An Architecture for Home Service Retrieval Based on Function Concept Ontology

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Abstract: This paper constructs ontologies for smart home to automate home service retrieval according to the functional properties. By analyzing the context of home service, firstly we differentiate seven key concepts in the domain and analyze the relations among them, and as a result, a domain upper ontology as a fixed viewpoint for further more detailed conceptualization is achieved. Then guiding with the upper ontology, function concept ontology is proposed with deeply categorization and systematization of functions. Finally a scenario of audible alarm of gas detective is given to present the architecture for service registry, retrieval and invocation based on the function concept ontology.

Keywords: Smart Home; Service; Domain Upper Ontology; Function Concept Ontology; Need

1Introduction

Smart home is different than the traditional home on its ability to perform function by integrating appropriate appliances automatically. To facilitate integrating services for households intelligently, ontologies are essential, as they act as the format explicit specification [1] for describing the services provided by networked devices, sensors, and other appliances. Thus the ontology-based semantic approaches could integrate services according to the specification automatically [2].

The designed ontologies focus mainly on context of service or QoS related service properties. The former kind of ontologies [3-5] believes the situational information is very import for deciding service behaviors in smart home. They define context as the situational information of entities. An entity is a person, place, or object that is considered relevant to the interaction between a user and an appliance, including the users and appliances themselves. As a result in an ontology-based context model, it usually contains concepts like device, person, time, place, weather, policy etc. and constructs ontologies for these concepts. With these ontologies service could interpret context information automatically, and adapt its behavior by setting different values to parameters according to the states of context. However the information for service itself is scarce, consequently the model could not select service dynamically. It means that if the trigger condition is activated by the context, the model could just invoke the predefined service which is hosted on the given device for users, and could not provide alternative solutions when the invocation of predefined service is failure. Moreover when a new device registers its services which have similar functions with existed services, the model should update all the triggered services according to some rules for smart home.

QoS-related service ontologies [6-10] construct ontologies for the concepts like cost, accuracy, performance, security, reliability, etc. which are non-functional properties of a service. With these ontologies when choosing the services which have the similar functions, the model could select the most prior service according to quality of service by customized rules such as utility rule, cost rule, etc. In QoS-related model the whole device is abstracted as one service with specific function, and as a result, the function of service originates from device function. It dose not present functional information for each service hosted on the device. It means that the device is considered as minimal unit for smart home, accordingly by function retrieval, the model would get appropriate device directly. This model facilitates the description of the device of which function is single. If the device has several functions, then the service abstracts from the device should be annotated with several functions. For example the air-condition device has cooling and heating two functions at least, and thus the functions of air-condition service should be cooling and heating simultaneously. Obviously this model is not quite suitable for versatile device which has multi-functions such as computer, PDA, etc.

This paper treats a service as one logic device with specific function, and provides functional information for each atomic service hosted on device. If a physical device hosts multi-services, then the device could be separated into several logic devices according to services, and one logic device implements one service. We annotate one function to each service by extracting function from logic device.

Diaz Redondo et al [11, 12] construct Operation-at-home ontology from device perspective to describe the function of service. They build Device-in-home ontology by collecting the typical home appliances (heating, dishwasher, blinds, and so on), and then abstract and classify functions from the device in the ontology to build Operation-at-home ontology for unifying the field’s conceptualization. However, the classification of services lacks a fixed viewpoint, i.e. they fail to form a domain upper ontology to describe the relations among concepts formally. The absence of upper ontology leads to ambiguous concept definitions. Especially the confusion of function and need would induce the function of service diversely in different contexts. Without explicit semantics of function, service could not be effectively retrieved.

To explicate the definitions of concepts in smart home field, firstly we analyze the context of home service to abstract service-related concepts from the context. Then we construct home service ontology as domain upper ontology to formalize the relations among the concepts. Finally, by refining the function concept of home service ontology, function concept ontology is constructed to classify home service semantically.

This paper consists of five sections. Section 2 abstracts key concepts of the field by analyzing the context of home service, and proposes home service ontology to explicate the relations among the concepts. In section 3 function concept ontology is constructed to classify home service semantically. The ontology is divided into five categories according to satisfaction process of need, and then the sub-concepts are refined based on the “way” in which the function is achieved. Section 4 provides ontology-based architecture for service registry, retrieval and invocation with alarm scenario of gas detective. Finally we conclude and present future work in section 5.

2 The Semantic of Home Service

2.1 Context of Home Service

Home service is an algorithm that is implemented on the computer (here the computer is a broad sense computer including PC, SCM, etc.). In order to achieve specified function that people want, the algorithm would control home appliances to alter the states of context. Consequently to extract service-related concepts from the field of smart home, we should analyze the context where home service runs first.

Rosenman and Gero[13,14] extend function-behavior-structure framework for improving intelligence of design system in mechanical manufacture, they analyze the relations among techno-physical environment, nature environment and socio-culture environment which have close relation with artifacts. For concept explanation they distinguish the context into three parts: external world, interpreted world and expected world.

Home service is an algorithm and it is also an artifact, however unlike other artifacts home service is not substantial. It means that the realization of service needs device as its carrier. When analyzing home service environment the carrier environment should also be involved, so the classification proposed by Rosenman and Gero can not satisfy our aim partially. Consulting predecessor research we introduce four different kinds of environments that are external world, interpreted world, expected world and computer world. Figure 1 depicts the relations among the four worlds.

