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WSN based Energy Management System

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***Abstract*— Presently energy unaware behavior and user activity has large impact on total electricity consumption. Due to this, there will be more electricity consumption in industry, agriculture, domestic and other sectors. To manage and save electricity, Wireless sensor network is the key element used in intelligent energy system. In this paper, the structure and its key technology of node system of wireless sensor network are introduced. It also includes the communication protocol between the nodes and software algorithm of wireless sensor/ actuator node in wireless sensor network. This paper also presents a wireless sensor-actuator network to monitor and manage thermostatically controlled loads, mainly heating and cooling loads. WSN network can be implemented for university environment.**

Keywords- Load management; wireless PAN; Wireless Sensor and Actuator Network.

I. INTRODUCTION

India is known to have some of the highest electricity power Transmission and Distribution losses in the world. These losses are both physical (weak, overloaded networks) and commercial. Electricity Energy use in the residential sectors having relatively low intensity as compare to industrial sector. Though electricity consumption is low in residential area but it affects on total global power consumption. There is need to improve and create energy efficient services and reduce electricity losses. To achieve goal wireless sensor and Actuator Networks (WSAN) is best solution to monitor and manage loads [3]. It is an effectively based on set of S/A nodes interconnected through a wireless protocol and a sink node that operates in complete autonomy. Which will greatly enhance effective load management and play an important role in supporting smart grid due to its advantages such as no wiring, installation fast, maintenance convenient, and flexibility, easy to expand. WSN network offers the residential customers a flexible, powerful and low-cost tool to modify their power demand profile, avoiding any additional wiring. It is also useful to extend the wireless sensor-actuator networks technology towards small customers. According to the previous contributions, this paper describes a novel wireless sensor and actuator network (WSAN) based on routing algorithms previously proposed by the authors [1] with the aim of offering a flexible, decentralized and low-cost communication control system for the residential power demand. The described solution, mainly focused on elemental heating and cooling loads, allows the individual residential customers to inhibit operation of the selected appliances for part of control time intervals in order to rearrange the daily load demand profile, offering the utilities increased flexibility to decrease the power demand peaks and improve the load factors—the ratio of average to peak power demand [3].

II. RELAVENT WORK

To achieve intelligent energy system two main approaches are considered with regard to communication requirement. These are wired and wireless solutions. Mainly wired standard require non negligible modifications in the building. Although power line carrier (PLC) solution need no additional wiring or construction. For the long distance communication we require additional filters and repeaters. Additional problems are also introduced due to signal reflection. Also at high frequency, it impacts on the electric loads [9].

Wired standards such as Ethernet or controller area network can fulfill our requirement but they are not designed under low consumption capabilities. These solutions are not useful for small number of clients. Wireless standards provide more energy efficient solution for intelligent system. Wireless solution includes Bluetooth, WiFi, ultrawideband, or IEEE 802.15.4 based-systems, such as Zigbee , WirelessHart. Bluetooth networks are not useful to meet the requirements of our purposes: maximum number of nodes connected, message routing capabilities or node power consumption.

WiFi and ultrawideband networks are not applicable for the present application due to their high economic cost. IR technology being capable of receiving the commands from the energy management system and emitting the designated IR control signals to the air conditioning appliances. In this case, the important drawbacks, mainly due to IR systems may suffer from blocking from persons and objects, resulting in problems on the communication link. WirelessHART is a wireless sensor technology based on Highway Addressable Remote Transducer protocol. It is a secure and TDMA based mesh networking technology operating in the 2.4GHz band. It is useful for real time industrial process control where strict timing requirements are demanded by the process[2].

