Smart Home Energy Management System using IEEE 802.15.4 and ZigBee

Dae-Man Han and Jae-Hyun Lim *Member*, IEEE

Abstract — *Wireless personal area network and wireless sensor networks are rapidly gaining popularity, and the IEEE 802.15 Wireless Personal Area Working Group has defined no less than different standards so as to cater to the requirements of different applications. The ubiquitous home network has gained widespread attentions due to its seamless integration into everyday life. This innovative system transparently unifies various home appliances, smart sensors and energy technologies. The smart energy market requires two types of ZigBee networks for device control and energy management. Today, organizations use IEEE 802.15.4 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. We present the design of a multi-sensing, heating and air-conditioning system and actuation application – the home users: a sensor network-based smart light control system for smart home and energy control production.*

This paper designs smart home device descriptions and standard practices for demand response and load management "Smart Energy" applications needed in a smart energy based residential or light commercial environment. The control application domains included in this initial version are sensing device control, pricing and demand response and load control applications. This paper introduces smart home interfaces and device definitions to allow interoperability among ZigBee devices produced by various manufacturers of electrical equipment, meters, and smart energy enabling products. We introduced the proposed home energy control systems design that provides intelligent services for users and we demonstrate its implementation using a real testbad.

Index Terms — Smart Home, Smart Energy, ZigBee, IEEE 802.15.4, RF4CE, 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 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].

Recently, organizations use 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. As an ecosystem, the Agreement offers everything future product and service companies need to develop ZigBee products. The smart energy networks could include both ZigBee 2006 and IEEE 802.15.4. It is suggested that the majority of the nodes in the network should be based on one stack profile or the other to get reliable performance. ZigBee smart energy certified products must be based upon a ZigBee Compliant Platform (ZCP)[2][3]. If the smart energy profile resides in combination with a private profile, the product should be ZigBee Manufacturer Specific Profile (MSP) licensed and must be smart energy ZCP certified[3]. This additional certification provides a guarantee that the fundamental stack is behaving correctly and the application is not abusive to the network. The smart energy networks will not cooperate with a consumer ZigBee Home Area Network (HAN) unless a device is used to perform an "application level bridge" between the two profiles or the HAN devices satisfy the smart energy profile security requirements[2][3].

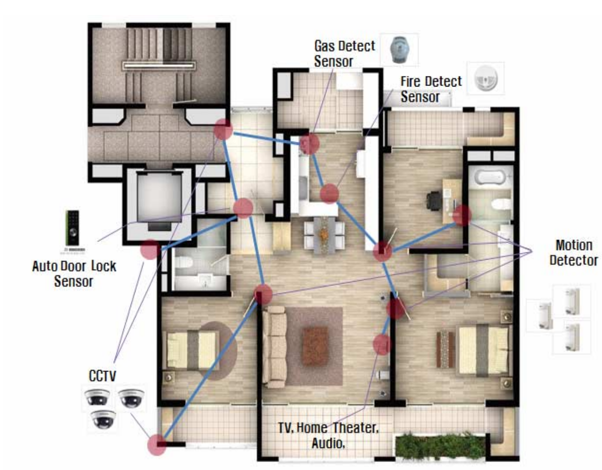

Fig. 1. HAN

This is due to the higher security requirements on the smart energy network that are not required on a home network. However, it is expected that home automation devices that are extended to include the smart energy profile can still operate in a home network. The ZigBee HAN makes possible

This work was supported by Priority Research Centers Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2009-0093825).

