Design and Implementation of Smart Home Energy Management Systems based on ZigBee

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Abstract — *Today, organizations use IEEE802.15.4 and ZigBee to effectively deliver solutions for a variety of areas including consumer electronic device control, energy management and efficiency home and commercial building automation as well as industrial plant management. The Smart home energy network has gained widespread attentions due to its flexible integration into everyday life. This next generation green home system transparently unifies various home appliances, smart sensors and wireless communication technologies. The green home energy network gradually forms a complex system to process various tasks. Developing this trend, we suggest a new Smart Home Energy Management System (SHEMS) based on an IEEE802.15.4 and ZigBee (we call it as a "ZigBee sensor network"). The proposed smart home energy management system divides and assigns various home network tasks to appropriate components. It can integrate diversified physical sensing information and control various consumer home devices, with the support of active sensor networks having both sensor and actuator components. We develop a new routing protocol DMPR (Disjoint Multi Path based Routing) to improve the performance of our ZigBee sensor networks. This paper introduces the proposed home energy control system's design that provides intelligent services for users. We demonstrate its implementation using a real environment.*

Index Terms — Smart Home, Energy Management, ZigBee, Sensor network.

I. INTRODUCTION

Moving towards the smart energy management will require changes not only in the way energy is supplied, but in the way it is used, and reducing the amount of energy required to deliver various goods or services is essential. The smart energy market requires two types of ZigBee networks for device control and energy management. These include neighborhood area networks for energy, using ZigBee for sub-energy within a home or apartment, and using ZigBee to communicate to devices within the home [1].

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Recently, Progress in personal home network device designs and wireless sensor network enables the Ubiquitous Computing environment [2]. It is to become a reality. This model certifies to provide adaptive information and services to users anywhere anytime using different devices.

ZigBee network model services have been proposed in different domains of our everyday life such as in homes, offices, streets, building and school. The wireless sensor network in the home area can be distributed in different various services throughout our daily lives. Developing assassin applications model and services for ubiquitous home network will confer important business value [1].

A number of projects and research have developed ubiquitous home network models. Compared to traditional home networks, the in-progress ubiquitous home network collects user activity awareness, as well as physical sensing information in the home environment, to support more smart and well-being home services. It has the essential to easy control consumer home network services used in livelihood. Eventually, users will experience the convenience of performing ordinary life styles and increased satisfaction offered by adaptive home services. Context-aware [3] is a kind of intelligent computing activities. For the humans, context-awareness is an essential capability for understanding the implicit information that is associated with the activities that they conduct. For example, context-awareness enables a person to follow an continuing conversation, and context awareness can help to guide the appropriate actions of a student when the student enters a classroom. For the computing systems, however, context-awareness is the capability to provide relevant services and information to the users based on their situational conditions (i.e., contexts). Several conditions are required to reap advantages from the ubiquitous home network. For instance, Context aggregator [3] should integrate diversified sensing information to perceive the current situation in the surrounding environment. Also, they should be able to control various consumer home devices. Therefore, Context aggregator should be designed distributing various tasks into proper computational units to reduce complexity. The home network systems may become complex, as the number of sensors and devices offered increases. Using a wireless sensor network with actuator functionality, our system can automatically gather physical sensing information and efficiently control various consumer home devices.

The system can efficiently distribute various tasks related to home network to corresponding components and implement real ubiquitous home services via smart sensors and actuators deployed in home areas.

