning. In the case of big sensed data handling, data are stored and extracted using a trained model learned by a specific type of learning algorithm to create knowledge. Monitoring and analysis of context information and collecting of environment status enable easy exchange and integration of data among interconnected devices.

III.3 Object virtualization for representing services on the web

Communication among the objects requires object virtualization for virtual representation on the web. In object virtualization, objects include an objectified value of their attributes. Physical and non-physical object's resources and attributes, such as resident profile, resource description, sensed data, interface type, location information etc., are virtualized for reusing, reconfiguring and recreating objects with user requirements.

Figure III.2 shows the object virtualization process from physical objects. Different attributes from different objects are combined for creating virtualized objects. For example, the location of one object, the date and time of other object, customer information and the sensed data of sensor objects are combined to create a newly specified composite virtual object that has more capability to provide services.

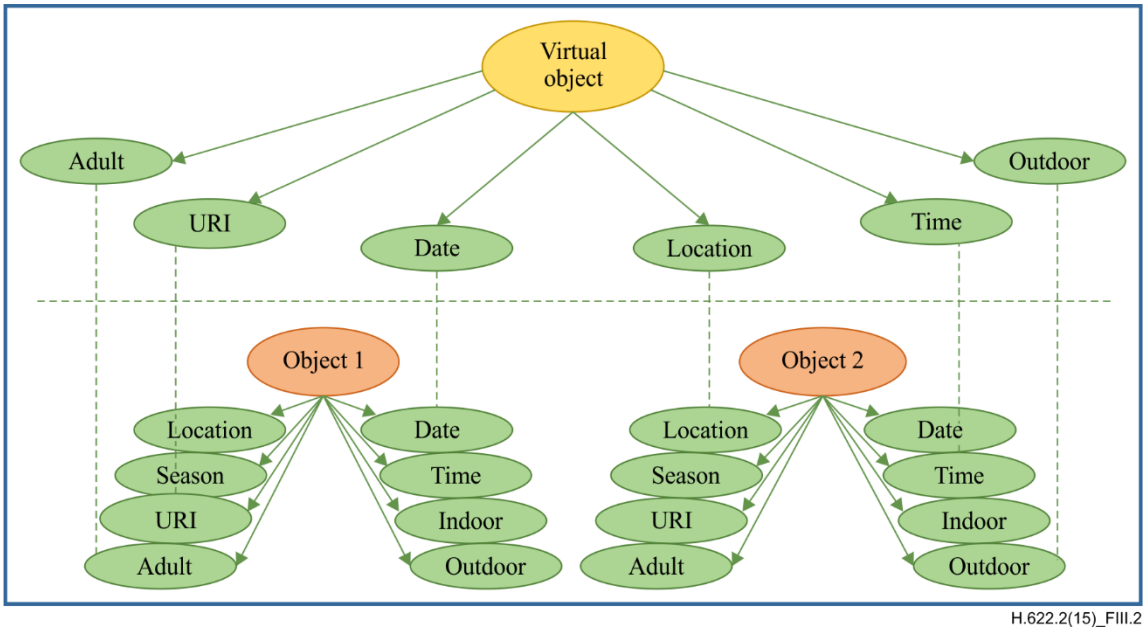

Figure III.2 – Object virtualization process from physical objects

Various physical devices are easily mapped with virtual objects through the web and this could be of benefit in creating a resident's personal IoT services that are ready to be used virtually.

Both explicit and tacit knowledge are processed for service creation in VHN. Explicit knowledge is represented by the virtual object, which is the virtual representation of a physical object. Examples of explicit knowledge are sensors, devices, resident's profile, etc. The properties and attributes of the virtual objects are the elements in explicit knowledge. Explicit knowledge is inferred to produce tacit knowledge. Tacit knowledge is represented by a composite virtual object to classify different services.

III.4 Ontology modelling for representing knowledge

Ontology represents the relationship among objects containing different parts that forms composition based on reasoning. The sensors and devices located indoors or outdoors of a home gather data in a specific location. All the sensed data, status of the devices, present condition, resident information and location are recorded in the database. Ontology mainly focuses on the reusing of existing ontology and interacting with applications. Figure III.3 shows the ontology model for the home network that represents knowledge.

