DESIGN AND IMPLEMENTATION OF BUILDING ENERGY MONITORING SYSTEM USING WIRELESS SENSOR NETWORKS

HASHEM GHORBANPANAH
MEEDC* – IRAN
h.ghorbanpanah@meedc.net

M.H YAGHMAEE MOGHADDAM
MEEDC* – IRAN
yaghmaee@ieee.org

ALI SAEEDI
MEEDC* – IRAN
a.saeedi@meedc.net

SAEED ALISHAHI
MEEDC* – IRAN
s.alishahi@meedc.net

* MEEDC: Mashhad Electric Energy Distribution co.

ABSTRACT

This paper describes an application of Wireless Sensor Network in monitoring and controlling of energy in residential and commercial buildings. In this project, we design four different electronic Nodes including Sensor Node, Socket Node, Digital Power Meter Interface and Coordinator Node. In the application layer, user friendly software is designed to control and monitor all nodes in the wireless network through GPRS or LAN with using C# programming language. Each user can remotely connect to this network and control each input and output of nodes and in the automatic mode, all nodes can control electrical device without management from the coordinator node side. In this paper we have discussed various aspects of this project.

INTRODUCTION

Smart environments represent the next evolutionary development step in building, utilities, industrial, home and transportation systems automation. Like any sentient organism, the smart environment relies first and foremost on sensory data from the real world. Sensory data comes from multiple sensors of different modalities in distributed locations [1]. Wireless Sensor Network (WSN) is one of the most important technologies in the 21th century. With emerging of the Wireless Sensor Network and improvement in its communication and sensing abilities, a wide range of application is defined for it. Given the growth in energy consumption around the world, what's the best way to control it? Perhaps one of the best answers to this question is summarized in the Intelligent Energy Management (IEM) in the consumers' side. For an IEM system we need to knowledge, but how knowledge obtained? Data collection is the first step to knowledge and whatever data is a more comprehensive, decisions are more accurate.
In the data collection layer, WSN can help you to obtain the best result because; user can install each node without wiring in short time and also choosing the best area to achieve most complete information without any restrictions.

WIRELESS SENSOR NETWORK

Wireless sensor network (WSN), which integrates sensor technology, wireless communication technology, embedded computing technology and distributed information management technology, has been under rapid development during recent years [2].
A wireless sensor network is a collection of nodes organized into an interactive network.
Each node consists of processing capability (one or more microcontrollers, FPGAs or DSP chips) and contain types of memory (for example NAND flash memories), with a RF transceiver module and also, each nodes have a stable power source (e.g., batteries and solar cells), and the last part of a node, it is accommodate various sensors and actuators. The nodes communicate wirelessly and often self-organize after being deployed in an ad hoc method. Such systems can revolutionize the way we live and work therefore in this project we want to use WSN technology to control and manage energy in building.

PROJECT GOALS

This paper describes an application of WSN in monitoring and controlling of energy in residential and commercial buildings. Therefore, we need to cover all parts of a building through an integrated network of information. The main goals of defining this project are shown in Fig. 1.

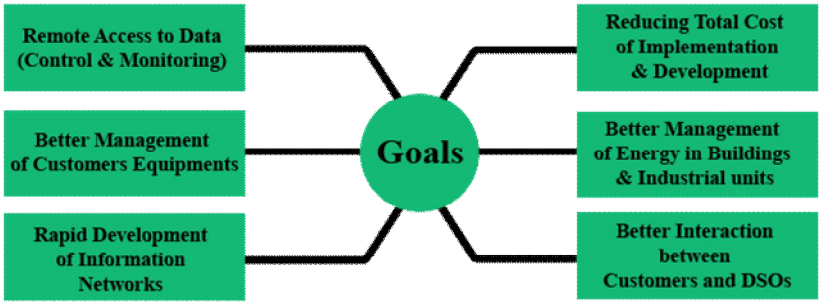

Figure 1: The main goals of the project

WIRELESS SENSOR NETWORKS

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area of home or industrial environment) through wireless communications. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as coordinator or concentrator) that can be used locally or is connected to other networks (e.g., the Internet or other WSNs) through a gateway. The nodes can be fixed or moving and also, they can be aware of their location or not [8]. They can be homogeneous or not; due to the vast potential of sensor networks to enable applications that connect the physical world to the virtual world.

DESIGN AND IMPLEMENTATION

This wireless network consists of spatially distributed intelligent sensor nodes to monitor physical or environmental conditions. Also, in this project we have designed and built intelligent sockets and digital power meters interface based on WSN technology. Considering the system functions and overall structure of wireless sensor network, we adopt embedded system technology based on hardware platform at concentrator unit. The strength of embedded system is capable of collecting and processing a large number of signals [6]. Each of nodes in this network is passes their data through the wireless network to a concentrator device. In the concentrator unit, all received data from each node is decoded and then will be sent to transfer unit.

