Building a Ubiquitous Multimedia Information Delivering Service for Smart Home

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Abstract

In ubiquitous computing environments like smart home, residents can conveniently enjoy various home entertainments, such as watching TV, listening music, etc, through invisible and virtual interactions between residents and the home accomplished by ubiquitous computing. This paper designs a Ubiquitous Multimedia Information Delivering Service (U-MIDS) for smart home, U-MIDS can automatically deliver multimedia information, such as MP3 music, Internet radios, (Text-to-Speech) spoken online news, and personal spoken messages, to the residents according to their positions and behaviors in a smart home. Basically, the U-MIDS consists of RFID modules, embedded network media players and a U-MIDS gateway. RFID modules are used to identify the identities of home residents and which room they locate. An embedded network media player is a device broadcasting multimedia information to home residents. The U-MIDS gateway can control these network media players to play desirable spoken information, music, etc. Besides, we also integrate semantic concepts and inference rules into the U-MIDS hoping home smarter. That is, the gateway of U-MIDS can automatically provide proper multimedia services for its residents according to residents' preferences, locations, situations, etc. Through our proposed U-MIDS, the residents can be freely and easily gather the ubiquitous multimedia information upon their locations, preferences, and home intelligence all the time.

1. Introduction

Home network is a fundamental facility in a modern home [14]. It offers wireless and wired network environments to connect various computers and networked appliances, such as home computers, laptops, PDAs, set-top-box, networked media players, WiFi VoIP phones, etc. The residents can use home computers or laptops to surf the Internet, set the set-top-box to watch television or popular movies, make some phone calls with their families or friends through wireless VoIP phones, or listen to the music or network radios by using networked media players. Through the connectivity and convenience of home network, we can imagine that home network will detonate the next revolution of home automation [6].

In order to make home smarter [1], some autonomous and intangible interactions between residents and home environment should be carried out [8]. These autonomic and invisible interactions can help the residents to enjoy freely and relaxingly their desired lives without any manual controlling or setting of computer-equipped home appliances. Therefore, ubiquitous computing can be really applied to build a smart home for the residents.

In 1991, the initiator of ubiquitous computing, Mark Weiser, said that "Such machine cannot truly make computing an integral, invisible part of way people live their lives." [17], the main concept of ubiquitous computing is to integrate computers seamlessly into the overall real world. Therefore, ubiquitous computing lets users communicate directly with their computing objects and the environment in invisible and untouchable fashions. Therefore, ubiquitous computing can integrate with home automation to build a smart home.

Although ubiquitous computing lets the home and its residents have invisible and direct interactions, but their interactions lack abilities of context awareness to model desired contexts for residents' needs. Thus, many researches have devoted to context-aware computing and wish to improve the intelligence of smart home [1, 8].

In home, residents may enjoy listening music and watching television to relax their working pressures. Sometimes, home residents hope that the home may be smarter, that is, the home should actively play some spoken multimedia information to remind its residents what things happened or what things should do for them. These kinds of context information may include home situations, preferred settings of its residents, etc. Therefore, multimedia service used in spoken information notification will be one of significant issues designing the smart home in the future.

In this paper, we try to propose a ubiquitous concept of multimedia delivering service, which is called Ubiquitous Multimedia Information Delivering Service (U-MIDS). U-MIDS is able to adapt autonomously its providing services and fit its residents' needs upon contextual interactions between the residents and their surroundings in smart home.

Through our proposed U-MIDS, home residents can get proper multimedia information, such as listening music, radio or spoken notification, etc, according to their locations (living room or study room), preferences (favorite music or radio station), home situations (guests visiting or lunch preparing), and proper times (lunch time or leisure time), while they live in smart home.

The rest of this paper is organized as follows. Section 2 introduces some relative technologies about ubiquitous computing, etc., and the developing trend of home automation. Section 3 describes the design concept of our proposed U-MIDS for smart home. Section 4 explains the implementation of our proposed U-MIDS system. Finally, we will make a conclusion in section 5.

2. Related Works

With the rapid development of home automation technologies, building a smart home is not longer a sheer daydream. Building a smart home should integrate various computing technologies, such as ubiquitous computing, context-aware computing, home automation technology, etc, to make intangible and autonomous interactions around the residents, computer-equipped objects of smart home, and home environment. Besides, it is another import issue to achieve the personalized home services for different residents' needs. Next, the key technologies of constructing smart home will be briefly described as follows.

2.1. Smart Home Architecture

Smart home is able to automatically sense the changes of home situations, dynamically response corresponding reactions and autonomously help its residents to make more comfortable lives [1]. The overview of smart home is shown in Figure 1, and it consists of home (information) appliances, computer-equipped furnishings, home networks, home gateways and home services.