Dae Man Han is a Research professor in the School of Computer Science & Engineering, Green Home Energy Technology Research Professor, Kongju National University, Republic of Korea (e-mail: *dmhan@kongju.ac.kr*)

Jae Hyun Lim is a Professor in the School of Computer Science & Engineering, Kongju National University, Republic of Korea (e-mail: *defacto@kongju.ac.kr*)

Contributed Paper
Manuscript received 06/02/10
Current version published 09/23/10
Electronic version published 09/30/10.

networks such as the Following Fig. 1. We present the design of a multi sensing and light control application based smart energy control system for reduced total energy cost. This paper designs smart home device descriptions and standard practices for demand response and load management "Smart Energy" applications needed in a smart energy based residential or light commercial environment. Installation scenarios range from a single home to an entire apartment complex. In Section 2, we review the previous work in related worked. Design of the applications of this paper is presented in Section 3. Developing of the applications presented in Section 4.

II. RELATED WORK

In this section, we briefly survey the existing works for smart home network systems and, based on their main contributions, try to classify them into real implementation system. The following subsections describe the ZigBee devices and approaches of the major tasks based on the capabilities of a control system described in Section 3.

A. Sensing Environment

In short, lighting control systems deliver the correct amount of light, where you want it, when you want it. Lights can automatically turn on, off or dim at set times or under set conditions, plus users can have control over their own lighting levels to provide optimal working conditions[4]. Lighting control helps to reduce costs and conserve energy by turning off (or dimming) lights when they are not required.

The simplest lighting control system turns off (or dims) lights at a specified time when the building is assumed to be empty, and turns lights back on again before people 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. Occupancy sensors are useful not only to address flexible working hours, but also to control lights in areas with irregular usage patterns. For example, lights could be dimmed by default in a large room like a laboratory or warehouse. When the sensors detect that someone has entered, the lights corresponding to the location in which the person is detected can be brightened to provide sufficient 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 building[5]. Photo-sensors and day-lighting, When sunlight comes streaming in through windows, electric lighting can be dimmed or even turned off. 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.

B. ZigBee Devices and Data Transfer model

A ZigBee device is a physical object equipped with a radio. Simple examples include a light switch, thermostat, and remote control. Logically separate functions may be implemented in a single device, and as such share the same radio for communication purposes. For example, a temperature sensor and accelerometer could be combined within a single device used for industrial plant monitoring applications[6][7]. A set of inter-communicating devices implement an application, such as a home automation system. While the PHY, MAC and network layers are used to create and maintain the communication network interconnecting individual ZigBee devices, the application support sub-layer is used to communicate application layer information between devices, such as a light switch commanding a light to turn on or off[7]. ZigBee networks include the following device types.

- Coordinator

This device starts and controls the network. The coordinator stores information about the network, which includes acting as the Trust Center and being the repository for security keys.

- Router

These devices extend network area coverage, dynamically route around obstacles, and provide backup routes in case of network congestion or device failure. They can connect to the coordinator and other routers, and also support child devices.

- End Devices

These devices can transmit or receive a message, but cannot perform any routing operations. They must be connected to either the coordinator or a router, and do not support child devices.

Three types of data transfer transactions exist. The first one is the data transfer to a coordinator in which a device transmits the data. The second transaction is the data transfer from a coordinator in which the device receives the data. The third transaction is the data transfer between two peer devices. In star topology, only two of these transactions are used because data may be exchanged only between the coordinator and a device. In a peer-to-peer topology, data may be exchanged between any two devices on the network. The IEEE 802.15.4 LR-WPAN employs various mechanisms to improve the probability of successful data transmission. These mechanisms are the CSMA-CA[7] mechanism, frame acknowledgement[8]. When the coordinator wishes to transfer data to a device in a beacon-enabled HAN, it indicates in the network beacon that the data message is pending. The device periodically listens to the network beacon and, if a message is pending, transmits a MAC command requesting the data, using slotted CSMA-CA. The coordinator acknowledges the successful reception of the data request by transmitting an acknowledgment frame. The pending data frame is then sent using slotted CSMA-CA or, if possible, immediately after the acknowledgement [3][6] [7][8].

III. SMART HOME DESIGN

Compared to traditional home networks, the in-progress ubiquitous home network collects user activity patterns, as well as physical sensing information on the surrounding environment, to support more smart and adaptive home services[9]. It has the potential to control consumer home devices used in everyday life. Eventually, users will experience the convenience of performing ordinary activities and increased satisfaction offered by adaptive home services.