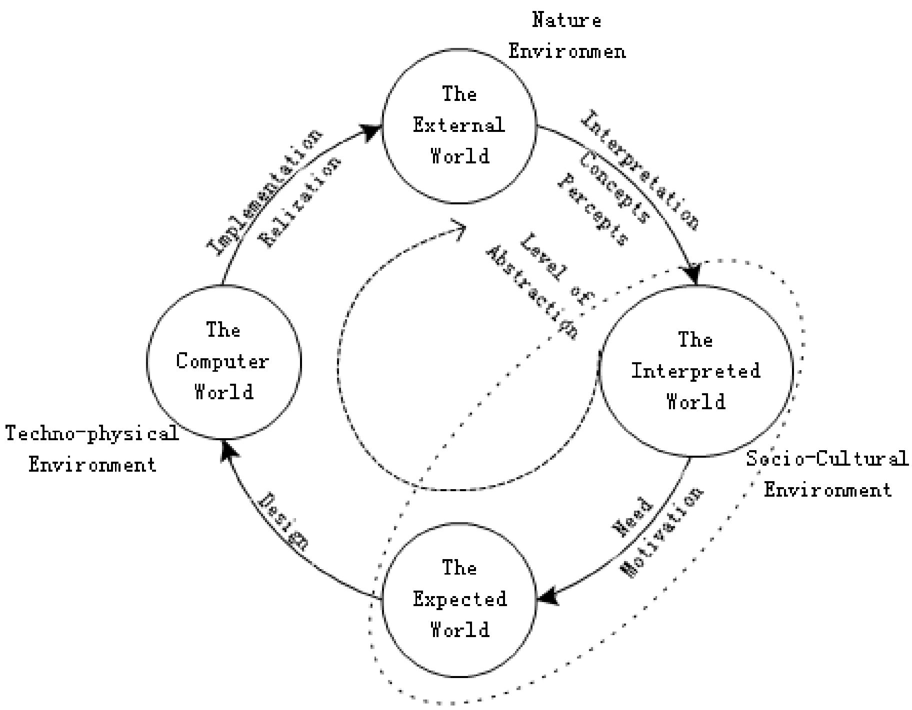

Figure 1 Four Worlds

The external world pictures the current state of the physical world.

The interpreted world is the one built up inside the human beings in terms of sensory experiences, percepts and concepts. That is, the internal representation of the external world that human interacts with. It triggers lots of unsatisfied needs.

The expected world is the one being produced by using devices so as to satisfy the needs of human beings. The functions of devices can be imagined according to current goals of human and interpretations of the current states of the external world.

The computer world is the one consisting of devices which are designed to satisfy human’s needs. It is responsible for transforming the expected world into the external world.

The four worlds are recursively linked together by four classes of processes. The *interpretation process* transforms variables sensed in the external world into interpretations of sensory experiences, percepts and concepts which in turn become part of the interpreted world. This process is done by the interaction of sensation, perception and conception processes. Then in *motivation process* the interpreted world is transformed into the expected world motivated by needs which are generated by human experiences. The needs are expressed as goals in the expected world. The devices in the computer world are designed to achieve the goals proposed in the expected world. The *design process* transforms the goals which are proposed in the expected world into the functions that could be provided by devices, and then the devices in the computer world would be designed according to the functions. Finally the *process of implementation* is an effect which brings about a change in the external world according to the function provided by the computer world. The four worlds from the interpreted world to the external world materialize conceptions of human beings gradually, and the level of abstraction is decreased as well. The home service which is a kind of artifact just sites in the computer world and would satisfy users' needs by controlling the device to realize specified function.

2.2 Home Service Ontology

By distinguishing home context into four worlds, we could abstract seven service-related concepts including "Need", "Context", "Device", "Function", "Way", "Content" and "Service".

Need and function are two easily-confused concepts. So in order to differentiate the concept function from need, we give the definition of two concepts first. Home service would affect the external world by device operation. The effect of service is recognized as function which implies the goal of service. We say that the service satisfies need, when the effect plays a positive role for human. Need and function are originated from different processes. Need is abstracted from the *motivation process* where the interpreted world inverts into the expected world, while function sites in the *design process* where the expected world inverts into the computer world. The levels of abstraction of two concepts are different either, according to above sub-section analysis the need concept is more abstract than the function concept.

To clarify the concept relations among need, function, service, content etc, the paper proposes home service ontology as a domain upper ontology for smart home. The ontology is expressed in the form of RDF diagram in figure 2.