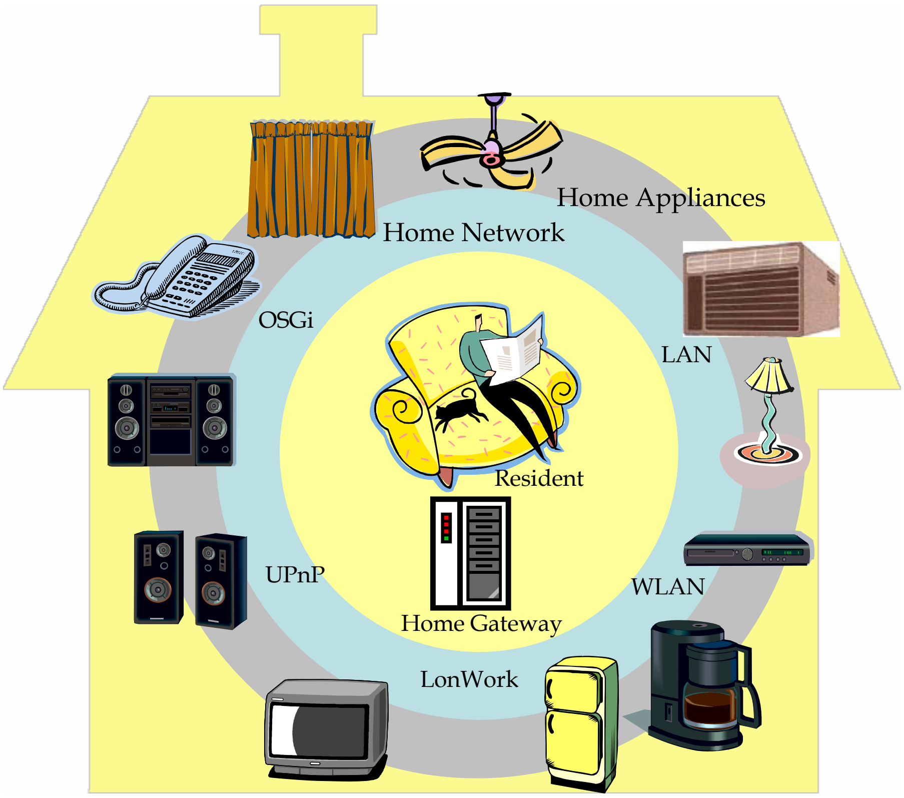

Figure 1. The overview of smart home

Home appliances and furnishings are connected together to form a home network through various home networking protocols and communicating mediums in home. Home gateway can assist residents cooperating interactive operations of those appliances and furnishings. Then, it can recreate a proper atmosphere for home residents according to their locations, situations and preferences. Finally, home residents can easily enjoy home services through autonomous operations of home gateway without any manned setting. However, which approaches can achieve living interactions between residents and smart home. These key issues can be accomplished by applying the context aware computing [2, 6, 11].

2.2. User Identification and Positioning of Smart Home

Every resident has his/her own living style. Smart home should be able to provide personalized home services for its residents. In order to identify various residents to provide personalized home services, identification technologies should be applied in smart home.

Radio Frequency Identification (RFID) is a well-kwon identification technology. RFID has wide applied to identify user identities and even provide different personalized services upon their identities. RFID is an essential of ubiquitous computing in smart home [12, 14]. Its residents can carry RFID tags and/or RFID tags are embedded into home equipments. Then RFID reader in home can intangibly sense these tags to identify and track where they are.

Through RFID, smart home can easily provide personalized home services for different residents.

Besides, identifying the locations or positions of home residents is a fundamental function in a smart home. RFID is also capable of identifying user locations based on the signal interactions between RFID tags and RFID readers. RIFD readers are usually installed on the fixed locations. Once home residents carrying RFID tags approach to the RFID readers, RFID readers will obtain the tag IDs accompanying home residents. After matching the relations between the sensed tag IDs and the location of RFID reader, it is very easy to know the current locations and position of identified home residents.

Although, RFID is able to identify home residents and their locations, and monitor their activities, the meaningful personalized context information has to be derived from raw data acquired by sensors. Many sensors and micro computer-equipped devices will be embedded into smart home to gather the contexts of personalized interactions between residents and smart home.

2.3. Context Modeling for Semantic Reasoning

Another important issue for building smart home is home automation. In fact, it is very difficult to reach the ideal home. For example, the residents may hope the home to automatically provide some proper services for them while staying in home according to their feelings and behaviors, and the environmental atmosphere around them. Thus, a well-known context model is needed for reasonable knowledge and concept expressions.

A proper context model can clearly represent the accurate meanings of context. Many researches have applied ontology technologies to model, classify and retrieve context information. For examples, Marek et al, [5] introduce the echo project for the museum guides. The framework incorporates the ontology context model into the Jess reasoning engine. The system records the objects which visitor has visited as his/her unique profile. While a visitor is roaming around the exhibition in further, the system can automatically provide guide or other proper audio objects in accordance with the user-defined rules in the reasoning engine.

Besides, Shu et al, also propose an algorithm to compute a semantic distance between each concept in ontology [13]. It is feasible to rank the depth of logical relation by compared with each property in the concept. This method facilitates the reasoning engine to decision the accurate decision.

In [10], there are five (4W1H) knowledge concepts, such as Who, What, Where, When, and How, that can clearly and easily model meaningful contexts of home interactions between smart home and its residents. That is, any context in home can be constructed by five concepts. For example, who concept takes the resident identification, where concept keeps the resident's location, when concept keeps the occurring time of context, what concept stores that what event should be happened, and how concept describes that how to do in this condition. Therefore,

As mentioned above description, the major benefit of ontology is to assist the system making a sensible decision after context interpretation and inference. This decision can lead the context aware system providing adapted services according to various contexts and situations.

2.4. Ubiquitous Multimedia Home Services

Smart home can provide various types of home services. These services may include autonomous adaptation of living circumstances, automatic cooperating of home appliances, self-acting home securities, high enjoyments of multimedia entertainments, smart living interactions of personalized resident preferences, etc. The target goal of smart home services is to facilitate more comfortable lives for its residents.

Multimedia home service is more popular among these services, because smart home has various embedded multimedia devices recessed in the wall to broadcast multimedia information. Besides, humans have sensory organs, such as eyes and ears, to recognize the information they feel. Therefore, home multimedia service is a good way of human-machine interfaces to communicate between smart home and its residents.

Through multimedia home service, home residents can easily listen to music, radio and spoken information notifying the changes of home situation from smart home. Even residents move around different rooms, multimedia home service is seamless and ubiquitous around them.

Building a smart home should indeed apply various embedded facilities and computing technologies to realize it, let the home have smart intelligence to help its residents making easily home lives. For these issues, this paper will focus on designing a ubiquitous multimedia service of smart home, and hope its residents can ubiquitously hear much multimedia information while they reside in it through this multimedia home service [15].