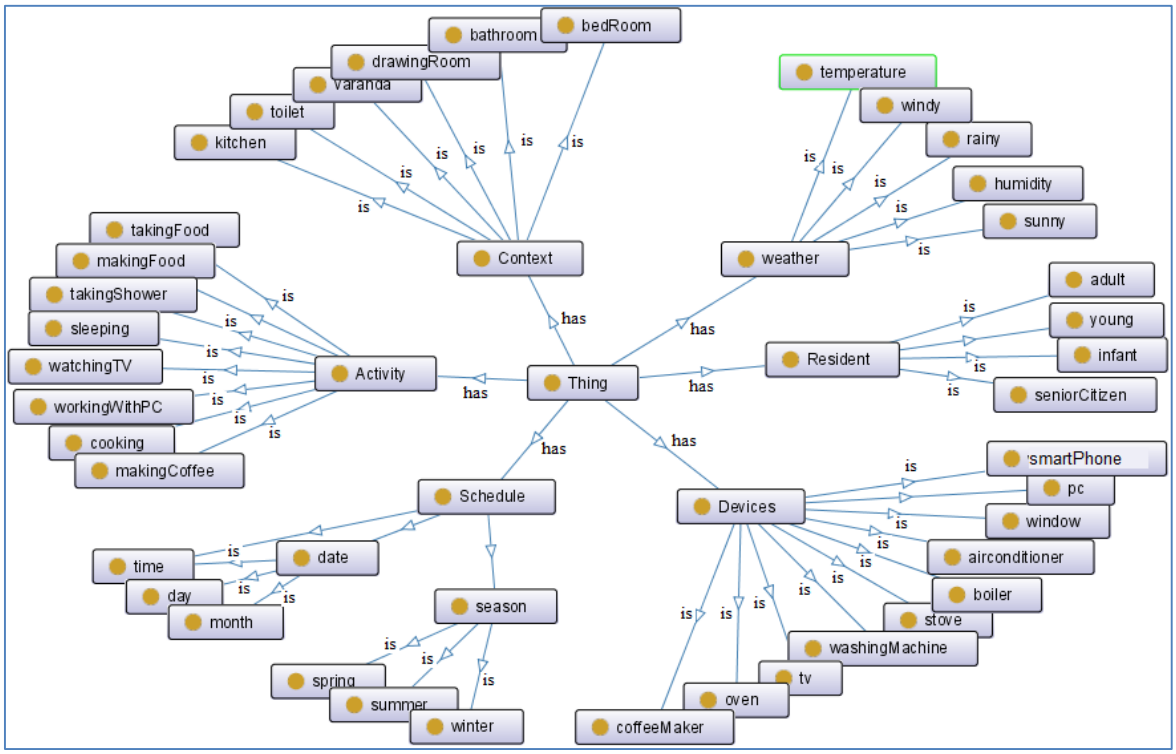

Figure III.3 – Semantic ontology model for a home network

Several classes and subclasses are mapped in a hierarchical manner to form the ontology. The activity class is further classified by its subclasses, such as taking food, sleeping, cooking, etc. The classes and subclasses are defined according to their properties, thus virtualizing a physical object on the web.

Appendix IV

Use case of context-aware services in VHN: smart energy-aware management

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

Energy management in a VHN service platform is a necessity. In order to manage energy in a VHN it is required to optimize the usage of energy. A VHN provides automated functions to save energy and provides a control function to the user. In order to provide a more intelligent service in terms of user satisfaction VHN provides some learning functions to adapt the system to user behaviour. If a VHN is constituted in a type of community, the energy efficiency management for the VHN will be performed by various featured functions. This appendix describes features for smart energy-aware management.

Figure IV.1 shows an example of context-aware services in a VHN.