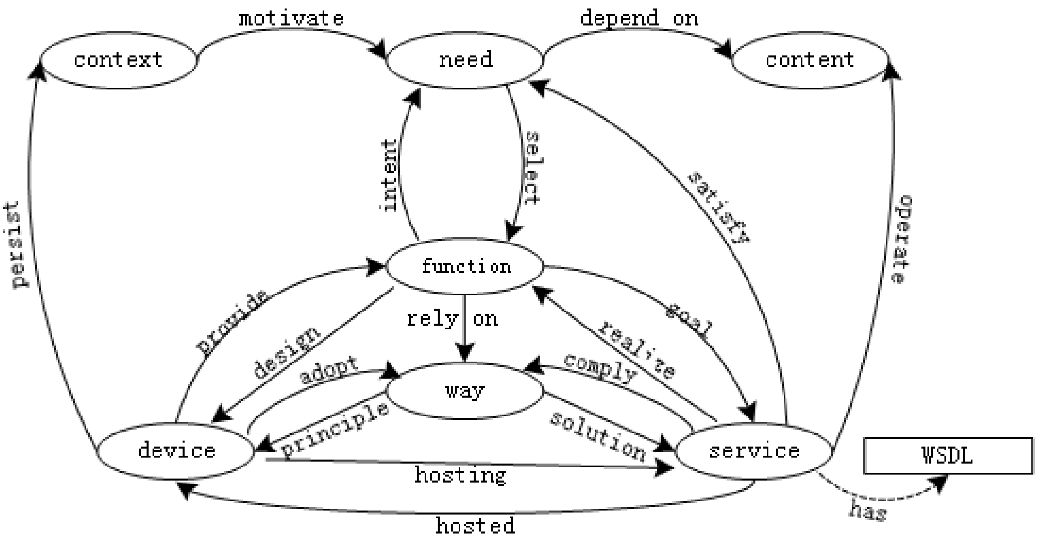

Figure 2 Home Service Ontology

As shown in figure 2, human's *need* is *motivated* by *context*. Since the context varies dynamically, the needs are changeful and diverse in daily life. On the one hand a need could be satisfied by various services, and on the other hand one service could satisfy a variety of needs which are motivated by different contexts. For example, an alarm need is motivated when insecure situation occurs in smart home. Then for residential users, the need could be satisfied by audio-playing service runs on audio device, and for outworkers, they could be informed the alarm by using SMS service provided by cell phone. Besides the alarm informing need, other needs like note reminding need and music playing need could also be satisfied by the audio-playing service. So it is not proper to annotate the audio-playing service with alarm informing need, namely the need concept could not explicate the semantic of service. Psychology researches [15, 16] that with the same need the goals may be such differences for kinds of people, and on the other side to the same goal the needs from different people are inconsistent as well. If we examine carefully the average needs that we have in daily life, we find that they have at least one important characteristic, i.e., that they are usually means to a goal rather than goals in themselves. Usually when a conscious need is analyzed we find that we can go behind it, so to speak, to other, more fundamental intentions of the individual. It is characteristic of this deeper analysis that it will always lead ultimately to certain intentions behind which we cannot go; that is, to certain intention-satisfactions that seem to be goals in themselves and seem not to need any further justification or demonstration. The fundamental or ultimate intentions of all human beings do not differ nearly as much as do their conscious everyday needs [17]. The intentions are always implied in the needs. Therefore to satisfy a need, consumer usually has to *select* a proper *function* which reflects the *intention* implied in the need. Moreover the function presents the *goal* of the *service*, and meanwhile it also guides the *design* of *device*, hence the device *provides* the function exactly. To achieve a given function also *relies on* specific *way*. The *way* interprets how a service controls the device to achieve a given function. It provides the *principle* for device design and *solution* for service development. Therefore the service always *complies* specific way which the device *adopts* as design principle. There could be more than one way for the same function. Therefore aiming one function, according to the different ways there should be many different types of devices and relevant services as well. Take print function for instance, all the printers should provide print function, however adopting different ways the printers could be classified into laser printer, jet ink printer and stylus printer, and the services *hosted* on the printers are different either. Generally, the *realization* of given function relies on service implementation, and the precondition is that the device which *hosts* the service should be *persisted* in the context. Furthermore in smart home to *satisfy* a need motivated by specific context, the service should present effective information for consumer by operating relevant data from the context. We call the object that the service *operates* *content*. So we can conclude that the satisfaction of need also *depends on* content which is carrier of information.

In conclusion, the satisfaction of need depends on information access. In order to generate effective information, we should select a service with given function according to the intention of need to operate context-relevant content and then present the content to consumer. The selected service should run on a proper device.

2.3 The Semantic of Service

The home service ontology explicates our viewpoint and formally defines service-related concepts from the unified viewpoint. In the ontology we differentiate function from need, which are usually confused with each other in other literatures. For instance other literatures recognize “illumination” and “guard” as the functions of “turn-on light” service. However from our viewpoint described above, the intention of “turn-on light” service is to adjust the brightness state of the external world, accordingly the service affects human vision, and then the function of the service is vision-related. The service which realizes vision-related function would actually alter the state of external world, and in different contexts the altered state may lead to different effects which eventually satisfy various needs such as “illumination” or “guard”.

By differentiate the concepts function and need, we believe that the function of a service is unique and fixed, while the needs which a service could satisfy are diverse with different contexts. Thus, annotating service with function as its semantic could explicate the classification of service.

The home service ontology as domain upper ontology defines seven key concepts in the field, and formalizes relations among them. By formally clarifies the whole process from need motivation to service invocation, it could promote the automation and intelligence of smart home by annotating the service with the ontology. However, the concepts in home service ontology are highly abstracted. To annotate the given service with specific function, we construct function concept ontology by refining the function concept of home service ontology.