3. Design Concept of U-MIDS

In previous sections, we have discussed some issues on ubiquitous computing, personalized services, and intelligent home services in smart home environment. In this section, we will propose a ubiquitous concept to build a ubiquitous multimedia information delivering service, which is called U-MIDS, for smart home. The system architecture of U-MIDS is depicted in Figure 2. At first, we will discuss which hardware devices are needed in our proposed U-MIDS.

3.1. Hardware Devices

From the viewpoint of hardware facilities, U-MIDS consists of a multimedia home gateway, embedded network media players, and RFID modules. Multimedia home gateway is responsible for identifying and tracking residents' identification and positions, and then delivering proper multimedia information to them according to their needs and situations. Each room will install an embedded network multimedia player to play various multimedia contents.

The main task of RFID modules is to identify and track residents' identification and location. In this paper, we use active RFID technology to achieve active wide range of user identification and tracking. Moreover, RFID modules consist of an active RFID reader positioned at home, active RFID field generators located at every room, and active RFID tags carried by residents. Figure 3 shows the process identifying and tracking home residents among non-contact interactions between RFID field generators, RFID tags, and RFID readers.

The RFID field generator is a tag "wake-up" device that sends out the field signal containing unique room identification continuously and periodically. When a resident enters the room, his/her tag is awakened and transmits identifying data to RFID reader asynchronously.

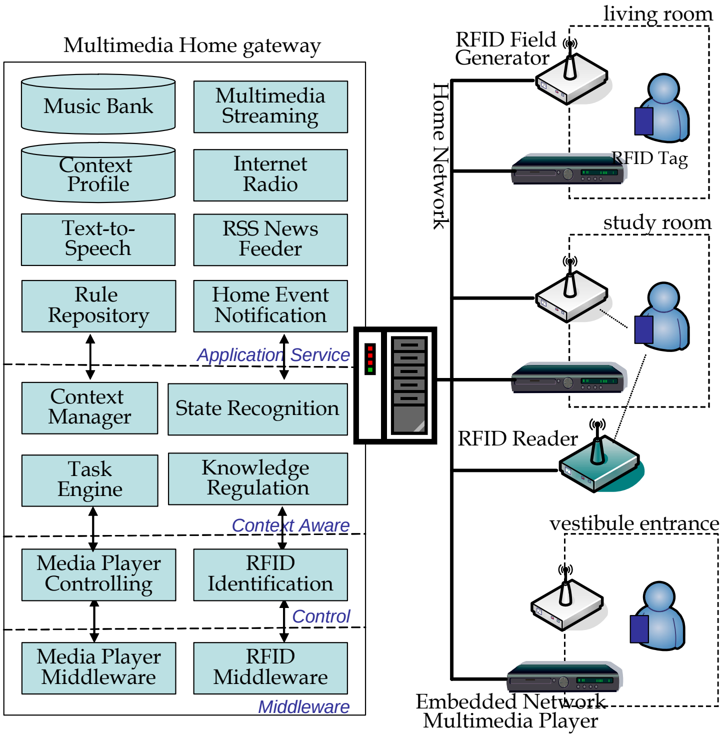

Figure 2. U-MIDS System Architecture

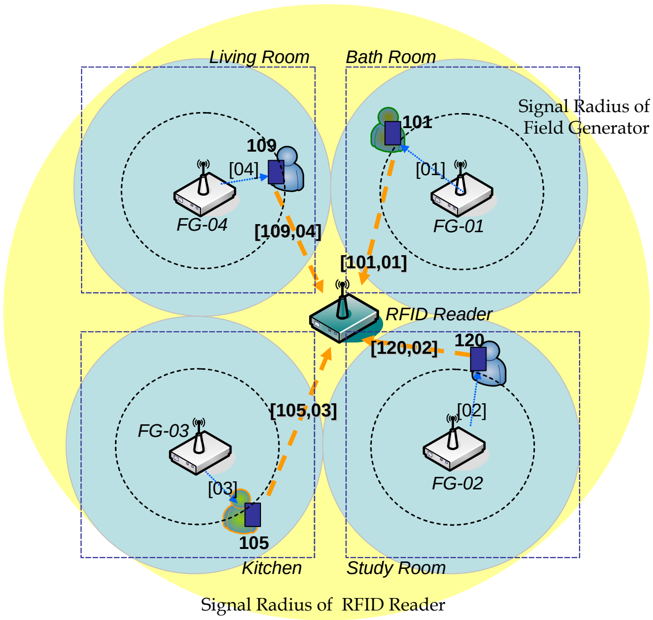

Figure 3. Using active RFID modules to identify and track identification and location of home residents

Afterwards, the reader receives the identification signal containing tag and field identifications from the awakened active tag. By the way, smart home is able to achieve basic user identification and location tracking functions. These functions can assist smart home to realize personalized home services for different residents. Besides, home residents may dynamically move among the home rooms. The multimedia home service is able to be redirect to their current positions and to achieve seamless and ubiquitous multimedia home services for moving residents.

3.2. Multimedia Home Gateway

Multimedia home gateway is the most significant component in U-MIDS. This gateway is divided into four layers: middleware, control, context aware, and application service layers. The main functionalities of home gateway will be described as follows.

Middleware Layer

The Middleware layer is an interface that provides a uniform interface for connecting the heterogeneous multimedia appliances and RFID modules over home network [2]. Currently, middleware layer we designed contains two main interface modules, one is media player middleware and another is RFID middleware. Both of them play a role of broker between physical devices and the abstraction services provided from the upper layers of home gateway [9]. The media player middleware is responsible for communication with various networked multimedia devices through different controlling and signaling protocols designed by different hardware manufactures. That is, media player middleware has a media broadcasting ability to play multimedia information via various networked multimedia devices under proper multimedia controlling protocols in a home network.