Several conditions are required to reap advantages from the ubiquitous home network. For instance, computing systems should integrate diversified sensing information to perceive the current situation in the home area. Also, they should be able to control various consumer home devices. The home system may become complex, as the number of sensors and devices offered increases. Therefore, home network systems should be designed distributing various tasks into proper computational units to reduce complexity. In this work, we design a smart home control system that can assign tasks to suitable components. Using a wireless sensor network with actuator functionality, our system can automatically gather physical sensing information and efficiently control various consumer home devices. We call this system the "Smart home control system". The system can efficiently distribute various tasks related to home network to corresponding components and implement real ubiquitous home services via smart sensors and controller deployed in home areas.

A. Scenarios

An end-user or installer would purchase devices, add batteries or connect their power sources, turn them on, and everything would work. Devices for a particular installation would automatically figure out that they were supposed to work together. Some coordinator or trust center would automatically set up security to ensure that only trusted devices could join the network and communicate only with other trusted devices. The applications would somehow bind to each other automatically without human intervention or the use of tools. The end-user would not need to do anything, let alone understand any concept of commissioning. We first focused on capturing and archiving sensory data from the set into a database in frame-rate synchronization using CC2430[10]. To do so, we developed the Device Binding System (DBS) with wireless light sensing module and network platform. The CC2430 is a true System-on-Chip(SoC solution specifically tailored for IEEE 802.15.4 and ZigBee applications)[10]. It enables ZigBee nodes to be built with very low total bill-of material costs. The CC2430 combines the excellent performance of the leading CC2420 RF transceiver with an industry-standard enhanced 8051 MCU[10]. The CC2430 is highly suited for systems where ultra low power consumption is required. This is ensured by various operating modes. Short transition times between operating modes further ensure low power consumption.

B. System Design

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 [11] [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. Although computerized control systems for lights in film and theaters are available as commercial products [7] [8], most current systems only provide actuation and do not exploit sensor data. We believe that it is important to know and use the live light information from light sensors deployed on the set. Real-time data accounts for how characteristics, such as light intensity and color temperature, change over time and deployments due to filament aging, supply voltage variation, changes in fixture position, and color filters. Without real-time measurement of light, it is time-consuming to maintain desired light intensities in certain area across many venues and over long periods. Light intensities and color temperature can be measured accurately by currently available handheld manual light meters.

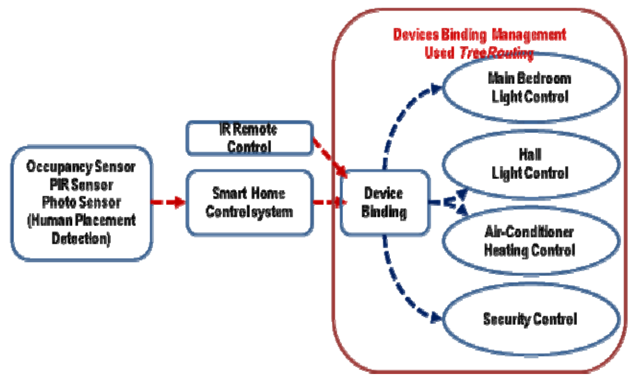

Fig. 2. Smart Home Control System

In the Fig.2. PIR sensors are used to detect human movement[9]. This information can be utilized for services detection. For example, while inhabitants are out of the home, if an unexpected movement occurs, motion is detected by the movement detector sensors; this event is then forwarded to the smart home control system. 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. 2. shows our smart home control system and its system modules[13][14][15][16].

C. (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 [17] 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. However, these devices have not been incorporated in computer systems supporting automatic light control and must be manually moved through different points in space.

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. 3 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 [17].