To design the concentrator unit, we use a Field-Programmable Gate Array (FPGA) for control process unit of hardware and protocol operation. Also, we use the following communication protocols in the system:

1. ZigBee protocol which is used to develop and manage wireless sensor networks (this is a communication protocol between the local network equipments in a district)
2. Modbus TCP/IP protocol which is used data transmission between customers system and DSO through of GPRS network and also wired LAN card.

For better management of wireless energy network through End-Users, two methods defined. First, through a human machine interface (HMI) to control the system components locally and the second method used for remote control network (LAN or GPRS) through a network base on application (BEMSpro) that is investigated in later sections of this paper.

Node hardware

The proposed system is composed of four communication modules; each of them can be through the WSN interface (ProBee-ZE10 Module) to transfer data up to 400 meters [3].Some of the most important ability of this module is shown in table 1.

Table 1: Specifications & Features of ProBee-ZE10 module

No.	Module Features
1	Fully supports ZigBee 2007 / ZigBee Pro stack
2	Integrated 2.4GHz, IEEE 802.15.4-compliant coprocessor
3	UART Signals Support
4	4 Analog Inputs and 13 Digital Inputs/Outputs
5	Network addressing: Channel, PAN ID, EPID
6	128 bit AES encryption algorithms
7	Network topology: Mesh
8	RF Data Rate: 250 kbps
9	Supply Voltage: 2.7~3.6 VDC

Different parts of the energy network are managed through the concentrator module; this module is one of the most important parts of the designed network. So, in this paper we have discussed a closer look at network components.

Concentrator module (Main Board)

The use of a coordinator node in a wireless sensor network can improve transmission performance and prevent data loss in the network. The data is forwarded from other nodes to a sink (coordinator) that can use it locally, or is connected to other networks (e.g., the Internet) through a gateway. The general structure of the code in each one is the same, with an initialization followed by a main loop. Upon the concentrator being started, the first action of the application is the initialization of the hardware then a network will be formatted [7].

The design of powerful coordinator node was a difficult before 32-bit RISC core was developed.

This electronic card combining a Xilinx Spartan-3A FPGA, a fully compliant 2.4GHz IEEE802.15.4 transceiver (ProBee-ZE10 Module), 64Kb of serial NAND flash, 1GB of Multi Media Card (MMC), 128Kb of RAM, onboard LAN card, USB and COM ports, 16 digital I/O, 4 analogue input and 2.8 inch of TFT LCD provides a versatile solution for wireless sensor networking applications. A coordinator node is shown in Fig. 2.

Figure 2: The hardware design of a coordinator node

The high level of integration helps to reduce the overall

system cost and increases extensibility of the network. The coordinator uses hardware MAC and highly secures 128 bit AES encryption accelerators for low power and minimum processor overhead [2].

Sensor Node

Sensor node is an autonomous device with inbuilt sensors for monitoring various environmental and physical conditions at various places and times. Each sensor node sensed temperature, detect gas and light.

Each sensor node including an ATmega32A (16-bit RISC core), a ProBee-ZE10 Module, COM ports, 4 digital I/O and 1 analogue input. The LM35 is a single chip relative temperature sensor. The Figaro TGS813 is an analogue gas detector sensor for detection of poison gas in the special region also, a photo-resistor or light dependent resistor (LDR) is used for detection of amount of light. LM35 and TGS813 are both analogue sensors with small size and low power consumption. Figaro's TGS carbon dioxide sensor was the alternative, which was the most compatible with low voltage sensor node.CO2 measuring takes longer time than other measurements and CO2 sensor voltage supply must be within +0.1V to 5 Volts. The carbon dioxide value can be read from the output voltage. All data received from each analogue or digital input port and after processing, the data are transferred to the microcontroller memory. Every sensor node in a specific time interval is connected to the concentrator node then in specific communication packet; data is transmitted to the concentrator node. A sensor node is shown in Fig. 3.

Figure 3: The hardware design of a sensor node

Socket Node

AC power plugs and sockets node are devices that allow electrically operated devices to be connected to the primary alternating current (AC) power supply in a building[4].In this project for control and monitoring of energy consumption per device, an E-card (socket node) is designed and constructed. The electrical devices in building or an industrial unit are connected to AC power (220v) through this model of nodes. Electrical parameters such as current, voltage, THD and Power Factor at this node is calculated and then compared with efficient operation set-point of the system; for online monitoring of system status through users, all data generated in this node are transferred to the concentrator node. The socket node is a combination of two relays to control electrical devices, A hall Effect-Based linear current sensor IC with 2.1kV (RMS) isolation and a Low-Resistance current conductor (ACS712), An ATmega32A microcontroller and a ProBee-ZE10 Module to connect socket nodes to WSN.

The socket node (see Figure 4) was plugged in to the AC power line through its input pins. Socket board is placed on the sensitive electrical components were protected from the moisture by a plastic coating spray [5].