3 Function concept ontology

3.1 Categories of Service Function

According to the definition of home service ontology, to satisfy a need people should select a specific function and then search service which is annotated by the function to operate relevant content. The selected function implicates the intention of the need, hence we abstract function by analyzing the satisfaction process of need. As figure 2 depicts, the satisfaction of need depends on information access. When a need is motivated, a service should generate effective information and then represent the information to consumer. Figure 3 pictures the lifecycle of information, as the figure shown the information is generated from source, transmitted through channel and represented in sink. The need would be satisfied within the whole process. So we abstract function by distinguishing the operations in the lifecycle of information.

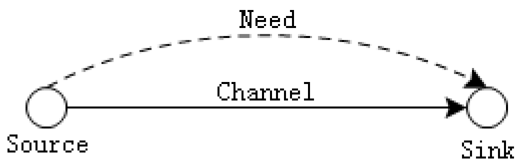

Figure 3 Lifecycle of Information

In the lifecycle of information, it would refer to five operations: collection, processing, storage, transmission and representation. Accordingly the function could be divided into five corresponding categories: collect, process, store, transmit and represent. Figure 4 illuminates the organization of the categories of function.

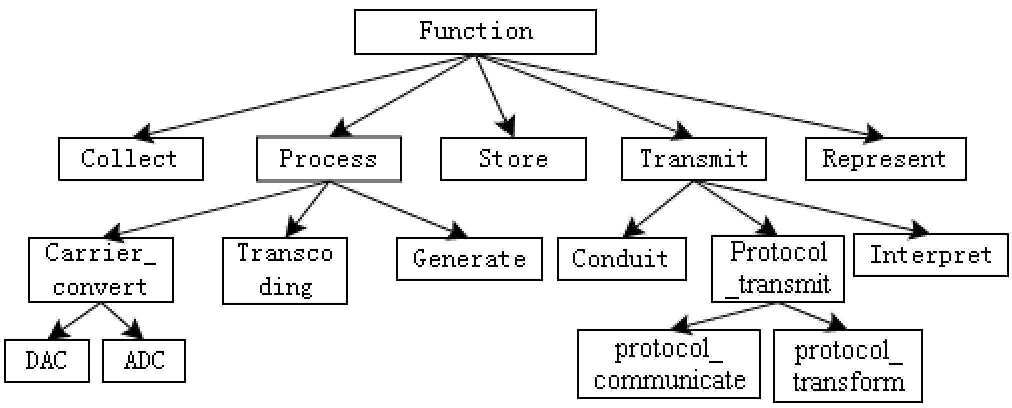

Figure 4 Categories of Function

3.1.1 Process Function

In above five categories process function is responsible for content processing. Content as the carrier of information contains three parts: carrier type, code format and semantic.

Carrier type denotes the information is carried by digital signal or analog signal.

Code format illuminates the format that the information coded. If the content is audio-related, the code format could be wav, midi, mp3, etc.

The semantic of content explicates the information that the content holds.

Consequently process function could be divided into three sub-categories (carrier convert function, transcoding function and generate function) according to the different facets of content that the operation targets.

Carrier convert function converts specific analog signal to appointed digital signal (DAC function), or the opposite (ADC function).

Transcoding function encodes the format of content into another format.

Generate function transforms the semantic of content. That is with generate function the information of input and output would be different.

3.1.2 Transmit Function

Transmit function provides channel for information transmitting between two services which are regarded as logic devices. According to the types of channel, transmit function could also be divided into three sub-categories: conduit, protocol_transmit and translate.

Conduit function transmits content without any operation, thus to realize conduit function dose not have to employ any services, i.e. there is no service would be annotated with conduit function. Conduit is just a virtual device, when two services are connected with conduit they could communicate with each other directly.

The service which is annotated by protocol_transmit function transmits data with specific protocol. When two services which are situated in two networks communicate with each other, they should search a protocol_transmit service to transmit data between the networks. According to the protocols that the networks adopt, the protocol_transmit function could be divided into two sub-categories: protocol_communicate function which is used for transmitting data for same protocol and protocol_transform function used for different protocols.

Consulting the object that the service orients, home service could be classified into two kinds. One is device-oriented service which provides content for device controlling. The content of this kind service is hard for users to understand. The other is user-oriented service which provides content for user consuming. For instance gasDetectiveServcie() service hosted on gas security device is device-oriented service. The service would output bit 1 when the poisonous gas exceeds secure threshold, otherwise the output would be bit 0. The bit 1 is hardly interpreted to the text “gas leak” which is suitable for user-oriented service operating. Thereby when different kinds of services transmit data, they should search a service whose function is interpret as medium. To interpret different contents, the device provider should offer a dictionary which explicates the semantic of content that the service operates. The dictionary could either be metadata or ontology. With a dictionary the service which is annotated with interpret function could transmit data between different kinds of services.

Above three transmit functions connects and transmits data between different functions. Therefore with transmit function bridging, it could give the implementation sequence of functions.

3.2 Refinement of Function

The five categories of function cover all the functions that are needed in the lifecycle of information. However, the level of abstraction of above functions is still very high. To explicate the semantic of service more exactly, the categories should be refined further more.

According to the definition of home service ontology, the achievement of given function relies on specific way which illuminates how to realize the function. Taking different principles there could be more than one way to achieve the same function. Accordingly for the function people could design different devices by adopting various ways and develop different services for the relevant devices. Namely the way which identifies the type of device and the solution of service provides theoretical basis for device and service classification. Consequently to annotate the classified service precisely, we could divide function into sub-functions based on different realization ways.