IEEE 802.15.4 standard we can select to meet our requirement regarding to wireless system in energy management in residential area. The amount of transmission data per node is very low—usually less than 100 bytes per minute, being this low-bandwidth network enough for the communication requirements. Secondly, IEEE 802.15.4 presents low interferences with other systems, even other 802.15.4 systems may coexist as long as different networks identifiers are used. In addition, IEEE 802.15.4 also includes coexistence with other protocols, increasing the

communication reliability through the application of different techniques[4],[5]. Domains of this technology is effective energy management schemes in residential area. Wireless sensor and actuator network (WSAN) based on routing algorithms with the aim of offering a flexible, decentralized and low-cost communication control system for the residential power demand. This system, mainly focused on elemental heating and cooling loads, allows the individual residential customers [3].

III. SYSTEM STRUCTURE

From figure 1, WSAN solution provides to monitoring and managing thermostatically controlled loads. Each individual load has a sensor/actuator (S/A) node based on an embedded system (microcontroller system) with wireless capacity, which reports about electrical and thermal variables to a special node called sink node. This node is connected to a personal computer (PC), where a load control algorithm is running to optimize the global power demand profile according to a prefixed target demand profile[3].

With this aim, the duty-cycle (on-period as a percentage of total time period considered) of the space heating and cooling loads are modified according to several customer comfort constraints by means of introducing switch-off time intervals forced by the node actuator. From the utility side, a decentralized control system is proposed where each sink node operates independently. Any sink node can then be interrogated by the utility through an Internet connection by means of TCP/IP links. This TCP/IP capability adds to the proposed solution a high flexibility and has been widely used in industrial automation solutions[3].

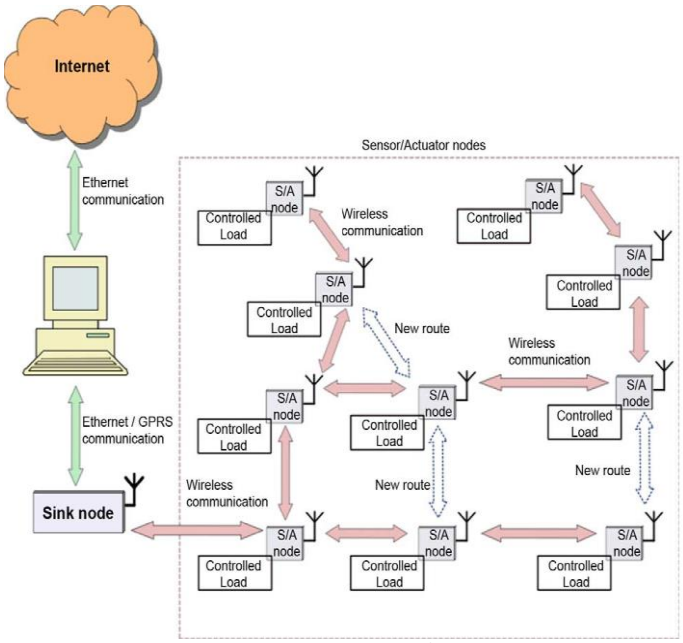

Figure 1 General architecture of system [3]

A. Method of data exchange on network

Instantaneous voltage and current values as well as environmental variables such as temperature, humidity and light intensity are collected by the set of S/A nodes and sent to the sink node through the wireless 802.15.4 network.

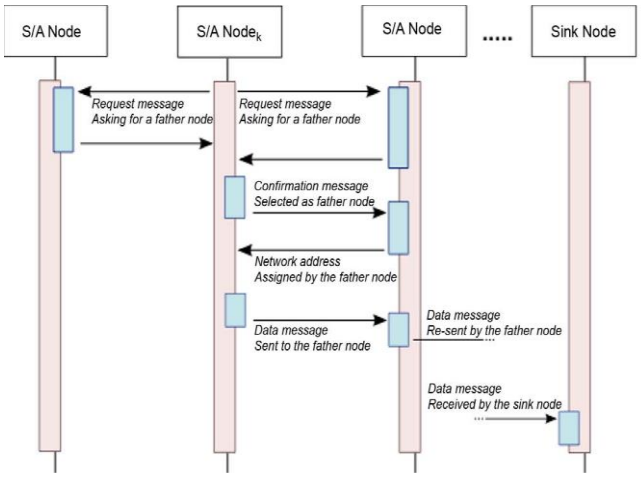

Figure 2. Example of data sent by S/A node [3]