Figure 4: The hardware design for a socket node

Digital Power Meters Interface

For digital power meter (single phase & three phases) electric parameters reading and remote monitoring of energy consumption in buildings, we designed a network interface with this equipment. This network interface can transfer any parameters of digital power meter such as current, voltage and active power to concentrator node, for using in other processes and changes in efficient operation set-points of other network nodes.

For this node, periodical sleep and wake modes were applied. In its turn, each node woke up and turned on its radio for 10 seconds, and then went back to sleep and turned off its radio for 10 min [5]. At a time, only one of the nodes is reading data from the sensors and waiting for a data request from the coordinator.

Software Platform Implementation

In application layer, we adopt network-based packets service, .NET Framework 3.0, C#.NET as the tools of implementation of network applications (BEMSpro) also we use SQL Server 2005 to build our database [6]. There are many information need to be store in database, including node information, status of wireless sensor network, status of each node, packet loss and file information. In management layer of application, we have two types of network management model.

1. Online and real time mode: Each user can be connected through a local network or a remote station to wireless sensor network; in fact, the user is connected to concentrator node via LAN or GPRS network. When user is connected to WSN, the status of each part of network (Sensor or Socket

node) can be read or modified by authorized users. (The delay in this mode is between 10ms to 10 seconds)

2. Offline mode: It will be activated when the network connection is disconnected. In this situation, each packet stored in the database and all data stored in log file is sent to coordinator after the connection established again. It has a significant impact on network stability.

BEMSpro software has 9 tab box selections: setting for network control, software configuration and relevant parameters, coordinator panel, sensor and socket panel and showing current status. By setting some parameters, it can perform the functions of communicating with port, data collection and data viewing [7].

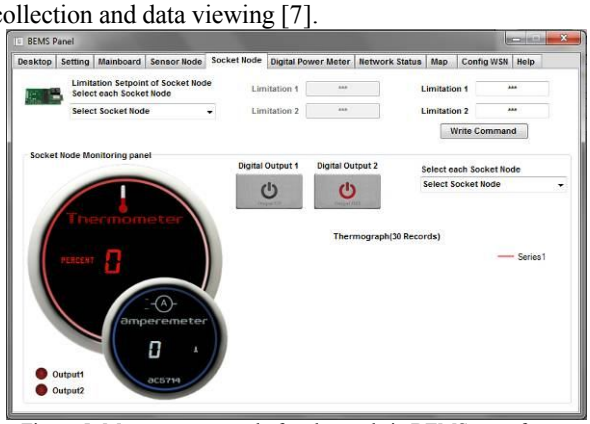

Figure 5: Management panel of socket node in BEMSpro software

CONCLUSION

In order to efficiently monitoring and controlling the energy of buildings, in this paper we research and design a network based management system with embedded control platform. The system provides a high level communication between each node (e.g., sensor or socket node) with a sink node in the energy network. In conclusion, this system provides an intelligent-based monitor and control platform for the wireless sensor network for home and building that some of its features and capabilities include as follow:

1. Improving energy management in buildings
2. Easy installation and high extensibility
3. Data transmission between customers and DSO through of GPRS network with ability of remote control for each node in the wireless network (Electrical devices that connect to each node; e.g., PC, lighting, heating and cooling systems and etc.)
4. Create an integrated database in the DSO level for better analysis of the customer's electricity network status.
5. Possibility of predict the status of power grid according to the information received from side of End-User in the electricity network.

After testing the system for three months, the system has been working normally and shows its competent abilities on controlling and managing energy in building.

Right now we are trying to raise the capabilities of the network with designing new nodes and implementation of specific algorithms on data received from the sample network. It is necessary to explain that this network now has been installed and used in the R&D centre of Mashhad Electric Energy Distribution Company (MEEDC).

REFERENCES

[1] D.J. Cook, 2006, "Wireless Sensor Networks", Department of Computer Science University of Virginia

[2] Zhou Yiming, 2007, "A Design of Greenhouse Monitoring & Control System Based on ZigBee Wireless Sensor Network", IEEE. 2563-2567.

[3] www.sena.com/download/manual_probee_ze10-v1.6.pdf

[4] en.wikipedia.org/wiki/AC_power_plugs_and_sockets

[5] Teemu Ahonen, 2008, "Greenhouse Monitoring with Wireless Sensor Network", IEEE, 1-4244-2368-2/08

[6] Gao qiang,2008 , " Research and Design of Web-based Wireless Sensor Network Management System for Greenhouse", 2008 International Conference on Computer and Electrical Engineering,657-661

[7] Yu Chengbo, 2009, "ZigBee Wireless Sensor Network in Environmental Monitoring Applications", IEEE, 978-983.

[8] Chiara Buratti, "An Overview on Wireless Sensor Networks Technology and Evolution", 2009 , ISSN 1424-8220(Sensors 2009), 6869-6896