Building a Smart Home System with WSN and Service Robot

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***Abstract*—Smart home environments have evolved to the point where everyday objects and devices at home can be networked to give the inhabitants new means to control them. Advances in digital electronics have enable the development of small in size and communicate in short distances sensor nodes.They are low-cost, low-power and multifunctional. The sensor nodes consist of sensing, data processing, and communication components, leverage the idea of Wireless Sensor Networks (WSN) based on collaborative effort of a large number of nodes. There are a large number of reseaches dealing with WSN applications, but it is still possible to explored in WSN development and maintenance. This paper examines the possibility of integration WSN and the service robots into a smart home application. The service robots can be considered to be mobile nodes that provide additional sensorial information, improve/repair the connectivity and collect information from wireless sensor nodes. On the other hand, the WSN can be considered as an extension of the sensorial capabilities of the robots and it can provide a smart environment for the service robots.**

Keywords-smart home; wireless sensor networks; service robot

I. INTRODUCTION

A smart environment is a physical world that is interconnected through a continuous network abundantly and invisibly with sensors, actuators and computational units, embedded seamlessly in the everyday objects of our lives [1].

A smart home is a residence in which computing and information technology apply to expect and respond to the occupants' needs and can be used to enhance the everyday life at home. Potential applications for smart homes can be found in these categories: welfare, entertainment, environment, safety, communication, and appliances [2].

Wireless Sensor Networks (WSNs) have become an attractive technology for the research community, particularly with the proliferation in Micro-Electro-Mechanical Systems technology which has facilitated the development of smart sensors [3]. Typically, a WSN is a distributed system that is composed of autonomous units with sensing capabilities (sensor nodes), interconnected by wireless communication system. This network offers potentially low-cost solution to several problems [4-8] including military target tracking, health care monitoring, environment control systems, animal monitoring, and Smart Homes

The WSN is built of sensor nodes, from a few to several thousands, where each node is connected to one or several sensors. A WSN measurement node contains several components including the radio, battery, microcontroller, analog circuit, and sensor interface. To accomplish the WSN for smart home, we must have considered the following factors:

1) Wireless technologies

With the various wireless technologies available in the market the rapid development of the WSN become practicable. The wireless technologies such as Bluetooth, IR(infrared), RF(radio frequency), ZigBee, Wi-Fi, UWB, WLAN, and NFC are commonly used.

2) Network topologies

We can use several network topologies to coordinate the WSN gateway, end nodes, and router nodes. Router nodes are similar to end nodes in that they can acquire measurement data, but we also can use them to pass along measurement data from other nodes.

3) Microcontroller

Microcontrollers comprise a CPU + timers + UARTs+ I/O + program memory + data memory + other features to reduce system component count. Usually include standard buses for communicating with other IC's.

Smart Home Service Robot(S-HSR) is a robot used for household chores on behalf of human. Human desires to get free of household affairs have increased the necessity of S-HSR. In the near future, every home will at least possess and use more than one S-HSR.

It would be possible to construct a mobile ad-hoc network with autonomous mobile sensor nodes, environmentally adaptive WSN deployment, and applications within various intelligent systems. Autonomous mobile robot can be used and act as high-performance mobile sensor node in WSN because robots equipped with various sensors and communication capabilities. If a robot can manipulate sensor nodes, that robot can change the range and topology of its WSN according to the communication conditions, sensing and adapting to the environmental situation. Radio signals emitted by the WSN nodes might also be used for location and tracking purposes, thus allowing the robot locate itself even in environments where GPS is not available [9].

This paper examines the possibility of embedding WSN and service robot into a smart home application. The integration of WSN and robotic systems in smart home has two fold. First the robots can be considered to be mobiles nodes that provide additional sensorial information, improve/repair the connectivity and collect information from static nodes. On the other hand, the WSN can be considered

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as an extension of the sensorial capabilities of the robots and it can provide a smart environment for the robots.

The rest of the paper is structured as follows. System architecture is discussed in section 2. Section 3 describes the implementation of the smart home system. Conclusions and future works are discussed at the end of the paper.

II. SYSTEM ARCHITECTURE

The architecture of the system is depicted in figure 1. Five main blocks are involved: the home server, the WSN system, smart devices, network of cameras, and the mobile service robots. The home server is the information center and the control center of the whole smart home system. It provides means to store information, monitor the smart devices, send tasks of the user, prepare plans in a centralized way, and monitor the tasks execution by the mobile service robots. It also encompasses the alarm monitoring station, which is in charge of performing cooperative perceptions processing, and specialized images processing activities such as leak detection and fire detection. A SQL Server database serves as a backend data store for the whole smart home system. It is located in home server, and stores all the information coming from the infrastructure for longitudinal studies and offline analysis.

The smart home system has the following three working mode:

- Autonomous Mode

Each room under monitoring deploys several fixed sensors, which is responsible for day-to-day information collection and reporting alarm when something emergency happens.

The home server analyses the site information and give the data to user for making decisions

- Emergency Mode

When the accident occurs, the mobile service robots enter into the accident location to carry out rescue tasks.