Another middleware, RFID Middleware, is responsible for a bridge between incoming tag information sensed by RFID readers and internal personal identifying information, such as resident name, or identity. That is, this middleware converts the incoming raw machine data into more semantic context. After this procedure, the upper layer of the gateway can make a further inference through the meaningful information converted by the Middleware layer.

Control Layer

The control layer of the gateway composes of various controlling units that can assist the gateway to operate different home appliances and RFID modules by using a uniform fashion through the middleware layer. This layer currently has two modules. One is media player controlling and the other is RFID identification. Media player controlling module is responsible for managing embedded network multimedia players, and RFID identification is in charge of residents' identification and tracking in smart home.

The goal of control layer is to hope that home gateway can operate different home appliances having same functionalities manufactured by different vendors in a uniform fashion. That is, our U-MIDS can equip with various network multimedia devices. Various devices may have different mechanisms or protocols to remotely operate these devices while playing multimedia information. Home gateway does not individually understand the complex device protocols or control units. Control layer will abstract similar control functions from different devices to be a uniform control interface. For example, the play command can be seemed as a common abstracting function among various networked multimedia devices. The gateway can choose any proper multimedia device and only sets the abstracting play command to play multimedia information. Currently, there are many various RIFD types and standards. For the same reason, the gateway a RFID control module in control layer to abstract various control mechanisms to be a uniform control function to operate different RFID readers and related modules.

Context Aware Layer

The context aware layer is the core of U-MIDS. It consists of context manager, state recognition, knowledge regulation and task engine modules. The module, context manager, is a repository for storing the context-aware concept provided from RFID readers. This component takes charge of providing accurate contexts to be instances of the ontology and maintaining their correctness of the instances.

Due to the different characteristics of each sensed context, contexts can be simply classified into two categories: persistent context and temporary context. Persistent context is difficult to be changed in the whole process such as the identifications information like person, object and region. In the opposite, temporary context is the information with certain restrictions, especially timing property. For example, the context of user location belongs to temporary context. Its context value will be changed while the use moves to another place. Once the time property of location context is expired, the context manager must gather the newest user location to maintain its correctness of the context again.

Knowledge regulation module is the key point of the context model in our U-MIDS. It takes charge of collecting all the contexts to construct the system ontology. The contexts may include residents' profiles, environmental description of smart home, object contexts stored from context profile in application service layer and context-aware context derived from context manager in context aware layer. The system uses the OWL (Web Ontology Language) to construct its context model [18]. Figure 4 shows an OWL example describing context entities and their properties, which include person, region, device, service, etc.

This approach can not only represent the information as the RDF-triple format explicitly, but also provide various vocabularies to describe the relationships between various concepts. Among these special vocabularies, there are the part of logic symbols, such as disjointness, symmetry and intersection, to assist the developers defining the association between classes and rules for reasoning. Thus, the ontology is responsible for providing available instances to help the reasoning engine to make a reasonable decision for satisfying the demands of home residents staying at home.

In order to clearly associate the relations among context entities, we adopt several key concepts from the research in [4], which is depicted in Figure 5. The context entities of the ontology are classified into five entities: person, location, device, activity and service entities. Personal entity is the main entity of the ontology describing personal identity information, e.g., RFID tag ID. It uses the "own" relation to associate with the device entity, the "located" relation to refer the region entity and " expect" relation to link the activity entity for a specific service respectively. Region entity represents the environmental context at certain location of the smart home. For example, the identity of RFID field generation can be seemed as the room ID in our U-MDIS. Device entity defines the service capability of the device, e.g., internet radio service provided from a network multimedia player. The Activity entity has two sub-entities. One is scheduled entity describing the context of user schedule stored in 4W1H format, and the other is deduced entity that can make a reasonable decision to form an appropriate service for home resident after the context interference by using the reasoning engine.

```
<rdf:RDF
  xmlns:    ="http://example.org/eg#"
  xmlns:eg  ="http://example.org/eg#"
  xmlns:rdf ="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
  xmlns:rdfs ="http://www.w3.org/2000/01/rdf-schema#"
  xmlns:xsd ="http://www.w3.org/2001/XMLSchema#"
  xmlns:owl ="http://www.w3.org/2002/07/owl#"

  <owl:Class  rdf:about="#Person"/>
  <owl:Class rdf:about="#Regoin"/>
  <owl:Class rdf:about="#Device"/>
  <owl:Class rdf:about="#Service"/>
  <Person rdf:about="#Tophina">
    <own rdf:resource="#PDA1"/>
    <located rdf:resource="#bedroom"/>
  </Person>
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    <hasDevice rdf:resource="#Computer"/>
  </Regoin>
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    <hasDevice rdf:resource="#Television"/>
  </Regoin>
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    <rdfs:range rdf:resource="#Device" />
    <rdfs:domain rdf:resource="#Region" />
  </owl:ObjectProperty>
  <owl:ObjectProperty rdf:ID="hasService">
    <rdfs:range rdf:resource="#Service" />
    <rdfs:domain rdf:resource="#Device" />
  </owl:ObjectProperty>
</rdf:RDF>
```

Figure 4. Using OWL to construct the context model of U-MIDS

State recognition is a reasoning module that can determine a suitable multimedia services inferred from the arranged contexts. That is, the state recognition analyzes the collected contexts, and then makes a corresponding decision lunching proper multimedia services to the particular residents [4, 6].