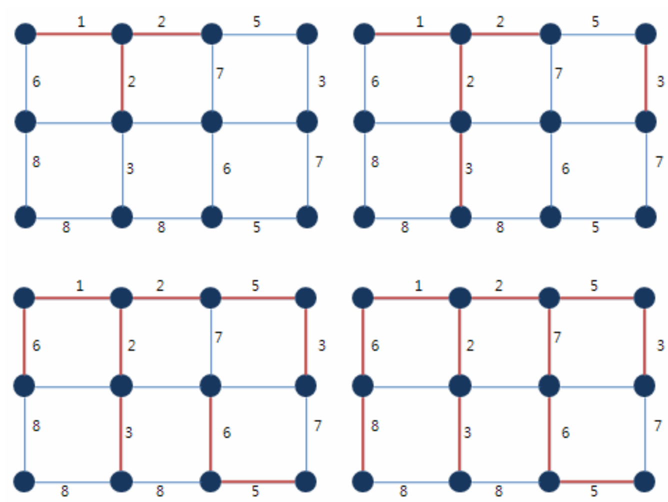

Fig. 3. DMPR Routing algorithm

D. Device Binding System

Bindings are connections between endpoints. An application design based on the remote control mentioned earlier is shown in Fig. 4. In this Figure, we survey that the remote control has bindings to all five devices, endpoint 1 of the remote control is bound to endpoint 6 of the main bedroom light, endpoint 8 of the remote control is bound to endpoint 3 of the heating and air-conditioning system, endpoint 4 of the security is bound to endpoint 5 of the security control system, endpoint 2 of the hall light is bound to endpoint 7 of the hall light control system and so forth.