- User Control Mode

Users can control the smart devices and service robots by the PDA or smart phone.

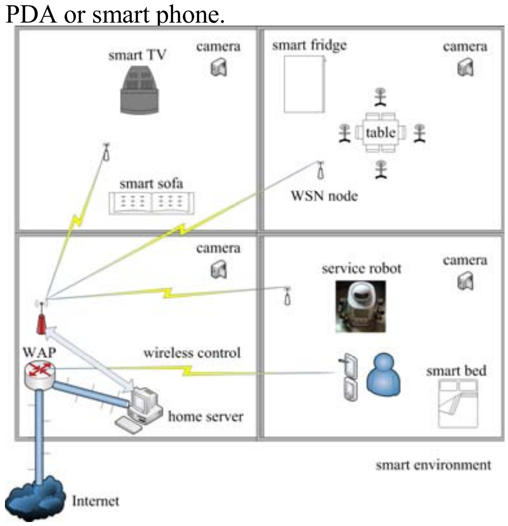

Figure 1. System architecture

A network of camera nodes is used to provide a full view of the smart home. Each camera may cover a part of the room and there might be some overlaps if the total area is small. Cameras are turned off in normal conditions to reduce unnecessary power consumption. At the time of the event, the camera nodes focusing on the position of the mobile node will be turned on and start capturing frames.

III. IMPLEMENTATION

A. Hardware of wireless sensor nodes

The main challenge is to produce low cost and tiny sensor nodes. With respect to these objectives, current sensor nodes are mainly prototypes. Miniaturization and low cost are understood to follow from recent and future progress in the fields of MEMS (Micro Electromechanical System).

In our project, WSN nodes are MICAz motes, featuring an ATMEL ATmega128L 8-bit microcontroller with 128 KB of in-system programmable memory.

The common components of the sensor node are sensing unit, analog digital converter, central processing unit, transceiver unit, and power unit. The Crossbow Company produces several motes: MICA, MICA2, MICA2DOT, and MICAz. Figure 2 shows a picture of the MICAz mote, which uses a Chipcon CC2420 Processor/Radio Transceiver module and follows the IEEE 802.15.4 and ZigBee Alliances at 2.4 GHz. The data rate is 250 kbps using a Direct Sequence Spread Spectrum (DSSS).

The MICAz CC2400 radio is capable of tuning within the IEEE 802.15.4 channels, which start from 2.405 GHz to 2.480 GHz with a 5 MHz separation. The 2.405 GHz channel is selected by default. RF transmission power can be programmed from 0 dBm to -25 dBm. It is preferable to choose the lowest transmission power, as it will reduce the interference and power consumption. Low power transmission keeps the range small, which reduces the probability of interference between motes. The RF Received Signal Strength Indication (RSSI) could be read directly from the CC2420 radio. The regular antenna used with the MICAz mote is a $\lambda/4$ long insulated wire, which is called a monopole antenna. The length of the antenna operating at 2.4GHz is 1.2 inches antenna. The length of the antenna operating at 2.4GHz is 1.2 inches.

Software on the motes runs under TinyOS [10]. TinyOS is perhaps the first operating system specifically designed for wireless sensor networks. Unlike most other operating systems, TinyOS is based on an event-driven programming model instead of multithreading. TinyOS programs are composed into event handlers and tasks with run to completion-semantics. When an external event occurs, such as an incoming data packet or a sensor reading, TinyOS calls the appropriate event handler to handle the event. Event handlers can post tasks that are scheduled by the TinyOS kernel some time later.

Both the TinyOS system and programs written for TinyOS are written in a special programming language called nesC which is an extension to the C programming language. NesC is designed to detect race conditions between tasks and event handlers.

Figure 2. MICAz mote

B. WSN system in smart home

In this work we use WSN to create a smart environment. The wireless sensor nodes can be embedded into the smart devices, and they can communicate each other by wireless. The implementation of an appliance through a WSN has some benefits, such as, processing capability, distributed processing capacity, sensing capability, etc.

We proposed a system that consists of various nodes on which sensors are connected. The network structure has master-slave relationship. The slave boards send the collected data from sensors to the master. The sensor node is powered with a battery and uses ZigBee technology to send the state of the sensors to the master node. The network is created in a simple star topology and due to this the computation and power demand is kept low. The data is sent to a master node connected to the personal computer. By placing slave sensor nodes everywhere in the house, the temperature, illumination, fire, gas leakage, water leakage, intruders detect information can be passed to a PC collecting the information from the master node. The temperature and light can be automatically controlled by sensor node in a normal range. Whenever, the critical condition arises, a buzzer will alert the user to take required action through the PC. The relays on the sensor node help to drive the required devices in order to control the critical conditions. Figure 3 shows the topology of the WSN system.

WSN system has two types of sensor node: master node and slave node. The slave node has ZigBee based communication module and it consists of other functional units such as sensing unit, signal conditioning unit, microcontroller, and battery for power supply. The master node has to transmit the information directed by computer to the slave node and to transmit the reply back to the computer. The master node establishes the communication to the computer via RS232.