In additions, we adopt Jena inferential engine (http://jena.sourceforge.net) to be the core of state recognition. Jena inferential engine allows the developers defining RFD schema, OWL schema or user-defined rules as its knowledge base. Once ontology instance is captured, the engine can reason the current instance based on that. Besides, rule repository from application service layer takes charge of providing various types of the rules to assist inference engine to determine whether service should be triggered to server specific residents.

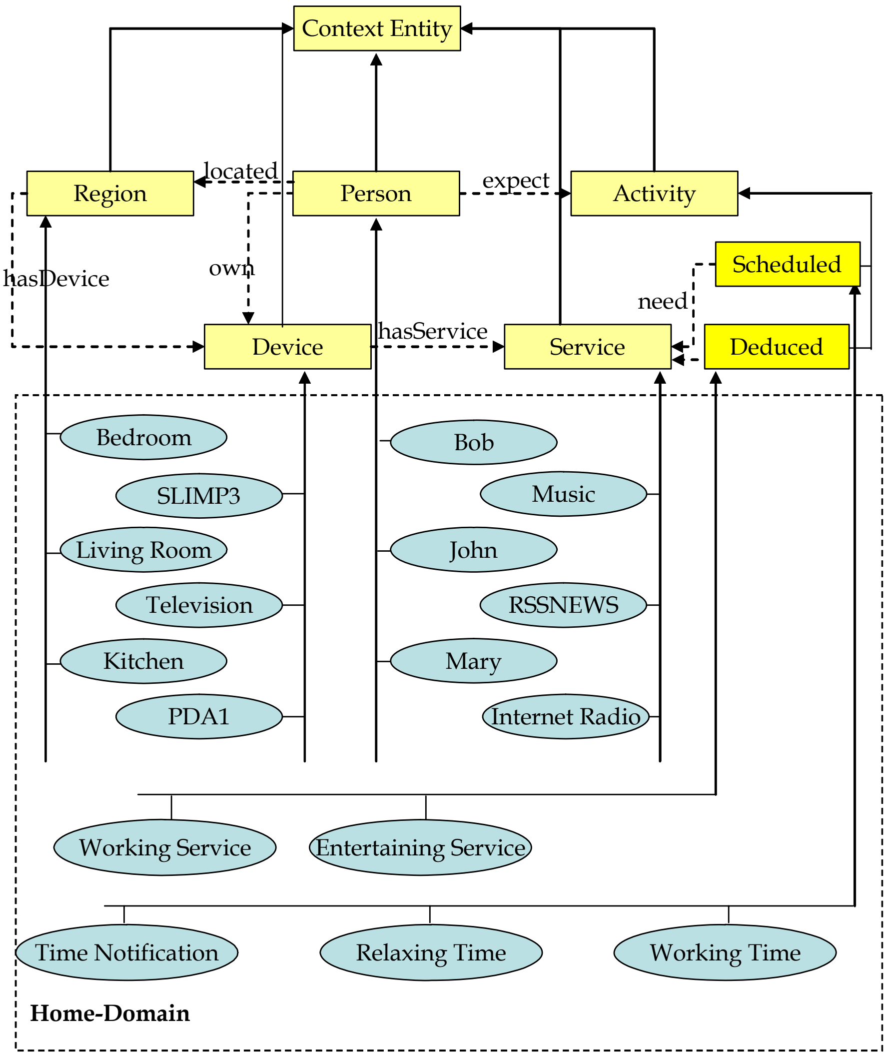

Figure 5. Associating the relations between context entities

Although state recognition can apply the rule inference to deduce reasonable services for home residents according to the sensed context and its knowledge regulation, a problem, multiple inferred results at the same time, still should be solved It is very difficult for the traditional inference engine to decide which service is the most proper without heuristic or manual assistance. Therefore, our system adopts the method similar to the research in [7], the state recognition will rank the scores of matching results by comparing each property between the service context from deduced and scheduled entities. After this process, the state recognition will trigger the most favorite service for home residents.

Task engine is an executing module. It may run multimedia home for home resident services upon the inferring decisions from state recognition at smart home. Besides, it will deal with the control layer of home gateway to perform some home facilities and deliver suitable multimedia information to its residents based on the inferring results.

The main interactions among the modules of the context aware layer of home gateway is shown in the Figure 5 and their operational flows are also listed as follows:

1. Context manager and context profile components provide the schema and instance contexts of knowledge regulation to construct its own ontology model.

2. After the ontology model has been constructed, state recognition loads the contextual data and related rules from the knowledge regulation and rule repository respectively. State recognition also begins to start the Jena reasoning engine for executing the rule-triggered inference procedure.

3. Once a service rule is triggered, state recognition will notify the task engine to execute the most fitting service for home resident according to the inferring results. Besides, if more than one service rules have been triggered in the same time, sate recognition would compute the semantic distance between user preferences and each service context in deduced active entities. Then the component would adopt the highest ranking service to execute.

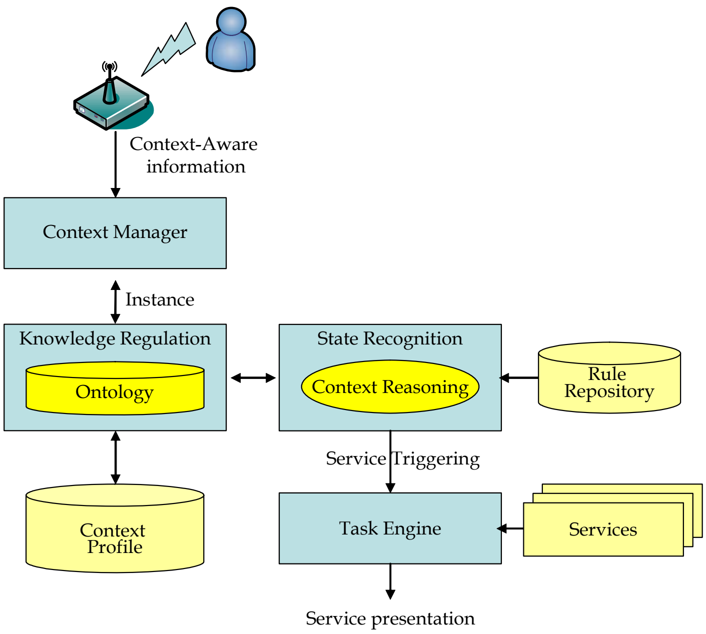

Figure 6. Operational interactions among the modules in the Context Aware Layer

Application Service Layer

The most upper layer of multimedia home gateway is application service layer. This layer can be classified into two categories, one is the service of multimedia streaming services and the other is the system repositories of the contexts, objects and inferring service rules.