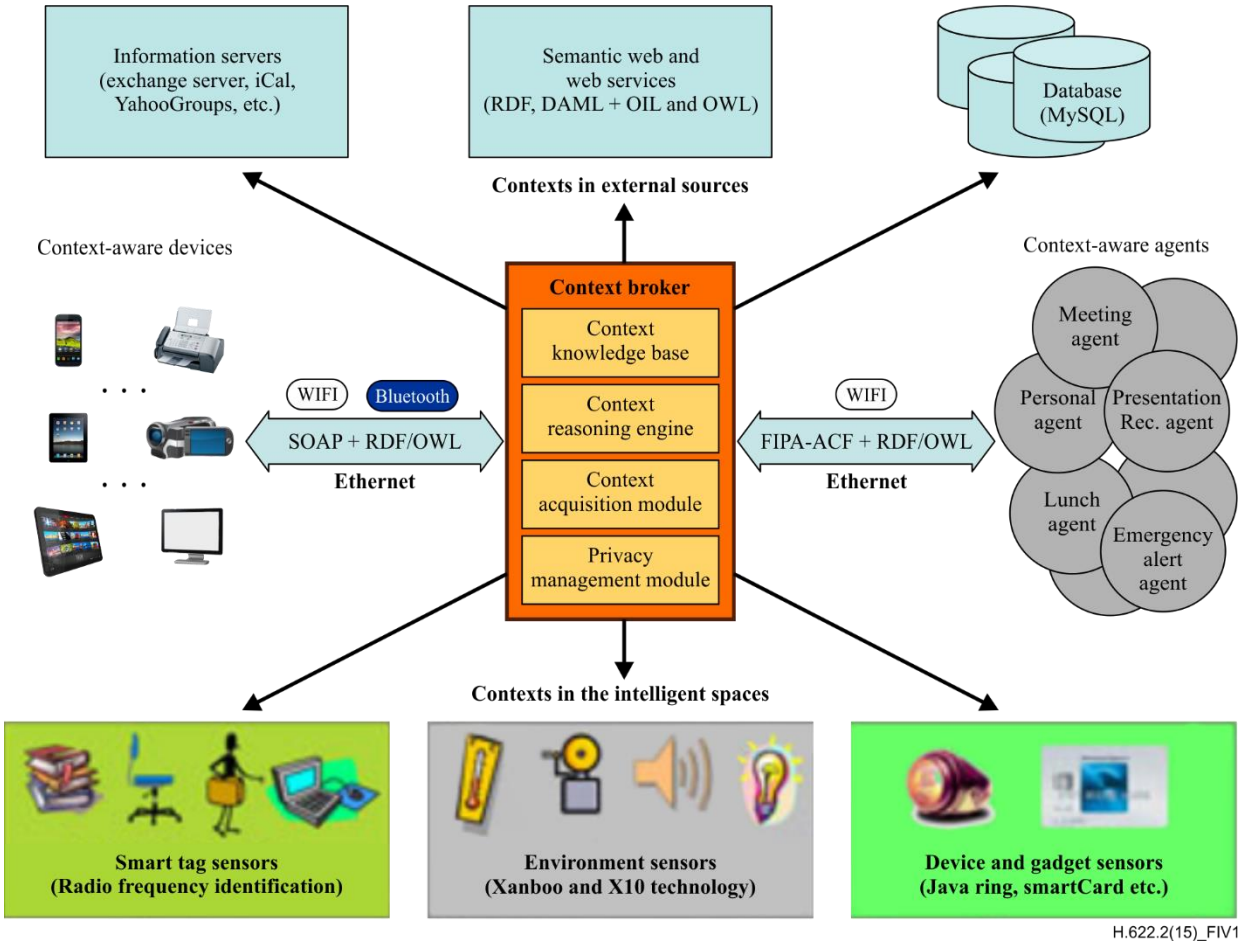

Figure IV.1 – An example of context-aware services in VHN

IV.1 Functional model of a smart VHN to support an energy-aware service

In order to provide energy efficiency in a VHN service platform it is required to monitor and measure values of physical objects in the home network. Messages and notifications are provided to the user in the VHN-SCF. Every device is connected through smart meters to the smart grid. Consequently, it is possible to see the energy consumption for each device. Figure IV.2 shows an example of a functional architecture for smart energy-aware management of a VHN. Adaptive learning process is used to provide more user comfort as well as to manage energy consumption intelligently.