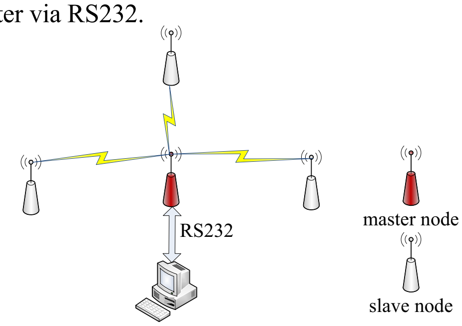

Figure 3. Topology of the WSN

C. Smart home service robot

The service robot in the smart home environment have the following key functionalities: localization, navigation, map building, human-robot interaction, object recognition and object handling. To execute the functions, a classical robotic platform should be equipped with sensors such as a ultra-violet sensor, an ultrasound sensor, a razor sensor, a range finder, or a camera as well as with a computing system that has a big memory.

The service robot used in this work is a wheeled differential drive robot called FutureStar. Its hardware is based on a motor control-board and a mother board of a desktop PC with a CPU Intel Pentium4 of 1.6GHz and 512MB of RAM. The sensors mounted on the robot are: a camera, encoders mount on the wheels, and a mote attached to the robot via USB. The control board and the service robot are showed in figure 4 and figure 5.

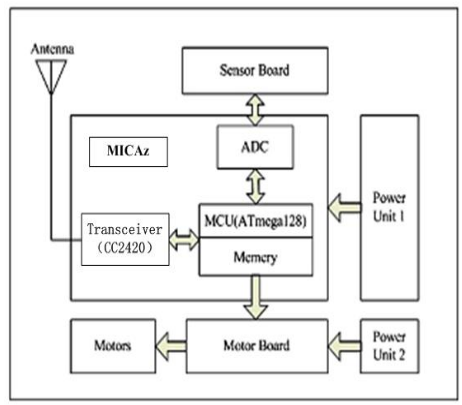

Figure 4. Control board structure

Figure 5. The service robot used in this work

IV. Conclusion and Future Work

In this paper we describe the architecture and implementation of a smart environment with WSN and service robot, in which the home server acts as an intelligent collaborator between our mobile service robot and the environment. To demonstrate the practicability of a WSN and service robot assisted smart home environment, we came up with devices required to provide reliable services, developed them, and implemented software for management and control.

The goal of our project is to show the usability of the service robots in our daily lives by constructing the smart environment for the service robots. This attempt is expected to enable humans to focus on the important tasks by liberating ourselves from unpleasant daily chores with the help of services robots.

Future work will focus on improvement of above proposed work and adding features to make a reliable smart home system.

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REFERENCES

[1] Soares, S.G., Tak a o, T.B., da Rocha, A., Ara u jo, R.A.M., and Barbosa, T.A.: Building Distributed Soft Sensors, International Journal of Computer Information Systems and Industrial Management Applications, 2011, 3, pp. 202-209.

[2] Sharma, U., and Reddy, S.: Design of Home/Office Automation using Wireless Sensor Network, International Journal of Computer Applications, 2012, 43(22), pp. 46-52

[3] Iniewski, K., Siu, C., Kilambi, S., Khan, S., Crowley, B., Mercier, P., and Schlegel, C.: Ultra-low power circuit and system design trade-offs for smart sensor network applications, in Editor (Ed.) Ultra-low power circuit and system design trade-offs for smart sensor network applications,2005, pp. 309-321.

[4] J. Wilson, V. Bhargava, A. Redfern, P. Wright, “A Wireless Sensor Network and Incident Command Interface for Urban Firefighting. Mobile and Ubiquitous Systems,” Networking & Services, Volume 00. 2007: IEEE Computer Society Washington, DC, USA.

[5] LI Li, LIU Yuan-an, TANG Bi-hua: SNMS: an intelligent transportation system network architecture based on WSN and P2P network,” The Journal of China universities of posts and telecommunications, 2007, 14(1) pp. 65-70.

[6] R. Szewczyk, A. Mainwaring,J. Polastre,D.Culler. :An analysis of a large scale habitat monitoring application, Proceedings of the Second ACM conference on Embedded Networked Sensor Systems (SenSys), 2004,pp.214–226.

[7] Burrell, J., Brooke, T., and Beckwith, R.: Vineyard computing: Sensor networks in agricultural production, Pervasive Computing, IEEE, 2004, 3(1), pp. 38-45.

[8] A. Arora,P. Dutta,S. Bapat,V. Kulathumani,H. Zhang,V. Naik, V. Mittal, H. Cao, M. Demirbas, M. Gouda, Y-R. Choi. : A wireless sensor network for target detection, classification, and tracking, Computer Networks (Elsevier), 2004, 46(5), pp.605–634.

[9] Vaidyanathan Ramadurai, Mihail L. Sichitiu. : Localization in WirelessSensor Networks: A Probabilistic Approach, Proceedings of the 2003 International Conference on Wireless Networks, 2003, pp.275-281.

[10] Hill, J., Szewczyk, R., Woo, A., Hollar, S., Culler, D., and Pister, K.: System architecture directions for networked sensors, Acm Sigplan Notices, 2000, 35(11), pp. 93-104.