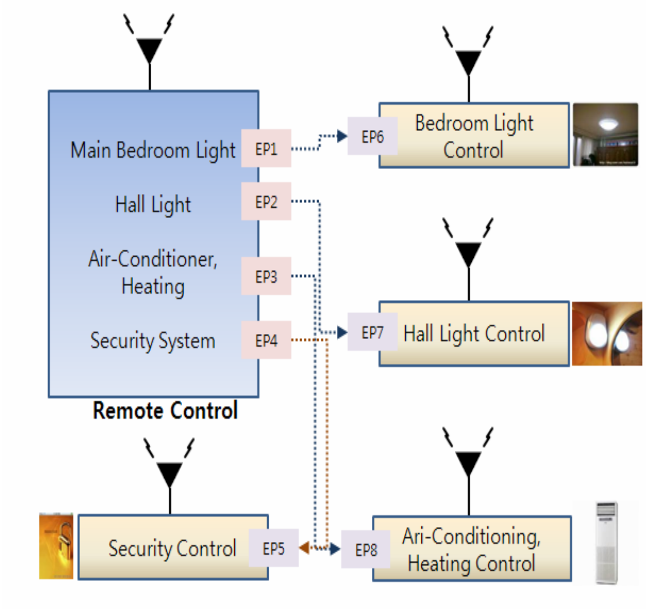

Fig. 4. Device Binding System

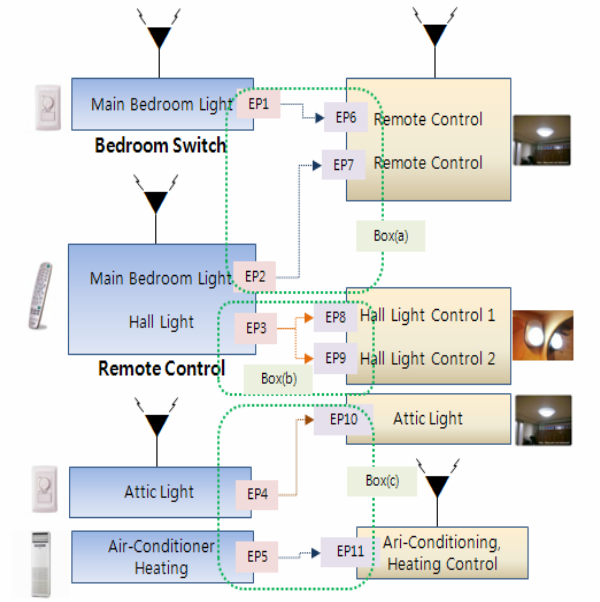

Fig. 5. Multi-Binding Devices

To complete the earlier discussion, consider this. Bindings are connections between two endpoints, with each binding supporting a specific application profile, and each message type is represented by a cluster within that profile. When combined with the network source and destination address which identifies a particular radio, in this frame containing the source and/or the destination endpoint, cluster ID and profile ID uniquely identifies a specific message type within a specific profile between two application endpoints associated with two specific devices. To demonstrate ZigBee's flexibility in handling scenarios, consider the more multi binding in Fig. 5. In this paper, we focus on a lighting system. Box (a) at the top shows a 3-way toggle switch while boxes (b,c) shows how multiple devices can be attached to a single device. In box (a), a bedroom light switch along with the remote control on the left, are bound to the main bedroom light on the right. In Fig. 5, we make a 3-way toggle switch, with both the main bedroom switch and the remote control acting as switches on the main bedroom light. This is achieved through two separate bindings, with both endpoints on the lighting device controlling the light bulb. In boxes (b,c), a single device on the right controls both the two hall lights1 and the hall light2. By binding the remote control and the hall switch control 2 to separate endpoints on the hall device, the same device can allow independent control of independent attached lights. The remote control, bound to the two hallway lights will independently control these lights, while the hall switch control 2 is independently bound to the other light.

4. Developing Control System

A. Binding Management

This discussion describes a specific binding management scenario for this specific application. Of course, each application will be different, but a range of binding command are available to facilitate many different scenarios. The most significant benefit with tree routing is its simplicity and its limited use of resources. By having a simple algorithm to determine whether an address is a child or a descendant of a child, or elsewhere on the tree, any router can make a routing decision simply by looking at the destination address. In these cases, a router simply decides to route a packet to one of its children or to its parent. As a result, precious memory resources need not be used to store routing information. Hence, very low cost devices can be deployed without routing capability, but can still participate in any ZigBee compliant network. Building on earlier discussions, this section describes a typical process for developing a new application. Defining and implementing the application profile. The first step is to define the application profile. As part of this exercise, an application profile, along with device definitions are required to meet the specific requirements of the application. As mentioned in the discussion on the ZigBee Cluster Library, where possible this library should be used to leverage existing definitions and code available from the platform provider. These three binding commands, supported in earlier releases of the ZigBee specification have been enhanced through the following additional commands:

- Bind_Register, which allows devices to register with the binding cache and download all bindings stored in the cache for that device.
- Replace_Device, which allow a new device (Y) to request that entries within the binding cache for an old device (X) be replaced by the new device (Y).
- Backup_Bind_Table to backup the primary binding cache to the second binding cache, and to recover the information from the secondary binding cache.

Starting in box (a), end devices are bound using some physical input (say, a button on each device and the remote control). Using the End_Device_Bind command, these bindings populate the binding cache.