This paper takes Represent function refinement for instance to demonstrate how to classify function with the guidance of ways. As figure 5 shown, by stimulating different human senses, there are many ways that could realize Represent function such as optical way, aurally way, tactile way, etc. Accordingly based on the different ways, the Represent function could be classified into Visual function, Hear function, Feel function, etc. Then for Visual function, with different sources of light it could be divided into Display function (to realize Visual function by projecting light actively) and Print function (to realize Visual function based on reflecting light passively). Apparently adopting different print principles, Print function could be classified into LaserPrint function, InkjetPrint function, and StylusPrint function.

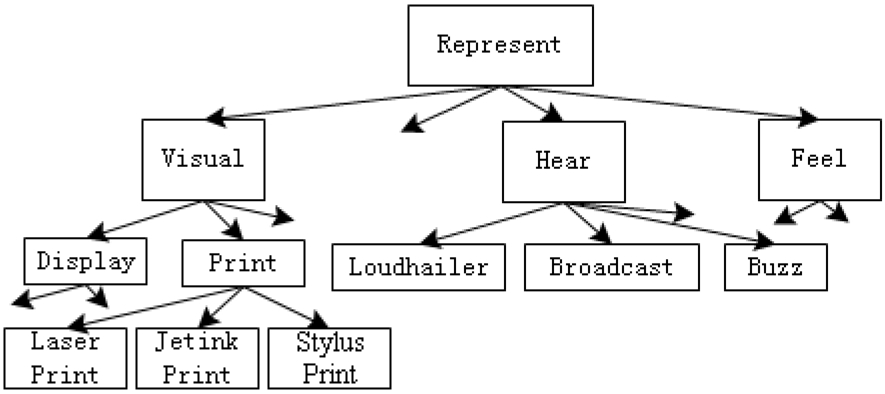

Figure 5 Portion Sub-functions of Represent Function

In function concept ontology the abstraction level of upper function is higher, and the corresponding service is more general. Contrarily the lower function is in a lower degree of abstraction, and the corresponding service is more targeted. For instance the solutions of printing services which respectively aim at laser printer and inkjet printer are different, because they have to tackle the details for different printing operations. Therefore the printing services should be annotated with more specific functions that are LaserPrint and InkjetPrint. On the other hand the printing service which is developed for logical printer provided by operating system could be annotated with more general Print function. Because the operating system shields the details of the differences of various printers, then the printing service could be adapted to different types of printers for Print function realization. Therefore unlike previous two printing services the solution of logical printer service is more versatile and the service could be annotated with function in higher degree of abstraction.

Same as the refinement of Represent function, by analyzing the ways of function other categories could be classified similarly.

4 Architecture for Ontology-Based Service Search

As home service ontology defined, function which indicates the intent of need presents the goal of service. It bridges the need and the service, so annotating service with function would automate service invocation for human's need. In this section a scenario of audible alarm of gas detective is used to show how to retrieve service based on function concept ontology.

4.1 Scenario Description

The essential service that smart home should supply is alarm service. The service should inform the insecurity when dangerous affairs occur. In smart home the gasDetectiveServcie() service which is provided by gas security device should ceaselessly detect the composition of air. When the poisonous gas exceeds secure threshold, the service would output bit 1 to denote the dangerous information.

Then the alarm service which is connected to the detective service may represent the information by aurally way, that is the service of which function is Hear should be invoked. Assuming that in smart home there are three devices would provide audio-play services. The first one is gasAlarmServcie() service which is provided by bell that comes with gas security device. The second one is FMService() service which is run on the radio. The third one is playServcie() service which is hosted on Bluetooth loudspeaker. Above three audio-play services should be invoked to inform the insecurity automatically when the detective service output bit 1.

4.2 Service Annotation with Function Concept Ontology

Smart home usually employs a residential gateway to manage the Home Area Network (HAN) as shown in figure 6. In HAN, appliances are connected to the residential gateway directly or indirectly, and access information from Internet through the gateway. Furthermore, to manage home appliances remotely, users could employ controller or other devices which could access Internet to send instructions to the gateway, and then the gateway would distribute instructions to relevant appliances. The residential gateway-centered HAN forms the infrastructure of smart home. When the device first enters HAN, it would register the services that it owns to service registry of residential gateway. Hereafter the gateway would retrieve proper services by searching the service registry. However the searching process retrieves services by matching the request with service name syntactically. Hence in the scenario described in section 4.1 the gateway could just achieve gasAlarmServcie() service by comparing to the request “alarm”. With keyword-based architecture, the gateway could hardly find other audio-play services simultaneously.