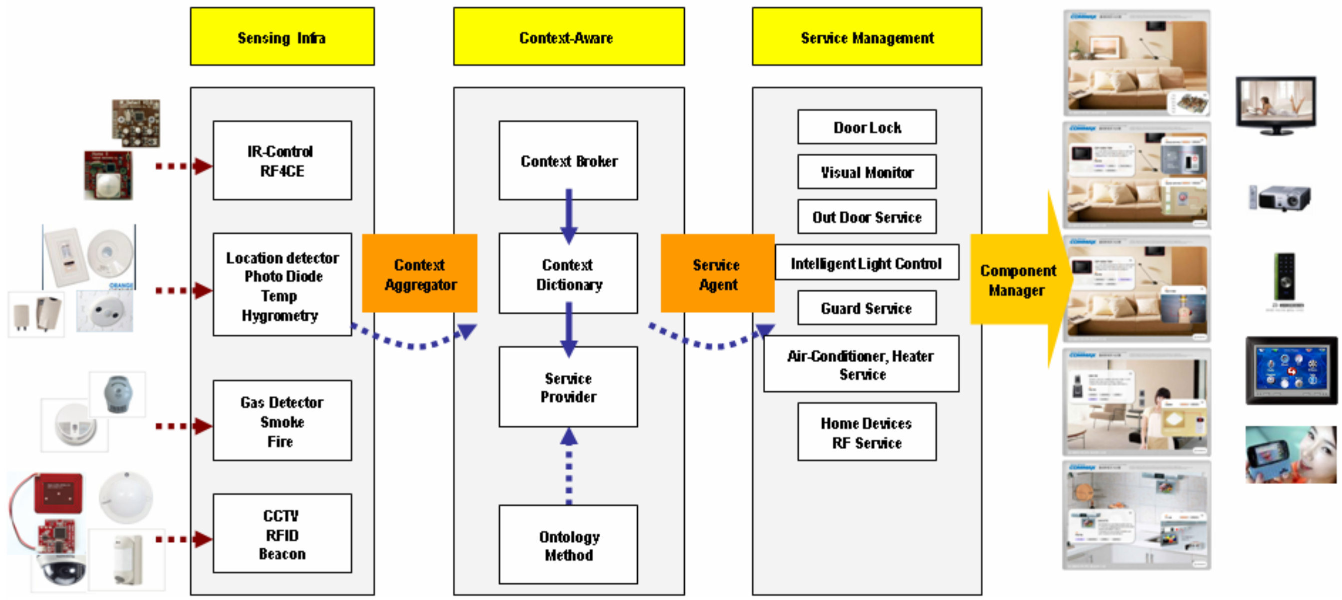

Fig. 1 Overview of the proposed Smart Home Energy Management System

Fig. 1 shows an overview of the proposed smart home energy management system. The system, being supported by underlying personal area networks and additional wireless communications technologies, can control consumer home devices such as lamps, gas valves, curtains, TVs, and air conditioners. It also interoperates with various mobile devices, such as PDA and mobile phones, using IEEE 802.11/802.3. Our Smart Home Energy Management System (SHEMS) based on personal area networks consists of various software components as follows.

Sensing Infra: The component gathers sensing data and special event information from the personal area networking infrastructure deployed in home environments. This sensing component provides this information to the decision component. A consensus definition of context is a collection of information that characterizes a person or a computing entity. Within in the smart space environment, I define the notion of context as the following: by context, I mean an understanding of a location and its environmental attributes (e.g., temperature, noise level, light intensity), and the people, physical objects, and computing entities that it contains. This understanding necessarily extends to modeling the activities and tasks that are taking place in a location as well as the beliefs, desires, commitments, and intentions of the human and the software agents involved.

Context-aware: Context-aware is a kind of intelligent computing behavior. For the humans, context-awareness is an essential capability for understanding the implicit information that is associated with the activities that they conduct. For example, context-awareness enables a person to follow an ongoing conversation, and context awareness can help to guide the appropriate behavior of a student when the student enters a classroom. For the computing systems, however, context-awareness is the capability to provide relevant services and information to the users based on their situational conditions (i.e., contexts). The following are some typical use case scenarios of context-aware systems in a smart meeting room environment: There are great challenges in building context-aware systems, developing accurate sensors to acquire information from the physical environment, building software infrastructure and tools to interpret and process the sensed information, creating data management systems to manage and store contextual data for later retrieval, and developing frameworks to address security and privacy issues associated with the context-aware systems.

Service Management: The decision component then adaptively selects the correct home services based on the current home state of affairs.

This paper details our proposed system and its implementation. The offerings of our projects are as follows: First, we suggest a more SHEMS based on wireless sensor networks and design it to be more adaptive with a network services component based approach. Second, we develop a new sensor routing protocol to gain adaptive control of smart sensors and sensing infra. Third, we implement hardware and software utilized in our system. Fourth, we show how real SHEMS scenarios operate and are implemented successfully in our system.

II. RELATED WORK

In this section, we briefly inspection the existing systems for SHEMS and, based on their main contributions, try to classify them into three types: *Context Aggregator oriented, Context Aware oriented and Service Engine oriented*. First, some work has focused on how to make the decisions for the home networks more efficiently. For example, the Mv Home project