Application service layer provides various multimedia information services constructing a ubiquitous multimedia home environment, such as multimedia streaming, internet radio, RSS news feeder, home event notification, and text-to-speech modules. The multimedia streaming module is the key function of the corresponding multimedia services, its main function is converting the multimedia object into the media streaming. This step is necessary because the system must provide the streaming media content to each media player everywhere in the smart environment through internet. Therefore, others services will apply the streaming service to process the media objects for data delivery before playing them to home residents.

Internet radio service is developed in our proposed system. The reason is that the most of radio stations have provided Internet radio services nowadays. Home residents can set the favorite radio station addresses in their user profiles stored in context profile, and then the system can play proper internet radios through networked media players according to the expectancies of home residents in home.

If the home is so smart, it will actively notify some home information or other things to its residents. Thus, home event notification module is able to automatically inform home residents about home situation upon associated home contexts. Besides, this module also can act the personal home secretary. That is, it can assistedly remind home residents that something should do upon some conditions and rules defined in their context profile.

In order to provide an advanced human-machine interface between smart home and its residents, the text-to-speech (TTS) module is proposed. This module uses voice synthesis to translate text into spoken audio, and spoken audio can be played through the networked media player. Home residents can directly understand the information spoken by synthesis voice. Thus, home event notification module may apply TTS module to generate spoken information informing home residents.

Many newspaper companies have already provided the really simple syndication (RSS) services of online news. Home residents can apply RSS news feeder module to subscribe the favorite news. This module will periodically retrieve the latest headlines from on-line news provides, and then speak them through a networked media player after TTS translation. Therefore, the gateway can automatically deliver the up-to-date news by spoken fashion to its residents while staying in home.

Home gateway has three main repositories, music bank, context profile, and rule repository, to store musical media, context entities, and inference rules respectively. Music bank is responsible for storing all the multimedia objects of the system, such as mp3-based music/song files. Context profile stores the environmental description of smart home, user profile and personal preferences of home residents, etc. It uses the well-known 4W1H (Who, What, Where, When, and How) concepts of knowledge representation [10] to model home contexts and residents' preferences.

The advantage of 4W1H concepts is an easy fusion method to infer some a reasonable decision by the rule matching approach. For example, the system can conclude there is a service that can present it for a person, it is easily to concern with who domain. The user location is refer to where domain. Similarly, the device contexts with the service abilities is refer to how domain. Finally, the sensed information containing the time information is refer to the when domain. Therefore, the system can make a good decision to provide the most appropriate multimedia service to its residents in smart home. Figure 7 shows a context model describing user behaviors and preferences of home residents by using the 4W1H concepts.

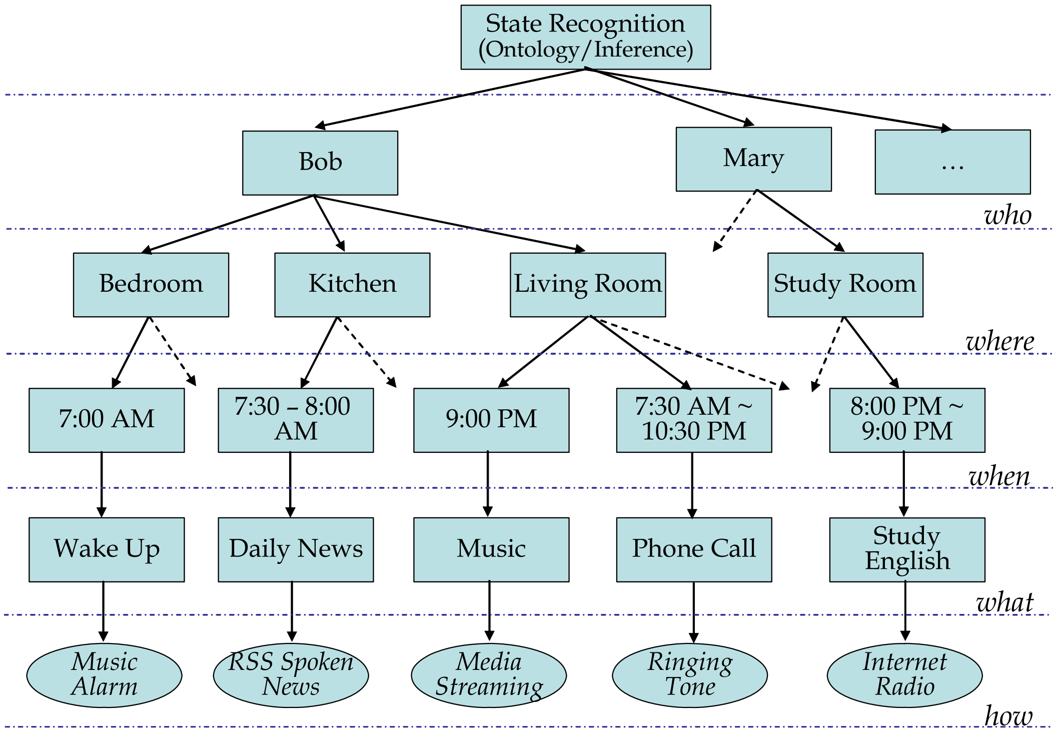

Figure 7. An example of home-context descriptions using the 4W1H concepts

Rule repository is a rule database used by the reasoning engine. The final goal of these rules is to infer proper services for home residents they want. The rule format is described like as Lisp language. Table 1 shows a partial list of inferring rules to reason in our proposed multimedia services.