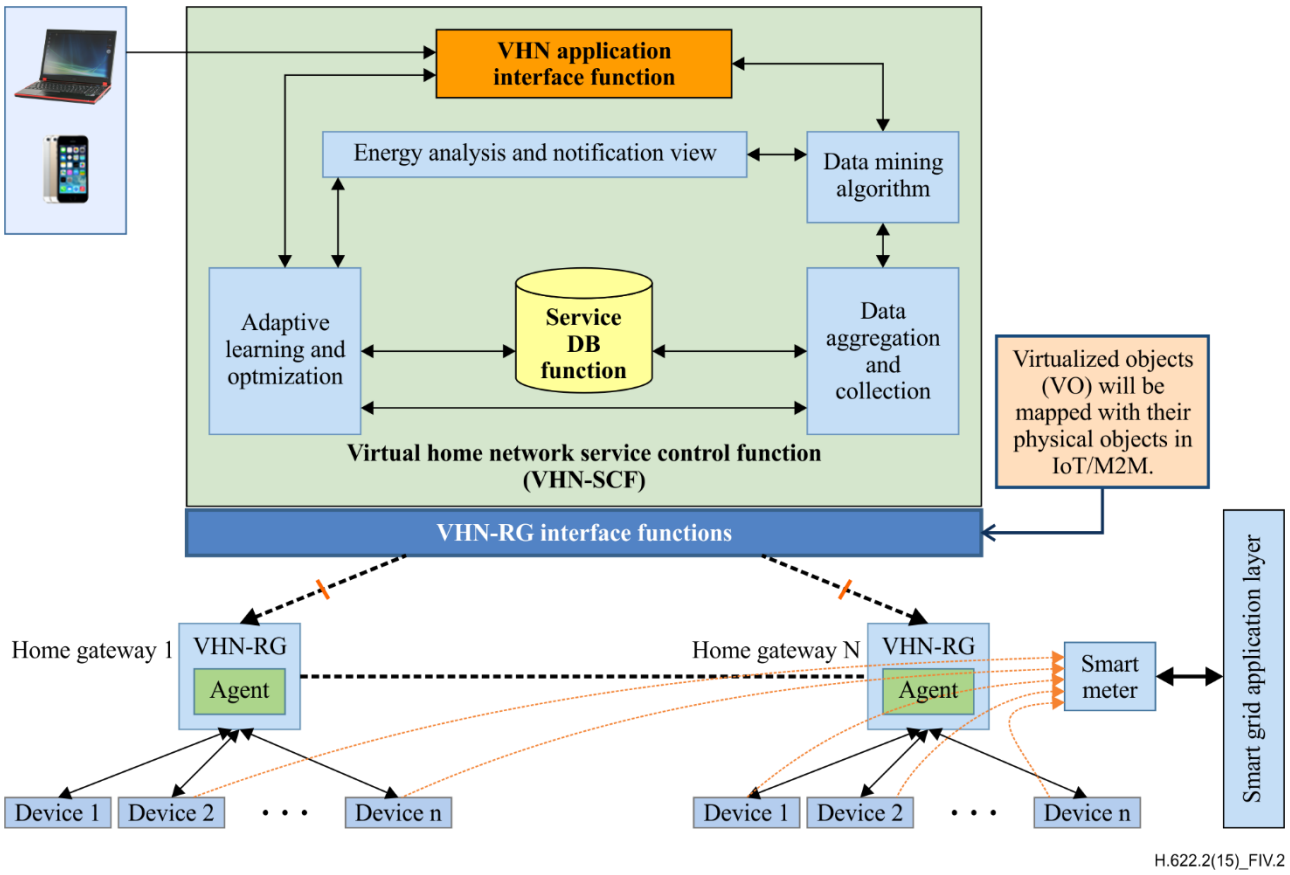

Figure IV.2 –Example of a functional architecture for smart energy-aware management of a VHN

IV.2 Ontology based reasoning approach for smart energy-aware management in VHN

An ontology based reasoning approach can be used to manage virtual objects, which are virtualized and mapped with physical objects in IoT/machine to machine (M2M), for energy efficiency in the VHN-SCF. Each device in the VHN can carry out pattern recognition, inference, and decision making with only the information available to it. For instance, a light or a computer monitor can determine whether to maintain its power status or not depending on the detection of people in close proximity. Figure IV.3 shows an example framework of an ontology based reasoning approach for energy management in a VHN service platform.