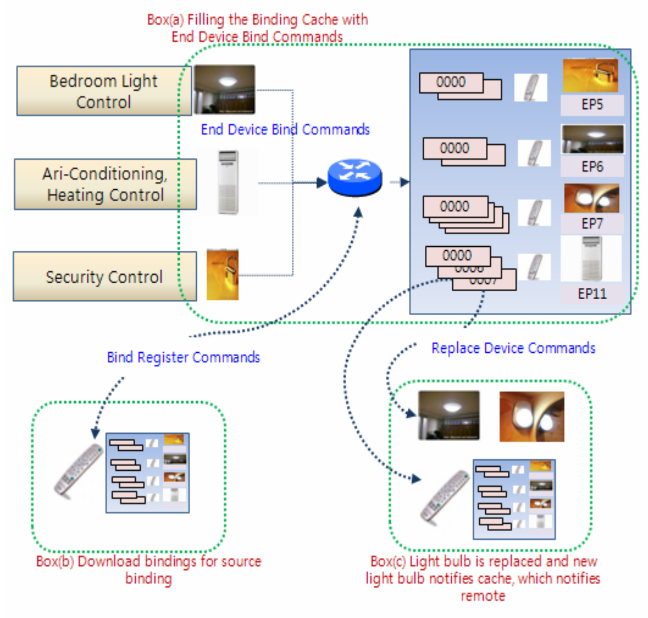

Fig. 6. Binding Management

Is shows in Fig. 6. In box (b), the remote control then issues a Bind_Register command to download all bindings for which it is the source device. This then allows the remote control to directly communicate to other devices without communicating via the binding cache. Finally, in box (c), should the lighting device fail, a replacement device would be substituted, and it would issue a Replace_Device notification to the binding cache that the original lighting device should be replaced by the new lighting device. The binding cache would then note that the remote control currently stores its own copy of its bindings for source binding, and would then send a Replace_Device command to the remote control to have its local copy of the binding replaced as well.

B. Sensor Network Analyzer (SNA)

The industry's most widespread solution for testing, analyzing, commissioning, and managing wireless embedded networks such as IEEE 802.15.4 and ZigBee. Daintree's SNA[18] extends traditional protocol analysis with powerful visual network analysis including visualization of network topologies, routing and application bindings, link quality and device states. In addition, the SNA provides multimode capture for analysis of large and physically distributed networks, and measurements for analysis of system performance. To significantly accelerate troubleshooting tasks, the SNA also provides ease-of-use features such as filters based on visual objects, user-definable protocol stack and ZigBee profile definitions using XML, comprehensive playback controls and breakpoints. Visualize tools is shows in Fig. 7. Visualize tools be comprehend device and network behavior quickly by troubleshooting visually. Observe your network's operation by visually analyzing how devices join the network, routing behavior, and application bindings.

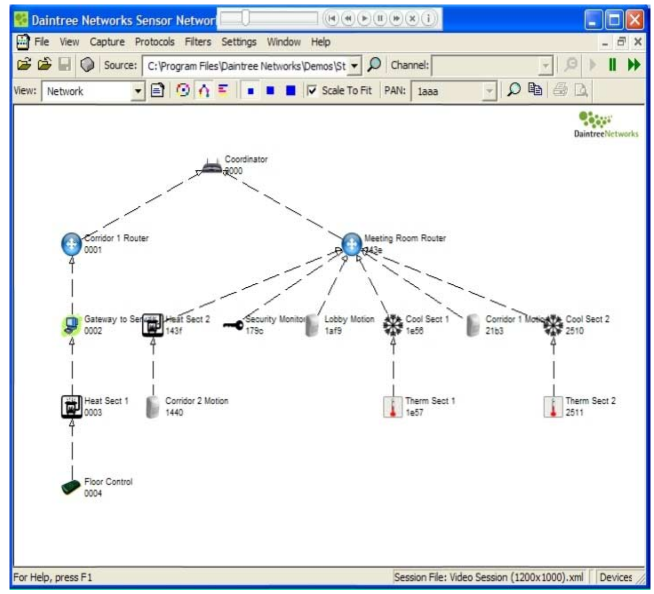

Fig 7. SNA Visual tool

Monitor the network tools is show a in Fig. 8. Find and examine devices using scanning and device discovery tools. Identify joined devices and the network structure, represented using a variety of views. Automatically obtain device type and device state information such as association permit. Discover networks, either passively without interfering with network operation, or actively to determine the structure of live operating networks after network formation. In Fig. 8, load an image, such as a floor plan, and then drag-and-drop devices to view the network as it is physically laid out. Understand network behavior in a physical context, and redesign network layout to improve performance. Most previous work on sensor placement deals with the coverage issue by regular placement or deployment to better estimate unknown fields . Variance-based approaches are used to estimate the field better by adopting an adaptive and incremental scheme to find the next placement locations of high variance (or entropy). In this case, the variance is computed based on the measurements by the currently placed sensors. Unlike previous research on sensor placement, in our application, the user knows what the resultant light field should be like. Thus, our system suggests sensor placement to verify if the intended light field is appropriately created. We combine the two typical approaches: the regularity-based technique and the variance-based technique [19].