Table 1. A partial list of inferring rules for reasoning

Decision Rule	Description
MusicBroadcasting	(?A type Person),
	(?A located ?B),
	(?B type EntertainingSpace),
	(?B hasDevice ?C),
	(?C hasService ?D),
	(?D type MusicBroadcasting)
	→ (?A expected MusicBroadcasting)
EntertainingSpace	(?A type regoin),
	(?A hasDevice ?B),

	(?B hasService ?C), (?C type EntertainingService) → (?A type EntertainingSpace)
Entertaining_music	(?A type Service), (?A type MusicBroadcasting) → (?A type EntertainingService)
Entertaining_radio	(?A type Service), (?A type InternetRadio) → (?A type EntertainingService)

4. Prototype Implementation of U-MIDS

In order to realize the possibility of achieving the U-MIDS in smart home, this section presents a prototype implementation based on our proposed U-MIDS platform. A prototyping scenario of the U-MIDS is shown in Figure 8.

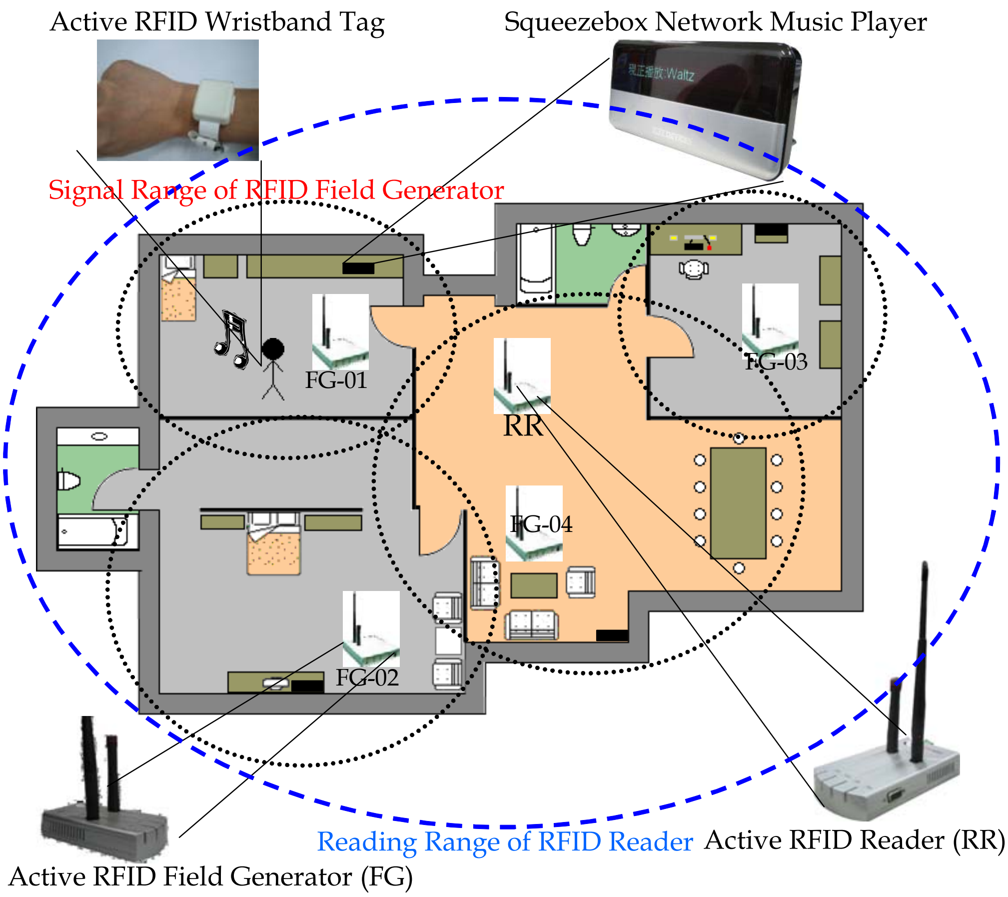

Figure 8. A prototyping scenario of the U-MIDS

In our prototyping U-MIDS, we use the Squeezebox Network Music Players manufactured by the Slim Devices Inc. (http://www.slimdevices.com) to be ubiquitous network media players embedded into every room in smart home. Squeezebox is an affordable way to deliver music into every room of your home. It plays a wide variety of digital music files, including uncompressed and lossless formats, across a true 802.11g wireless network connection. Squeezebox also has a large size of high-resolution vacuum fluorescent display. It is able to be a ticker to display the text-based scrolling information on it upon our requirements. Therefore, Squeezebox is very proper to be an essential audio property of smart home.

The functions of resident identification and tracking in U-MIDS are done by the ActiveWave RFID solution manufactured by ActiveWave Inc. (http://www.active-wave.com). This solution is an active RFID technology providing long-range identification. Its RFID tag has a read range of up to 85 meters. ActiveWave field generator and rFID Reader are able to adapt the signal strength to adjust the effective reading range of RFID tags according to different identifying conditions. Thus, it is also recommended to be a wide range solution of user identification and monitoring. By the way, in our proposed smart home every resident brings a wristband RFID tag on his/her wrist. Home residents can freely and precisely be positioned and tracked in home by using ActiveWave RFID solution.