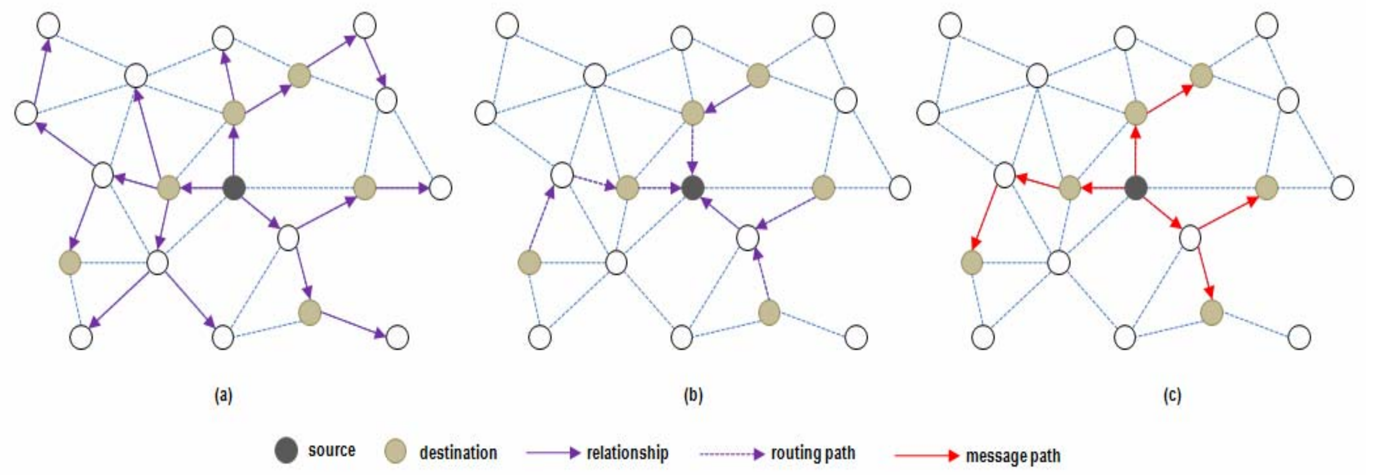

Fig. 2 Overview of the proposed DMPR

[3] focused on the design of intelligent agents and the role of prediction algorithms, based on the inhabitants' repetitive actions to automatically provide adaptive home services.

The Smart Aware Home project [4] deals with decisions about the inhabitants' location and movement detection within a house, utilizing multi-camera tracking, audio/video sensors and automated disjointing of sound sources. Secondly, the research effort for providing more convenient and smart services for home environments has also been conducted. The ZigBee home network systems [5] utilized pressure-based floor sensors to achieve efficient recovery and summarization of video and audio data. When a pressure-based floor sensor detects the person's movement, the information is analyzed to index the video and audio sensor data. This demonstrates efficient multimedia services for the human movement patterns. Bae et al.[6] proposed TV-oriented design to manage data broadcasting services, based on a common purpose platform middleware. Stankovic et al.[7] presented challenging issues for the provision of healthcare services in the home arena. Last, more practical research to emphasize a real implementation has been done as well. Mori et al.[8] suggested a ubiquitous sensing room equipped with cameras, various sensors and RFID to measure natural daily human behavior. Silva [9] built the ubiquitous home as a real test-bed. It is equipped with several cameras, microphones, RFID and sensors. The author suggested a new database system and communication middleware for home management [10].

Compared to existing work, this paper focuses on the so called active sensor network-based home control system to efficiently distribute home control tasks to appropriate components and automatically manage consumer home devices. It makes home network's configuration and management more convenient and comfortable. Consumer home devices have self-configuration and self-organization features using smart sensors or actuators. We have implemented the ubiquitous home services based on our proposed system with various home appliances, smart nodes and communication technologies [10].

III. SHEMS ARCHITECTURE

In this section, we design the SHEMS structural design utilized in the proposed management system. Our SHEMS consists of a number of sensor nodes. They may proffer sensing data, such as gathering reality home environment information and controlling various consumer home devices. Although these two types of smart nodes have different functionalities, they both have the computation and RF (Radio Frequency) communication abilities to automatically establish wireless networks. We design the Interaction element and new routing protocol to interact with our control home system and automatically establish networks. In the following subsections, we describe how smart devices can interact with and be controlled by our home system, and how they can form multi path networks wirelessly.

A. Smart Spaces

Smart spaces (e.g., intelligent rooms, smart space, hospital, smart vehicles) [3] are instances of pervasive computing systems. These systems usually consist of a community of agents that can coordinate and cooperate with each other to provide services to the human users. Some characteristic applications of a smart space include automatically capturing free-hand sketches and presenting the meeting outline to the absent participants, and teleporting graphical user interfaces from mobile devices to stationary desktop computers, and assisting researchers to reschedule meetings and seeking replacement speakers. We believe intelligence home is a necessary property of the smart spaces. In a smart space, the users will be surrounded by a vast amount of computing services and devices. In order for the users to concentrate on their specific tasks, the smart space should attempt to minimize the amount of manual overhead that is required to configure, control, and manage those services and devices. Hence, I believe intelligent behavior and decision making capabilities are essential in the realization of smart spaces.