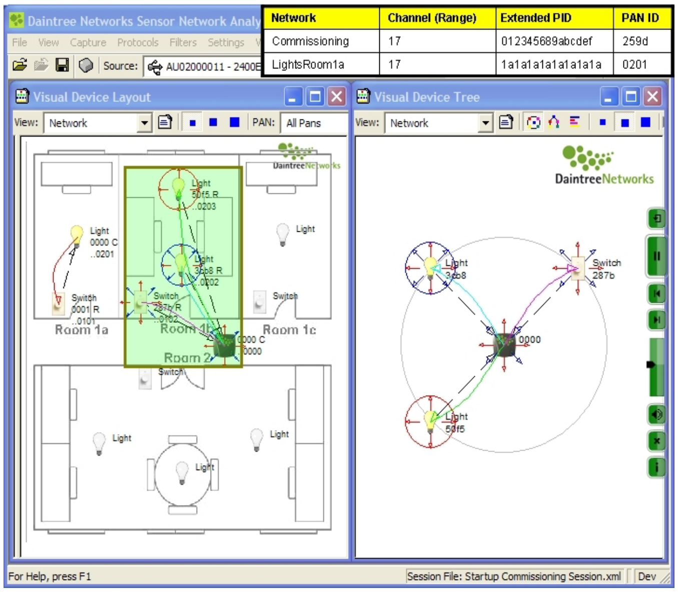

Fig. 8. SNA Device View

Following the definition of the application profile is of course, the development of the necessary code for devices around these definitions. With standardization around the ZCP framework, development tools will be increasingly available using standard description languages such as XML, as well as for analysis and testing. This facilitates a single definition of the application profile that may propagate through the entire development, test and commissioning tool chain.

5. Conclusions

Ubiquitous home networks excite new possibilities. We address a new smart home control system based on sensor networks to make home networks more intelligent and automatic. We implement the proposed system and develop related hardware and software. We suggest new ubiquitous home scenarios based on the proposed system. We expect that our work contributes towards the development of ubiquitous home networks. Energy savings and user happiness are two major design considerations for modern lighting systems. Global standards like ZigBee RF4CE for RF-based consumer electric remote controls are going to change our expectations for the home entertainment experience. A smart home control system can provide both significant cost savings in a home environment, as well as a great level of flexibility and control for the building administrators, and great comfort for the occupants. The most effective way to reduce lighting energy is to turn lights off. The second most effective way is to turn them down. An automated control system can do both for you based on factors such as occupancy, available daylight and time of day. Removing the wires from the lighting controls provides additional benefits, including greater flexibility in where controls can be placed, and significant savings in installation by avoiding the expense and disruption of wiring. You save money not only on the installation and usage costs, but many governments are providing tax incentives to encourage "green home" buildings. In short, these systems save money and make good sense. As a part of future work, we will apply IEEE 802.15.4astandard technology in our home network systems to support location services[20].

References

[1] ZigBee Alliance, ZigBee Specification. version1.1, Nov.2006.

[2] Zigbee Alliance, Smart Energy Profile Specification, version1.0, March. 11.2009.

[3] Institute of Electrical and Electronics Engineers, Inc., IEEE Std. 802.15.4-2003, "Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (LR-WPANs)," *New York, IEEE Press*, Oct. 2003.

[4] V. Singhvi et al, "Intelligent light control using sensor networks," SenSys '05, 2005.