After illustrating the hardware facilities equipped within smart home, a multimedia home gateway of U-MIDS has been built. Several application services described in section 3 have been implemented and integrated into the multimedia home gateway of UMDIS, such as media streaming and Internet radio services, device controls of the Squeezebox followed by the SLIMP3 client protocol proposed by Slim Devices Inc., text-to-speech translation functioned by IQ-MP3 which is a TTS product of IQ Technology Inc. (http://www.iq-t.com), spoken rss online news, personalized voice secretary, home event notification, etc.

A screenshot of the U-MIDS gateway is depicted in Figure 9. The U-MIDS gateway can show that how many residents are in it, where they are, and what things they do now. If its residents move around different home rooms, then it will deliver proper multimedia information to the rooms they stay upon the inferring decision of the U-MIDS. Figure 10 shows a snapshot of Squeezebox in living room. It illustrates that Bob stays at living room at 6:30 pm, listens his favorite song - “Inner Universe”, and reads the headline evening news from Squeezebox.

Figure 9. A screenshot of the U-MIDS gateway

Once U-MIDS senses an update-to-date context collected by context manager, state recognition may apply inferring rules from rule repository to reason that which service is feasible for home resident upon the current contexts. For example, Bob moves to the bedroom from the kitchen. The location property of person entity about Bob will be immediately updated for keeping the correct context value. Table 2 shows a partial result of context inference according to the rules depicted in Table 1 after the context reason process. The inferred context means that Bob stays at bedroom now, there is a SLIMP3 device, and four kinds of multimedia services provided from SLIMP3 device are available for Bob. As the result, the system decide which service is the best for home residents after computing the semantic distances among the inferred service context and the environmental context stored in context profile. Figure 11 illustrates a decision result after reasoning process. It shows that Musicbroadcasting service has the highest ranking score after semantic distance computing, and then the system finally makes a decision to provide the MusicBroadcasting service, which is better than others, for Bob at bedroom, By the way, the home will automatically offer appropriate services to its residents based inference result of state recognition and home intelligence can be achieved simultaneously.

Figure 10. A snapshot of the Squeezebox Network Music Player

Table 2. Partial inferred results in reasoning process

eg:bedroom
- (eg:bedroom rdf:type eg:Workingspace)
- (eg:bedroom rdf:type eg:Entertainingspace)
- (eg:bedroom eg:hasDevice eg:Computer)
- (eg:bedroom eg:hasDevice eg:SLIMP3)
- (eg:bedroom rdf:type eg:Regoin)
eg:Bob
- (eg:Bob eg:expect eg:MusicBroadcasting)
- (eg:Bob eg:expect eg:RSSNEWS)

- (eg:Bob eg:expect eg:Message)
- (eg:Bob eg:expect eg:InternetRadio)
- (eg:Bob eg:located eg:bedroom)
- (eg:Bob eg:own eg:PDA1)
- (eg:Bob rdf:type eg:Person)

eg:device

- (eg:SLIMP3 eg:hasService eg:Multimedia_broadcasting)
- (eg:SLIMP3 rdf:type eg:Device)

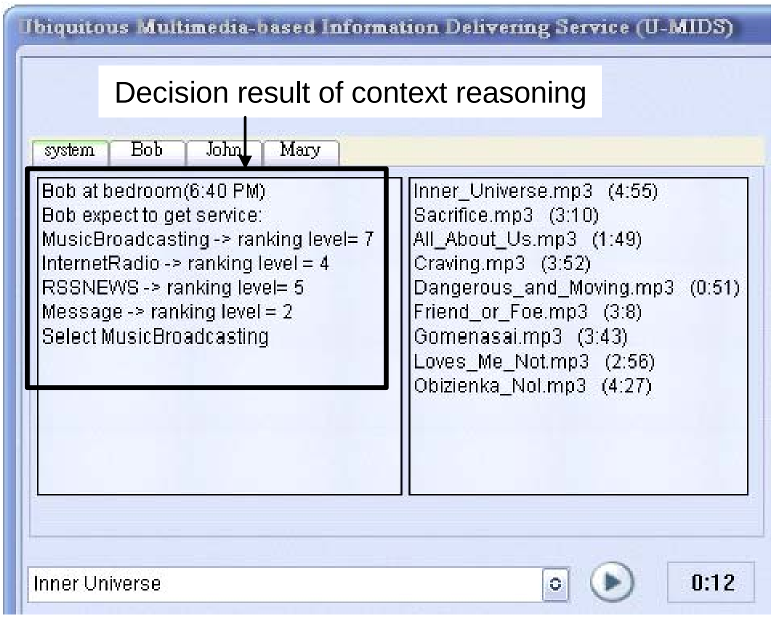

Figure 11. Decision result after context reasoning process

5. Conclusion

In this paper, we propose a ubiquitous multimedia information delivering service (U-MIDS) for smart home. We have also integrated an active (ActiveWave) RFID solution and embedded (Squeezebox) network media players to realize a prototyping implementation of the U-MIDS. Through U-MIDS, home residents can enjoy ubiquitous multimedia services in home.

Besides, U-MIDS also integrates context ontology and inference engine to make the home smarter. Using context ontology, it can assist the home reasoning over low-level raw contexts to derive out the high-level abstracting context. Thus, U-MIDS can easily apply the context aware concept to perform feasible multimedia service for home residents based on the inferring result of collected context by home.

Although our proposed U-MIDS can provide various audio-based multimedia services for home residents in smart home, there are still several new trends and issues of smart home that can be integrated into the U-MIDS, such video-based multimedia services, advanced identifying and tracking mechanisms – bioinformatics identification and wireless sensor networks, home automation, environmental surveillance and home security, home healthcare, etc. Through ubiquitous and context aware computing technologies to achieve above services, we believe that the dream of smart home will come true in the future.

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