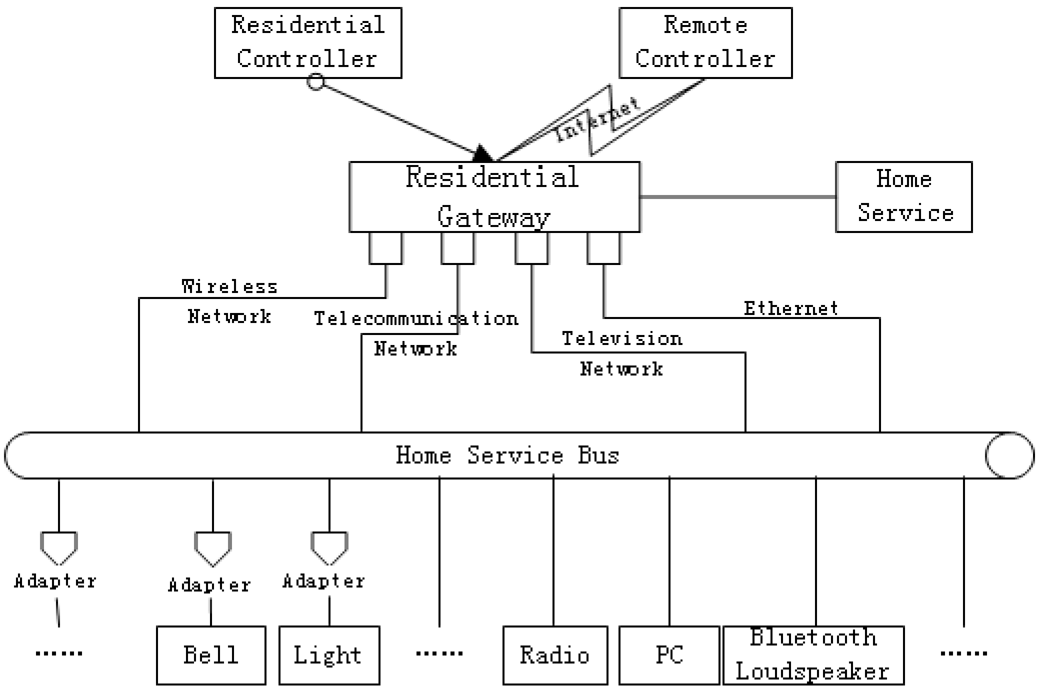

Figure 6 Model of Home Area Network

To solve the syntactic problems brought by keyword-based mechanism, we enhance residential gateway by expanding service registry with function concept ontology. By annotating service with function, the gateway could semantically retrieve and invoke services which would satisfy given need based on function concept ontology reasoning.

4.2.1 Service Register

In the alarm scenario of gas detective, there are three devices: bell, radio and Bluetooth loudspeaker. When they attend into home area network, the devices should register services which are hosted on them to the service registry. The current service registry of residential gateway stores a table-based representation of the home service. Then in service discovery process, the residential gateway would search services by matching service name syntactically. For appending addition semantic information to service, the service registry should be expanded as shown in figure 7. We add Function instances item to the service registry. The new item which stores the instance of the function provides the semantic information for service.

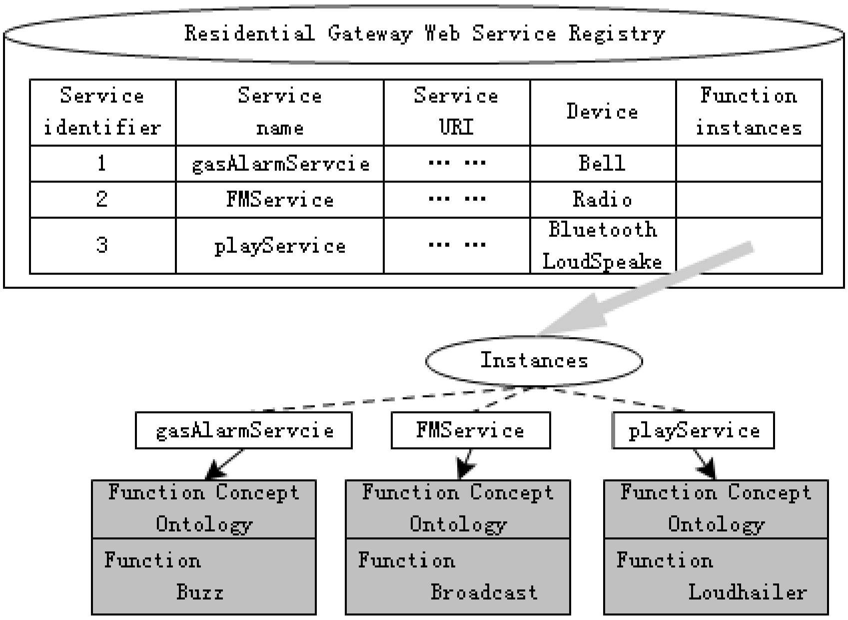

Figure 7 Instances of Function Concept Ontology

In the scenario, the above three services realize same Hear function with different ways. According to the principles which the devices adopt, the services could be annotated with lower degree of abstraction and more accurate functions. As shown in figure 7, the services are annotated by Buzz function, Broadcast function and Loudhailer function respectively. That is declaring instances for the function concepts and describing the services with the instances. The instances are declared as follow:

<Buzz rdf:id="Buzz_GasAlarmService "/>
<Broadcast rdf:id="Broadcast_FMService "/>
<Loudhailer rdf:id="Loudhailer_PlayService"/>

Then the URI address of instance of function concept ontology would be stored into the corresponding Function instances item of service registry.