B. Smart Sensors and Context Architecture

We have developed the smart sensor nodes that are classified into two different types of a generic sensor and an actuator [10]. Generic sensor typed nodes try either to detect the general physical sensing measurements such as temperature, humidity and light or check for the special events such as gas leaks, human movement and window status detection. Whereas, actuator typed nodes can directly control consumer home devices. In our system, some actuators are deployed near the consumer home devices and connected to their electronic switch by the relay switch module. The control ability of actuator is limited to turn on/off actions, because the relay switch module simply works as an electronic switch. Our actuator typed node utilizes IR (Infra-Red) communication also in order to instruct complex consumer devices such as TV, Air Conditioners and Air Cleaners [10]. This collaboration among actuator nodes and consumer home devices leads an extension beyond traditional wireless sensor networks. Our active sensor network can collect diversified sensing information and control various consumer home devices. The generic sensor and actuator nodes are managed by the Sensing Component and Control Component, respectively. Each node should have multi-path routing protocol to automatically establish the wireless network between smart nodes.

C. Context Aggregation

This is designed to address the extremely common communication pattern in which another device in the home network must communicate on a regular basis with a multi device, known as an aggregator. For many sensor networks are a service this in the only traffic on the network, but even when there is other traffic, as in a home control system, there is often a central controller or TV, DVD that acts, for all intents and purposes, as an aggregator [4]. In order for aggregators to be generally accessible, every router in the network must have an entry in their context dictionary for the aggregator. For personal area networks this means that the same aggregator must be discovered many times over, and, if a number of sensors try to discover the aggregator at the same time, the ensuing broadcast storm may cause route discoveries to fail or to produce sub-optimal sensors. The system proposed in the IEEE802.15.4 and adopted in the ZigBee is one in which the aggregator announces its presence using a special node discovery frame, which, as it transits the network, causes entries pointing to the aggregator to be set up in the data tables of context broker that relays it [3].

D. Service Agent

Each smart node should have a special computational entry, which can understand commands transmitted from the home system and recognize its tasks according to its sensing or actuator functionality, to interact with our home system. We develop the Interaction Component on smart nodes as a part of our system for this purpose. Since each node is equipped with special capabilities such as gas detection, relay switching and IR controlling, each node may perform different actions according to its capabilities. Our Interaction Component is design to distinguish these different capabilities and perform adaptive operations. It can respond with appropriate responses to commands transmitted from the home control system.

E. Components Manager

These components represent some ubiquitous smart home services provided by our system. Examples include services for home automation, home security and home management.

F. (DMPR) *–Disjoint Multi Path Routing Protocol*

Each node should have multi path routing protocol to automatically establish the wireless network between smart nodes. We develop a new On-demand based routing protocol named as "DMPR (*Disjoint Multi Path Routing Protocol*)".

We proposed routing protocols are difficult to accommodate to dynamic topology variations and to interact with our home control system. We design a new routing protocol specifically for home networks. Our proposed protocol establishes the wireless network, based on the *Kruskal's* algorithm [11] value measured from the RF radio. This idea of using the value for the routing purpose has been presented in the ZigBee PAN standard as well, but it is different from our DMPR protocol in that an on-demand approach is utilized there to make a routing path and hence many control packets are often required.

Kruskal's algorithm is an algorithm in graph theory that finds a minimum spanning tree for a connected weighted graph. This means it finds a subset of the node that forms a network that includes every node, where the total energy level of all the nodes in the network is minimized. If the network is not connected, then it finds a minimum spanning network (a minimum spanning tree for each connected component). *Kruskal's* algorithm is an example of a greedy algorithms. Fig. 2 illustrates a proposed DMPR in used SHEMS.

It works as next follows: create a network N (a set of nodes), where each node in the graph is a separate network and creates a set S containing all the nodes in the network , while S is nonempty and N is not yet spanning , remove an node with minimum energy from S. If that node connects two different networks, then add it to the network, combining two networks into a single network otherwise discard that node. At the termination of the algorithm, the network has only one component and forms a minimum spanning network of the graph. Where N is the number of nodes in the graph and V is the number of vertices, *Kruskal's* algorithm can be shown to run in $O(N \log N)$ times, or equivalently, $O(N \log V)$ time, all with simple data structures. These running times are equivalent because: E is at most $V2$ and $logV2 = 2logV$ is $O(\log V)$. If we ignore isolated vertices, which will each be their own component of the minimum spanning forest, $V \leq N+1$, so $\log V$ is $O(\log N)$.

The proposed DMPR works as follows. When forwarding the data packet to the sink, the node selects the special node having the best *Kruskal's* algorithm value among neighbors. The routing topology is adjusted dynamically, since nodes check neighbors *Kruskal's* algorithm value lists whenever transmitting data. Users can easily see the sensor network topology established in the home, since each packet contains its forwarded routing path list in the packet header. Using this routing path list our home system can discern the routing path from the system to each smart node. We utilize the B-MAC protocol for shared data access, and a special narrow-band RF device that supports the *Kruskal's* algorithm value, based on the IEEE 802.15.4 standard. We also develop a new topology viewer program to show the established smart node topology in our smart home system [12].