Each S/A node can route the data from further nodes. The collected data travel through the wireless network by means of a succession of hops from node to node until the destination node sink node is reached. The 802.15.4 network is implemented as a logical tree, in which each S/A node fulfils message router functions to make possible a hop-by-hop communication. Independent 802.15.4 networks can be spread over the same set of customers using different network identifiers and/or different physical channels (at 2.4 GHz, sixteen different channels are available).

A message sent by a S/A node is then routed to its father node, and this father node to its corresponding father until the sink node is achieved. The way of S/A node identifies the address of its father node is based on a dynamic configuration of the network. As S/A node asks for a father node broadcasting a request message. Several S/A nodes can answer to this request, according to a function of the radio signal quality and the father distance (on hops) from the sink node, each S/A node will select one of them, reporting a confirmation message as those one has been selected as father node. A network address is then assigned by the father node following the addressing mechanism. This identification system allows an easy integration of new nodes without any additional cost [3].

B. The structure of wireless sensor network

The node system of wireless sensor network consists of wireless transceiver module with the protocol of IEEE802.15.4, microcontroller system, sensor system and the interface, power supply system and other memory store units.

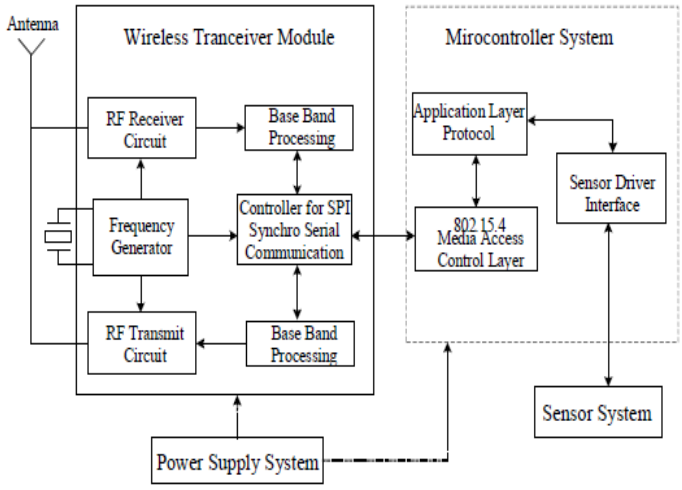

Figure 3. The system structure node of wireless sensor network.

Wireless communication module has the function of wireless transceiver, it includes two parts: RF and base band, the foregoing provides the air interface of data communication, the latter provides the physics channel of data link and data grouping. Microcontroller takes charge of link management and control, run the communication protocol of base band and other relevant processing, includes set up data link, frequency chosen, link type supported, media access control, power mode and safety algorithm. The adjusted analog signal of sensors will be saved in the temporary memory after A/D converting, and then it will be transmitted to the main node by wireless channel. The node system can be powered by exterior DC power or battery group. If we need to increase the communication distance, the transmit power of antenna needs to increase the power of amplifier.

C. Communication protocol of the nodes in wireless sensor network

The wireless applications with sensors and remote control do not need large transmission bandwidth, they need lower transmission delay and lower power consuming, so it will has customer hold better long live battery and more parts on the board. This system adopts the IEEEE 802.15.4/ZigBee protocol, basically it consists of the two layer PHY and MAC of standard IEEE 802.15.4, and its main advantage is lower cost, easy set up, credible data transmission, lower power and safety for all layers[5],[6],[7],[8].