4.2.2 Service Retrieval

When the gas secure device inspects that the poisonous gas has exceeded secure threshold, the alarm need would be motivated by the context. To satisfy the alarm need, we should represent the information about "gas leak" to consumer. Through analyzing the intention of need, Hear function could be selected to represent the information, it means that a service which is annotated with Hear function should be retrieved to satisfy the alarm need. Figure 8 shows the process from the need motivation to service selection for the scenario.

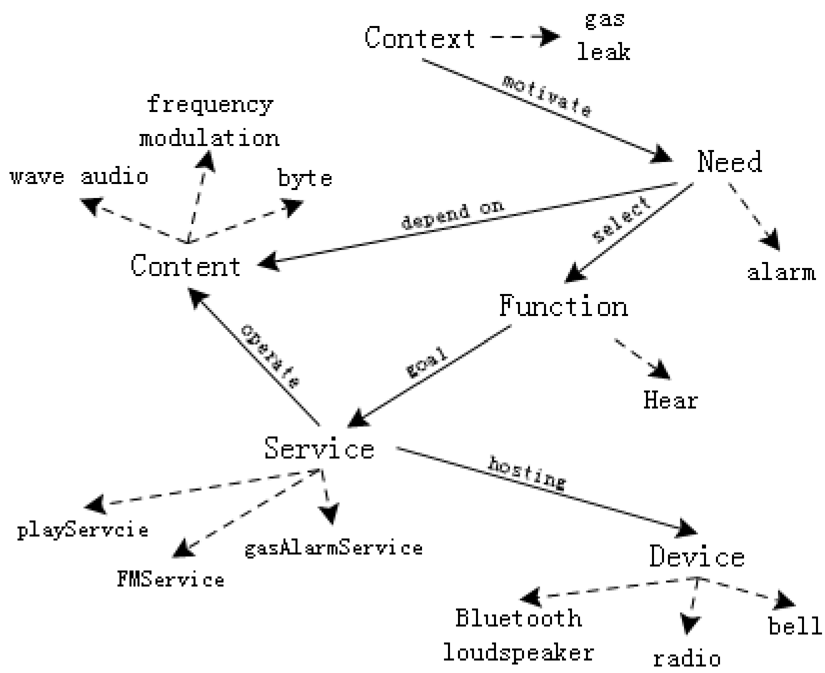

Figure 8 Service Selection

By appending service registry with function concept ontology, residential gateway could semantically search services by reasoning the instances of function which consumer requests. In the alarm scenario, residential gateway would reason the instances of Hear concept in function concept ontology. As figure 5 depicts, Buzz, Broadcast and Loudhailer are the sub-concepts of Hear concept. According to individual reason of ontology, the instances of sub-concept are also instances of parent concept. Thus by reasoning instances of Hear concept, gasAlarmService service, FMService service and playServcie service three services which are annotated by the sub-concepts of Hear concept would be retrieved.

If the alarm need select Represent function which is higher degree of abstraction and more general function as the intention of the need, then by reasoning function concept ontology we could achieve other services more than above three services. With broader sub-functions, the new achieved services may satisfy alarm need by presenting information with flashing red light or stimulating human perception etc.

4.2.3 Service Invocation

Once services which could represent alarm information are retrieved, the residential gateway should invoke the services automatically. The following would present how the gateway invokes above three audio-play related services.

(1) gasAlarmServcie

Both of gasAlarmServcie service provided by bell and gasDetectiveServcie service hosted on gas detective device are device-oriented services. The gasDetectiveServcie service would output bit 1, if the poisonous gas exceeds threshold. Then the input of gasAlarmServcie service would be bit 1, and the bell should ring to inform the alarm. The contents that the two services operate are consistent, so the services could transmit data with conduit. Namely above two services could be connected without any translation. Once the gasDetectiveServcie service detects danger, the gateway could invoke gasAlarmServcie service directly, as shown in figure 9(a).

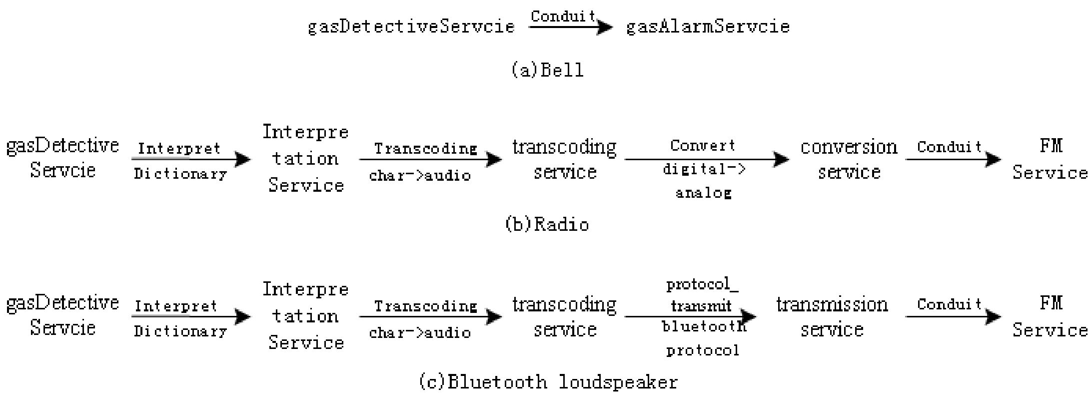

Figure 9 Service Chain

(2) FMService

Unlike gasAlarmService service the FMServcie service hosted on radio is user-oriented service, while the gasDetectiveServcie service is device-oriented service. It means that FMService service could not process the content given by gasDetectiveServcie service. Then two services should be connected with an interpretation service as medium, namely the gateway should search a service of which function is Interpret. The interpretation service would interpret the output bit “1” from gasDetectiveServcie service to text “gas leak”, and then transmit the text to FMService service as its input. The interpretation is based on the dictionary supplied by service provider. Afterwards we connect the interpretation service to gasDetectiveServcie service.