[5] M.-S. Pan, L.-W. Yeh, Y.-A. Chen, Y.-H. Lin, and Y.-C. Tseng, "Design and implementation of awsn-based intelligent light control system," *ICDCSW* '08, pp. 321-326, 2008.

[6] I. F. Akyildiz, W. J. Su, Y. Sankarasubramaniam, E. Cayirci, "Wireless sensor networks: a survey," *Computer Networks*, vol. 38, pp. 393– 422, Oct.2002.

[7] 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.

[8] 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.

[9] 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.

[10] Liu. Yanfei, Wang. Cheng, Yu. Chengbo, Qiao. Xiaojun, "Research on ZigBee Wireless Sensors Network Based on ModBus Protocol," *Information Technology and Applications, 2009. IFITA '09. International Forum on,* vol. 1, pp. 487 - 490, 2009.

[11] *IEEE Computer Society*, MAC and PHY Specifications for Low-Rate Wireless Personal Area Networks (LR-WPANs), IEEE 802.15.4 TM-2003.

[12] *IEEE Computer Society*, Low-Rate Alternative PHY Task Group of IEEE 802.15.4 (TG4a) for the ranging and location, IEEE 802.15.4a-2007.

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

[14] A True System-on-Chip solution for 2.4 GHz IEEE 802.15.4 / ZigBee.

[15] Wei Yuan, Xiangyu Wang, Jean-Paul M.G. Linnartz, "A Coexistence Model of IEEE 802.15.4 and IEEE 802.11b/g," *IEEE Symposium on Communications and Vehicular Technology*, Nov. 2007.

[16] Roy.A, Das.S.K, Basu. K, "A Predictive Framwork for Location-Aware Resource Management in Smart Homes," *IEEE Transaction on Mobile Computing*, vol.6, pp.1270-1283, Nov. 2007.

[17] 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.

[18] Seong Hoon Kim, Jeong Seok Kang, Hong Seong Park, Daeyoung Kim, Young-joo Kim, "UPnP-ZigBee internetworking architecture mirroring a multi-hop ZigBee network topology ,"*Consumer Electronics, IEEE Transactions on,* vol. 55 , pp. 1286 - 1294 2009.

[19] Heemin Park, Jeff Burke, Mani B. Srivastava, " Intelligent Light Control using Wireless Sensor Networks for Media Production," *KSII Transactions on Internet and Information Systems*, vol. 3, no.5, pp. 423-443, Oct. 2009.

[20] Valero.M.A, Valillo.L, Penalval.A, "AN Implementation Framework for Smart Home Telecare Services," *Future Generation communication and networking* (fqcn 2007), vol. 2, pp.60-65, Dec. 2007.

BIOGRAPHIES

Dae Man Han is a Research Professor in Computer Science & Engineering at Kongju National University in Chun-an si. He received a B.S. degree from the School Civil Service Examination, Republic of Korea in 1998, a M.S. degree from Suwon University of Computer Science, Republic of Korea in 1999, and a Ph.D. degree from Suwon University, Hwasung si, in 2006. He is currently with the Green Home Energy Center in the Kongju National University, Republic of Korea .

His interest is in the research areas of Wireless Sensor Networks, Data Communication, Home networks, Green Energy, Smart Home, IEEE 802.11/802.15.4 MAC protocols, ZigBee networks and implementation of real sensor platforms. E-mail: *dmhan@kongju.ac.kr*.

Jae Hyun Lim is a Professor in Computer Science & Engineering at Kongju National University in Chun-an si. Republic of Korea, leading the Wireless Internet Technology (WIT) Laboratory. He received BS and MS degrees in Electrical Engineering from the Chung-Ang University, in 1982 and in 1988, respectively and Ph. D in electrical engineering from the Chung-Ang University, Republic of Korea, in 1998.

His interest is in the research areas of Wireless Sensor Networks, Context Prediction Services, Green Energy, Ontology, Wireless Sensor networks and implementation of real sensor platforms. E-mail: *defacto@kongju.ac.kr*.