D. Nodes Software System

The ZigBee specifications define three networking topologies suitable for various applications. Star networks are common and provide for very long battery life operation. Mesh, or peer-to-peer, networks enable high levels of reliability and scalability by providing more than one path through the network. Tree networks combine the benefits of both for high levels of reliability and support for battery powered nodes. Our system is based on the star network. The software algorithms of the three kinds of nodes are shown in Figure 3. Once the coordinator (portable controller) started, it created its personal area network (PAN) and allowed the end devices (sensor actuator nodes) to join the network. After the wireless sensor network formed, it received the sensor data and displayed them on the LCD. Commands could be sent to wireless actuator node determined by the expert strategies. Manual operation was also accessible to the users by pressing the buttons. The application puts the nodes into doze mode whenever possible to save energy [8].

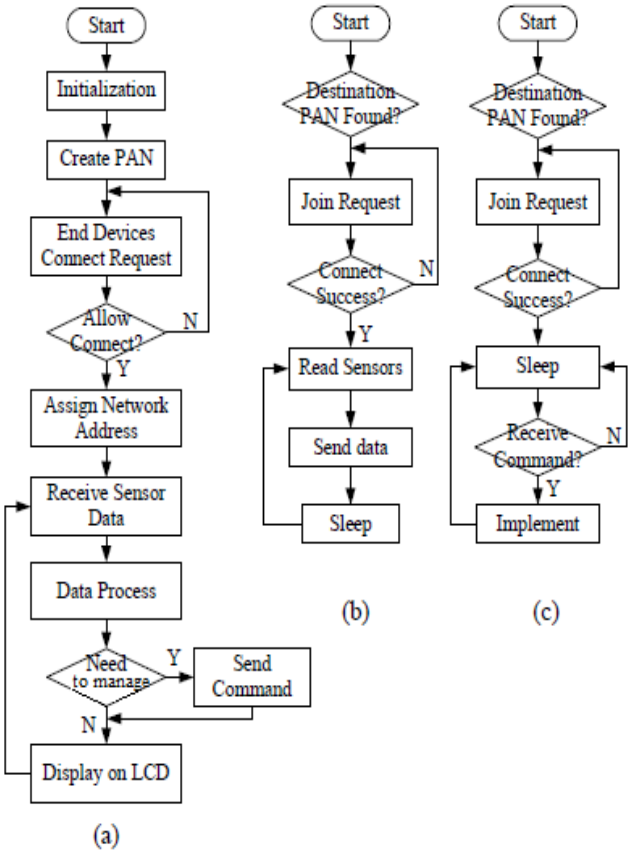

Figure 4. Program algorithm flowchart of portable controller (a) ,wireless sensor node (b) and wireless actuator node (c)

IV. PERFORMANCES

A. Node Power Consumption

The power consumption determines the service life of those battery-powered nodes working in the field. Since the portable controller in our system can be powered by external power supply and the wireless actuator node are mostly in sleep mode.

B. Communication Range

According the communication range through packet error rate (PER) testing using portable controller and wireless sensor node as the master module and slave module respectively. The test was carried out in the open air and 1m above the ground without barrier between the devices. The sensor node sent 10000 frames to portable controller via the RF link in different

distance and the PER was checked for the valid communication range which turned to be up to 400 meters.

C. System Cost

The load management system is developed with module design which helped to reduce the cost. The wireless sensor node and actuator node was about 30 US dollars and the portable controller was around $100. The total cost to build up a wireless field load management system depended on the area, and for a case of 5000*m2*, it was approximately $400 in terms of hardware cost.

V. CONCLUSION

Current situations show that electricity control is mainly done manually, from switching lights and appliances to control heating systems. However, user activities and behaviors have large impact on electricity consumed in all sectors of buildings such as residential, offices and retail sectors. Significant amount of electricity spent for these buildings can be saved by using wireless sensor and actuator network. In order to realize this approach, user activities and behaviors are required as the most important input for energy efficient management. An application of wireless sensor-actuator networks is useful to monitor and control thermostatically controlled electrical loads. The system allows the customers to collect both electrical and environmental parameters as well as to modify their power demand profile through forced switching-off time intervals applied on the cooling and heating loads through local S/A nodes, maintaining minimum comfort levels.

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