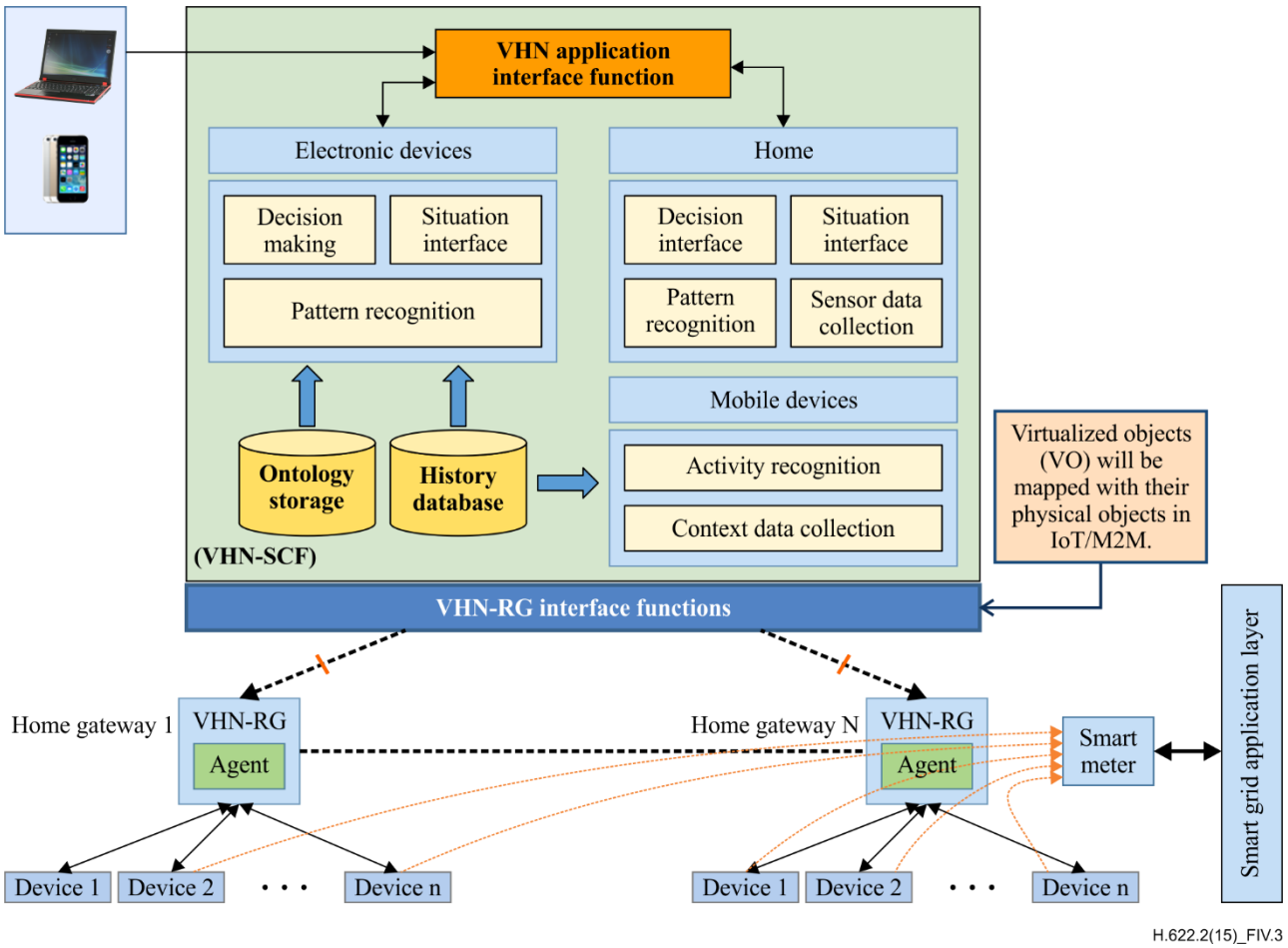

Figure IV.3 – Ontology based smart energy-aware management in VHN

This system assumes electronics devices are connected to a smart controller which can report the device's power status to the server and control the device as commanded from the server. Although not shown in this framework, the VHN assumes that other information such as weather and room temperature can be collected through the Internet and wireless sensors if necessary. Each resident's mobile phone serves as a generic sensor which can report its owner's contextual data (e.g., locations, schedules, preference). Furthermore, it is expected that sophisticated mobile devices can replace the home server. Figure IV.3 shows an example of an ontology map for the energy-aware management in a VHN service platform.

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