IV. THE PROPOSED MANAGEMENT SYSTEM

It then receives the physical sensing data of interest, or a special event from the corresponding sensors. These operations are managed by *Context Aggregator*, and the gathered information is forwarded to *Context Aware*. *Service Engine* can select the adaptive home service based on these detected physical sensing data and Reasoning Engine. The selected services are operated with the help of Control Services and Additional Communication Components according to the predefined scenarios in Service Components. Fig. 3 shows the SHEMS architecture in our proposed home control system. In this section, we detail each Service's operations.

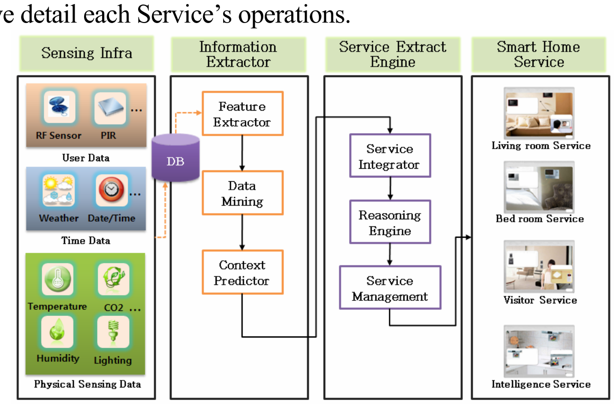

Fig. 3 Block diagram of the SHEMS

A. Sensing infra

The Sensing Component is designed to receive and request the physical sensing data and specific events of interest from smart nodes. This component manages the generic sensor nodes in the active sensor network. Sensing data collectors encapsulate information about a single piece of sensing data, such as location or activity, for example. They provide a uniform interface to components that use the sensing data, hiding the details of the underlying context-sensing mechanisms, allowing them to treat implicit and explicit input in the same method [4]. Context Aggregators allow the use of heterogeneous sensors that sense redundant input, regardless of whether that input is implicit or explicit. Aggregators maintain a persistent record of the context they sense. They allow other components to both poll and subscribe to the context information they maintain.

Aggregators are responsible for collecting information about the environment. Context aggregator is very similar to a sensor widget, in that it supports the same set of features as a widget. The difference is that an aggregator collects multiple pieces of context. In fact, it is responsible for the entire context about a particular entity (person, place, or object). Aggregation facilitates the access of context by applications that are interested in multiple pieces of context about a single article.

B. Information Extractor

Feature Extractor is used to abstract or interpret context data. For example, a context aggregator may provide location context in the form of latitude and longitude, but an application may require the location in the form of a street name. A Feature Extractor may be used to provide this abstraction [4]. A more complex interpreter may take context from many widgets in a conference room to infer that a meeting is taking place. In an open and dynamic environment, no single agent will have complete knowledge about its sensing data.

Data Mining is an effective mechanism to help this system to build contextual databases. Effective communication is required for sensing data sharing. In order to communicate, independently developed agents must share a common ontology and communication language [4]. In the previous systems, because contextual information is typically represented using programming objects and ad-hoc data structures, it cannot be effectively shared among the independently developed agents. However, some approach has suggested the use of a shared database repository to facilitate knowledge sharing. In this approach, the shared database schemas are used to function as a shared ontology between different agents. As the database is updated by different agents when new knowledge is acquired, the database becomes a shared knowledge base for these agents.

Context Predictors are intended to be persistent, running 24 hours a day, 7 days a week. They are instantiated and executed independently of each other in separate threads and on separate computing devices. The Context Toolkit makes the distribution of the context architecture transparent to context-aware applications, handling all communications between applications and components. When a piece of contextual information is asserted into the knowledge base, the Context predictor first selects the type of context it attempts to infer.

C. Service Extract Engine

Service Reasoning and algorithm can play different roles in sensing and knowledge sharing. In sensing, context reasoning is a process that reasons over the sensing data to make interpretations about the context. In knowledge sharing, context reasoning is a process that reasons over different contextual knowledge to detect and resolve inconsistent information. Reasoning Rules defined in *Jess* are executed as part of the Context Architecture's reasoning implementation. The following is a high-level description of the reasoning algorithm:

When a piece of contextual information is asserted into the knowledge base, the Context Architecture first selects the type of context it attempts to infer (e.g., the location of a person or the state of a meeting). If such information is unknown, the Context Architecture decides whether such type of context can be inferred using only ontology reasoning. If logic inference is required, the Context Architecture attempts to find all essential supporting facts by querying the ontology model. After collecting all supporting facts, the Context Broker converts the RDF (Resource Description Framework) representation of the facts into the corresponding Jess representation and asserts them into the Jess engine. After executing the pre-defined forward-chaining procedure, if any new facts can be deduced, the Context Architecture adds their corresponding RDF representation into the ontology model. In Easy Meeting, the logic inference procedure helps a Context Architecture to reason about the state of a meeting (i.e., pre-meeting, meeting in session, post-meeting), the arrival of an anticipated meeting participant based on the presence of their personal devices, and the absence of an anticipated meeting participant [4].