Moreover FMService requests frequency modulation signal as its input, while the output of interpretation service is digital signal. The carrier types of the contents are still inconsistent, it means that the carrier type of output should be converted into specific analog signal. So the gateway has to search a service whose function is Carrier_convert function to unify carrier type. By reasoning function concept ontology, several services which are annotated with Carrier_convert function would be retrieved. Among them there may be a service calls digital signal of which format is WAV as input and outputs frequency modulation signal. Then the conversion service could be connected to FMService. Although both contents operated by interpretation service and conversion service are digital signal, the formats of contents are still inconsistent. One is audio format data, the other is character format data. Accordingly a transcoding service is needed to harmonize the format of contents. It means that the gateway has to search a service of which function is Transcoding. If there exists a service transcodes Unicode text to WAV audio format, then through interpretation service, conversion service and transcoding service the output of gasDetectiveServcie service and input of FMService service are finally compatible, and the gasDetectiveServcie service and FMService service could be connected with assistant of above three services. The service chain is shown as figure 9(b).

(3) playService

Similar with FMService service of radio, the playService service hosted on Bluetooth loudspearker is user-oriented service as well, so as last section analysis an interpretation service should be connected to gasDetectiveServcie service to interpret bit “1” into text “gas leak”. Additionally the output of interpretation service and input of playService service are digital signals without consistent format, thus a transcoding service is also wanted to harmonize the format of contents for the same reason as above section analysis.

Further more Bluetooth loudspeaker has special demand for communication, it transmits data complying with the Bluetooth protocol. Thereby a service of which function is Protocol_transmit should be employed to transmit data between playService service and transcoding service. If the device which provides the transcoding service takes another protocol such as 802.11 protocol for communication, then the gateway should search services annotated by Protocol_transform which is sub-function of protocol_transmit to accomplish the interaction between different protocol services. Figure 9(c) shows the service chain for the connection between playService and gasDetectiveServcie.

4.3 Algorithm of Service Chain

For a given need, a specific function would be selected and the services which are annotated by the function should be retrieved by reasoning function concept ontology. Then the residential gateway should invoke the retrieved services automatically. However the input of retrieved service may be inconsistent with the output of its prior service, and the communication protocols of two services may be different as well. In order to connect retrieved service with its prior service smoothly, the gateway has to provide automated semantic translation for contents and transmissions between two services. We propose an approach uses a recursive back-chaining algorithm to determine a sequence of service chain with which the contents and transmissions of two services could be converted consistently.

Assuming that GoalService is target service, and GoalContent[N] are the contents that the GoalService operates. GivenService is original service which would provide contents to the GoalServcie, and GivenContent[N] are the contents that the GivenService operates. The following pseudocode representation of the algorithm returns a service chain, if the wanted services are existed in service registry.

```
findServiceChain (GoalContents[N], GivenContent[N]){
 For i=0 to N {
       chains[i].add (GivenServcie);
       chains[i].add (GoalService);
       contentMatched = transferContent (GoalContent[i], GivenContent[i], chains[i]);
       if not contentMatched
        return null;
       protocolMatched = transferProtocol (chains[i]);
       if not protocolMatched
        return null;
 }
 return chains;
}

transferContent (GoalContent, GivenContent, chain) {
 services = findServicesByFunction (Process);
 foreach service in services {
        if service.Output equal GoalContent
               if service.Input equal GivenContent
                      chain.insert (service);
               else {
```

```
                chain.insert(service);
                transferContent (service.Input, GivenContent, chain);
            }
        if chain.getNextService.Input equal GivenContent
            return true;
    }
    return false;
}

transferProtocol (chain) {
    preService = chain.getFirstService;
    linkService = chain.getNextService;
    while (linkService != null) {
        services = findServiceByFunction (Protocol_transmit);
        foreach service in services
            if service.protocol equal preServcie.protocol
            and service.protocol equal linkServcie.protocol {
                matched = true;
                chain.insert(service);
                preServcie = linkService;
                linkService = chain.getNextService;
                break;
            }
            else
                matched = false;
        if ! matched
            return false;
    }
    return true;
}
```

5 Conclusion

To automate the process from need motivation to service retrieval and invocation, this paper proposes home service ontology which is domain upper ontology for home field to explicate the relations among concepts based on home service context analysis. Then we construct function concept ontology by refining function concept of home service ontology to annotate the semantic of service. Finally we take alarm scenario of gas detective as an example to represents how to register, retrieve and invoke a service based on function concept ontology.

As home service ontology depicts, besides function, content and device also have close relationship with service. Consequently offering semantic information for content and device could assist service filtering. One step further, and part of our future work, is to construct content and device ontology by abstracting effect elements of service searching. With these two ontologies annotation, services with same function but different contents and devices could be distinguished.

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