D. Smart Home Service

One of the goals in this paper is to propose the new ubiquitous home services that offer inhabitants more comfortable environments to perform day-to-day tasks. The Service Components include these home services. The Decision Component selects an adaptive service, and it may be performed using Control Component and Additional Communication Components according to the predefined scenarios. We have designed and implemented seven different kinds of intelligent home services on our proposed system. These services are classified into three types: first, home automation services controlling air conditioners, air cleaners and curtain movements, according to the weather. The second, home security services, detects potential crimes and prevents gas explosions. The last is the home management services via the Internet. More details on these service operations are discussed in the next section.

V. IMPLEMENTATION DETAILS

To show the achievability of the proposed architecture, we implement our home control system and dynamic sensor networks with various consumer home devices in a house. We developed all the related hardware and software for our system. In this section, we present the potential ubiquitous home services provided by our system.

A. Sensor/Actuator Node Implementation

We have developed a smart node that has sensing, processing and networking abilities. It is equipped with a low power microprocessor and a narrow-band RF device that can support physical-layer functionalities of IEEE 802.15.4 [12]. It is 40mm x 70mm in size, powered by two 1.5V AA batteries. Three type sensors are included in the smart node: light, temperature and humidity sensors. Our smart node has a 50 pin connector that is directly matched to the microprocessor to add additional hardware. Various optional sensor and actuator modules can be equipped with our smart node via this 50 pin connector. To collect diversified sensing information and control consumer home devices, we developed the several additional optional modules equipped with our smart node. They are connected to the 50 pin connector and are directly controlled by the microprocessor in our smart node. Using the additional modules, the smart node is divided to the generic sensor and actuator nodes. The advanced sensing modules are weather, bio, gas and motion detection sensors that can measure the pressure, the accelerated velocity, the pulse rates, the body heat, a gas leak and the motion, respectively. The actuator modules are Infra-Red and relay modules. The Infra-Red module supports IR communication that can control TV, DVD and air conditioners. The relay modules can switch power on/off in electronic devices and control a motor. These actuator modules enable the role of smart nodes to be changed from just a physical information detector to an electronic device controller. These options boards are managed by our OS level libraries. Fig. 4 shows the floor plan of the home network for the experiments. In the first experiment, the climate control application monitored the current temperature of the real environment with the retrieved temperature service for the temperature sensor node on the ceiling. Specifically, the application monitored the current temperature by invoking to read the temperature method of the sensor service every time a periodic data packet from the temperature sensor node was received. If the temperature of the real environment exceeded a predefined limit, the application tried to retrieve an Electric-Fan or Air-Conditioner proxy service from the service registry. When the application found the Air-Conditioner service for the air conditioner in the real environment, it turned on the air conditioner by invoking the turn on method of the Air-Conditioner service as shown in Fig. 4. When a Zigbee-enabled electric fan was newly deployed to the real environment, an Electric Fan service was downloaded from the proxy service bundle download server and registered in the service registry. Then the application was automatically notified of the registration of the Electric Fan service and turned on the electric fan by invoking the turn on method of the Electric Fan service.

Fig. 4 Pictures of Sensor Nodes in Real House

In the second conduct experiment, the home security application monitored the security status of the real environment with the Magnet Sensor service for the magnetic door sensor node deployed before the experiment as shown in Fig. 4. When the door was opened, the magnetic door sensor node sent a data packet to the SHEMS. Then the application was notified that the data of the Magnet sensor service was modified and got the status of the door by invoking the read method of the Magnet sensor service. After learning that the door was open, the application sent an alarm message to the user through the cell phone message server. When an additional magnetic sensor node was newly deployed to the window of the real environment as shown in Fig. 4, the home security application was notified of the registration of another Magnet sensor service.

B. Description of Smart Home Services

In this subsection, we introduce several ubiquitous home services. These services are implemented based on our proposed home network systems. Fig. 5 depicts our home services. In this subsection, we describe the deployment of smart nodes and their possible operation in the home. Fig. 5 shows some of the pictures of the deployment in our implementations. The following list details their functions. The Customer simply powers the SHEMS Device and initiates the joining process per the SHEMS Device manufacturer's instructions. Different SHEMS Devices may employ different methods to initiate the joining process such as simply powering the device on or by pushing one or multiple buttons in living room. Infra-red (IR) device can support IR communication with complex consumer home devices. The user can control these home devices using the web browser via Internet. Our system utilizes a RFID card and RFID reader located near the door, instead of a key, to confirm the person's recognition. The home control system decides whether or not to open the door based on the TAG ID in the RFID card of visitor. Upon deciding to open the door, the system transmits the corresponding Control-Command to the actuator node on the door lock device.

Fig. 5 Pictures of our Smart Home

A gas sensor is deployed near the gas valve to prevent a gas explosion. The gas sensor frequently checks gas in the atmosphere and reports the values to our home system to prevent gas explosion. On detecting a large amount of gas, the gas sensor immediately instructs the gas valve actuator node to turn off the valve using its relay switch module. In this situation, there is no latent time to exchange commands with the home control system. The gas sensor autonomously operates, and later informs the home control system. Fig. 6 shows the AMI Meter and Gas, Fire detecting devices in lifetime.

Fig. 6 Pictures of AMI and Gas Fire Detector

Upon initiating the join process, the SHEMS will scan for AMI Meters to join. It is possible the SHEMS may be in range of more than one AMI Meter and will attempt to join the first AMI Meter it finds. However, only the AMI Meter that has the correct security key for this specific SHEMS will allow the SHEMS to join. If an AMI Meter receives a request from a SHEMS device it does not recognize it will reject the SHEMS. The SHEMS device will try other AMI Meters until it is allowed to complete the join process.

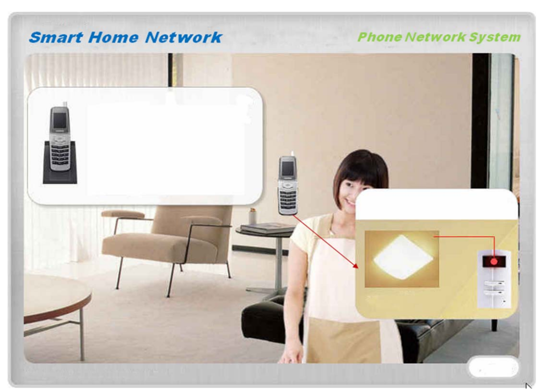

Fig. 7 Pictures of Visitor and Remote Light Control System

Fig. 7 shows the Visitor Systems and Remote Light Control Systems. In some cases, friends and family may visit the home while the resident is absent. The visitor activate the doorbell, the doorbell event is generated in the active sensor network. Our home control system automatically supports a connection between inhabitant and visitors through the CDMA modem. The user can communicate using a cellular phone, and visitors also respond using a mike and speaker in the door.

Fig. 8 Pictures of Temperature and Air-Conditioner Control

Fig. 8 shows the Temperature and Air-Conditioner Control Systems. The home control system can deduce the proximate atmospheric conditions in the house using temperature, humidity and pressure information from sensor nodes. The home control server can adaptively control the air conditioner and air cleaner using the Infra-Red node. The magnetic reed switch is equipped with the window boundary to detect its status. When a window is suddenly opened by some intruder, the reed switch sensor can recognize this and inform the home control system of the event. The home control system can transmit special Control-Command packets to open or close curtains. A smart actuator is deployed near the curtain and its relay switch module is connected to the motor linked to move curtains.

Fig. 9 Pictures of Intelligence Consumer Electronics

Fig. 9 shows the Intelligence Consumer Electronics in Kitchen. The sensor node can control illumination of the lamps via the relay switch module. Photo-sensors and day-lighting, When sunlight comes streaming in through windows, electric lighting can be dimmed or even turned off. TV, DVD, air conditioner and air cleaner can be controlled by SHEMS. The home system can control home lighting in accord with the PRI sensors are used to detect human movement. This information can be utilized for intrusion detection in reasoning engine. For example, while residents are out of the home, if an unexpected movement occurs, resident activity is detected by the movement detector sensors; this event is then forwarded to the home control system. The simplest lighting control system turns off (or dims) lights at a specified time when the home is assumed to be empty, and turns lights back on again before resident arrive for work the next day. This is a start, but with today's offices where people are increasingly working longer, more flexible hours, additional controls are needed.

In SHEMS, Occupancy sensors are useful not only to address bendable working hours, but also to control lights in areas with irregular usage patterns. For example, lights could be dimmed by default in a kitchen like a home. When the sensors detect that someone has entered in the place, at that time, the lights corresponding to the place in which the person is detected can be brightened to provide satisfactory illumination. Occupancy sensors can also be used to create "corridors of light" to follow people like security guards and cleaners as they move through a home. And as the natural light fades, the lights can automatically come back on again. This helps not only to conserve lighting energy, but also to reduce the amount of heat being emitted by the electric lights, which in turn, can help save money on air conditioning costs. In addition to the automated control provided by the timers and sensors, lighting control systems can also place control in the hands of individuals. People often require different levels of lighting depending on factors such as their age and the type of work they are doing. Lighting systems can provide the ability for office workers to adjust personal lighting levels directly from the PCs on their desks.

VI. CONCLUSION

Smart home network excite new possibilities. We proposed a new smart home energy management system based on ZigBee sensor networks to make home networks more intelligent and automatic. The role of the SHEMS for managing energy usage is a crucial factor in addressing the home's growing energy concerns. The Smart Energy initiative serves these needs by providing an adoptable and sustainable experience by linking new and useful digital technologies to the needs of consumers. By empowering consumers with near real-time information of their energy usage through an array of products and services, the intent is to help consumers use energy more efficiently and also to minimize their personal impact on the environment. We implement the proposed system and develop related hardware and software. We suggest new SHEMS based on the proposed system. We expect that our work contributes towards the development of ubiquitous home networks. As a part of future work, we will apply IEEE 802.15.4 standard technology in our home network systems to support location services.

REFERENCES

[1] Tasshik. Shon, Yongsuk Park, "A Hybrid Adaptive Security Framework for IEEE 802.15.4-based Wireless Sensor Networks," *KSII Transactions on Internet and Information Systems*.vol.3, no.6, Dec. 2009.

[2] T. Yamazaki, "Ubiquitous Home," *International Journal of Smart Home*, vol. 1, no. 1, pp. 17-22, Dec. 2007.

[3] Wang Chun-dong, Liu Xiao-qin, Wang Haui-bin, "A Framework of Intelligent Agent Based Middleware for Context Aware Computing," *Natural Computation.2009.ICNC'09.Fifth International Conference on*, vol.6, pp.107-110, 14-16. Aug. 2009.

[4] S. K. Das, D. Cook, A. Bhattacharya, E. O. Heierman and T.-Y. Lin, "The Role of Prediction Algorithms in the MavHome Smart Home Architecture," *IEEE Wireless Communications Magazine*, vol. 9, no. 6, pp. 77-84, 2002.

[5] Young-Guk Ha, "Dynamic integration of zigbee home networks into home gateways using OSGI service registry," *IEEE Transactions on Consumer Electronics.*, vol. 55, Issue. 2, pp.470-476, May. 2009.

[6] Yu-S. Bae, B.-J. Oh, K.-D. Moon and S.-W. Kim, "Architecture for Interoperability of Services between an ACAP Receiver and Home Networked Devices," *IEEE Transactions on Consumer Electronics*, vol. 52, no. 1, pp. 123- 128. 2006.

[7] J. Stankovic, Q. Cao, T. Doan, L. Fang, Z. He, R. Kiran, "Wireless Sensor Networks for In-Home Healthcare: Potential and Challenges," *Proc. of the Workshop on High Confidence Medical Devices Software and Systems*, June 2005.

[8] T. Mori, H. Noguchi, A. Takada and T. Sato, "Sensing Room: Distributed Sensor Environment for Measurement of Human Daily Behavior," *Proc. of the International Conference on Networked Sensing Systems*, June 2004.

[9] G. C. de Silva, B. Oh, T. Yamasaki and K. Aizawa, "Ubiquitous Home: Retrieval of Experiences in a Home Environment," *IEICE Transactions on Information and Systems*, vol. E91-D, no. 2, pp. 330-340, 2008.

[10] Changsu, Suh. Yong Bae, Ko. "Design and Implementation of Intelligent Home Control Systems based on Active Sensor Networks," *IEEE Transactions on Consumer Electronics*, vol.54, no.3, Aug. 2008.

[11] Joseph. B. Kruskal,"On the Shortest Spanning Subtree of a Graph and the Traveling Salesman Problem," *In Proceedings of the American Mathematical Society*, vol. 7, no. 1, pp. 48–50, Feb. 1956.

[12] Michael T. Goodrich , Roberto. Tamassia," Data Structures and Algorithms in Java," *Fourth Edition. John Wiley & Sons, Inc*., ISBN 0-471-73884-0. Section 13.7.1: *Kruskal's Algorithm*, pp.632. 2006.

[13] Heemin. Park, Jeff. Burke,Mani B. Srivastava, " Intelligent Lighting Control using Wireless Sensor Networks for Media Production," *KSII Transactions on Internet and Information Systems*.vol.3, no.5,Oct. 2009.

[14] Demin. Wang, Bin. Xie, Agrawal. D.P, "Coverage and Lifetime Optimization of Wireless Sensor Networks with Gaussian Distribution," Mobile Computing. IEEE Transactions on, vol 7, Issue 12, pp1444-1458, Dec. 2008.

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