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Wireless Sensor Network: A Framework for Power and Temperature Monitoring Utility System

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Abstract- Wireless sensor network provides a backbone for various applications ranging from health care to remote monitoring especially in inaccessible terrains. In this paper, a smart power and temperature monitoring utility system using wireless sensor network is proposed. The system utilizes wireless power and temperature monitoring devices and control units. The proposed framework would be used to monitor electrical parameters such as voltage, current and power of household appliances as well as their corresponding temperature. The measured electrical parameters and temperature values are transmitted via ZigBee node to the base, a central controller which receives the transmitted data. A Wi-Fi adapter connected to the computer system USB ports ensures it is connected to the internet via wireless connection. The base is the internet gateway, relaying readings received via wireless from sensor nodes to the online platform. The appropriate electrical loads and devices can be monitored as well as controlled through a developed mobile application (Power App) to access a Customer Management System database, an online cloud service on which data will be logged and graphed and viewed in real-time by mobile users thus, providing reliable data that can be used in making informed decision.

Index Terms -- Smart meters , smart power grid, temperature monitor ,wireless sensor, network, monitoring system, zigbee.

1. INTRODUCTION

Intelligent electricity consumption and monitoring services strongly rely on smart power grid and the concept of modern management techniques, which rely on advanced metering, high efficiency control, high speed communication, and robust energy storage technology, to realize the real-time interaction between power networks, customer energy flow, information flow, and business flow [1]. The power grid is not only an important part of the electric power industry but also an important part of country's sustainability. With the dependence on electric power gradually increasing, demand for the reliability and quality of the power grid is also on a steady rise globally.

A smart electricity grid creates possibilities for new techniques such as smart metering – with far-reaching impacts, delivering power more efficiently and reliably through demand response and comprehensive control and monitoring capabilities; using automatic grid re-configuration to prevent or restore outages. Wireless sensors represent a key enabler for the smart-grid and smart metering to reach its potential. The idea behind the "smart" grid is that the grid will respond to real-time demand; in order to achieve this, sensors will provide "real time" information. Wireless sensors network as a smart sensing peripheral infrastructure can be an important means to promote smart grid technology development. Wireless Sensor Network (WSN) appears as a technology upon which broad fields of applications have been built and can still derive their basis, drawing interest in various areas. Their ability to sense and communicate without a fixed physical infrastructure makes them an attractive technology to be used for measurement and monitoring system [2].

Due to the rising cost of energy generation and distribution around the world, there is a need to provide innovative techniques of efficiently utilizing energy while also managing equipment. Enterprise level companies, in particular, remain under constant pressure to lower the cost of ownership of assets and justify investment while the consumers at other end are not left out. Nevertheless, few studies have been carried out over time to address some of these shortcomings. Consequently, a Smart Power and Temperature Monitoring Utility System using wireless sensor network have been proposed. The proposed system would be used to monitor electrical parameters such as voltage, current and power of household appliances as well as their corresponding temperature. This innovation will help to address the problem of electricity waste and will also put into check, the possibilities of fire outbreak in industrial, residential or controlled spaces through a developed twenty – four (24) hours monitoring platform that would be used to efficiently manage energy consumption and equipment/appliances temperature.

Furthermore, it will also provide to the general populace, a medium in which they can remotely turn off devices that are mistakenly left on to prevent both wastage and hazards due to mal-functioning of these devices.

The rest of the paper is organized as follows: the background concepts are discussed in section 2;

related works are highlighted in section 3; section 4 examines the methodology while section 5 concludes the paper.

2. BACKGROUND

2.1 Wireless Sensor Network

According to [3], WSN can generally be described as a network of nodes that cooperatively sense and may control the environment, enabling interaction between persons or computers and the surrounding environment. IEEE survey also described WSN as a network, which integrates sensor technology, wireless communication technology, embedded computing technology and distributed information management. The wireless sensor network is simply a collection of sensor nodes organized into an interactive network.

The sensor node is one of the main parts of WSN; the hardware of a sensor node generally includes four parts: the power and power management module, a sensor, a microcontroller and a wireless transceiver, as shown in Figure 1. The power module offers the reliable power needed for the system. The sensor collects and transforms signals such as light, vibration, heat and chemical signals into electrical signals and then transferring them to the microcontroller.

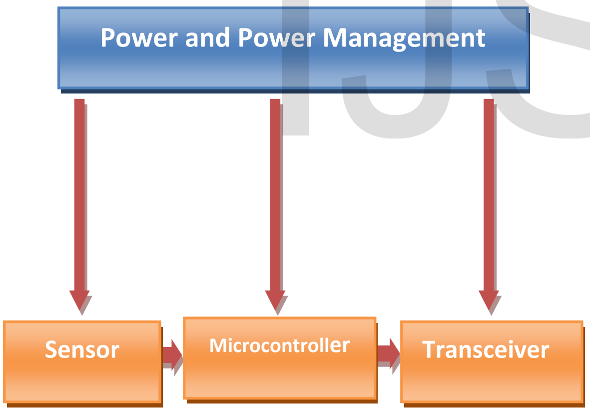

Fig 1: Sensor node parts

The microcontroller receives the data from the sensor and processes the data accordingly. The Wireless Transceiver (RF module) then transfers the data, so that the physical realization of communication can be achieved. Sensor nodes monitor the collected data to transmit along to other sensor nodes by hopping. During the process of transmission, monitored data may be handled by multiple nodes to get to gateway node after multi-hop routing, and finally reach the management node through the internet or satellite, as shown in Figure 2. It is the user who configures and manages the WSN with the management node, publishes monitoring missions and collection of the monitored data [1].

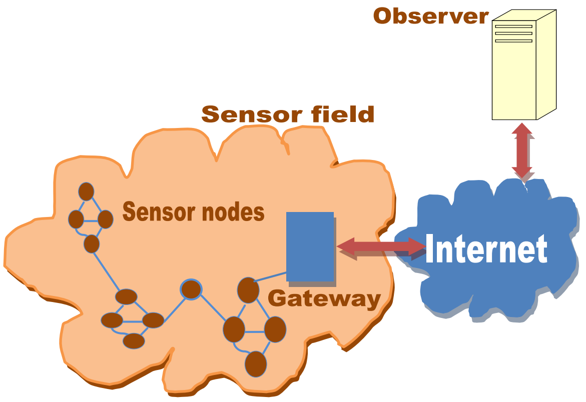

Fig 2: Hardware structure of a WSN

2.2 Smart Grid and Smart Meter

Most countries of the world share common challenges when it comes to energy. Nigeria as a developing nation is not left out with her own energy peculiarities: power outage is inevitable, demand is rising, fire outbreaks is increasing, activities of vandals and environmental concerns are changing the way that energy is generated and distributed. Due to these factors utilities around the world are seeking more efficient, reliable and secure ways to manage energy generation, transmission and distribution [4]. The development of an integrated, information technology (IT)-enabled, national electric power grid called “smart grid” has emerged as an effective approach that offers significant benefits for any country. Such a “smart grid” supports the expansion of distributed, often renewable, electricity production; lowers costs; promotes energy efficiency; and improves both the reliability and security of the entire production, transmission, and distribution system [5].

Smart metering is the most important mechanism used in smart grid for obtaining information from end users’ devices and appliances, while also controlling the behavior of the devices. According to [5] smart meters are electronic measurement devices used by utilities to communicate information through network interface for billing consumers and operating their electric systems. The recorded consumption of electricity at regular intervals is made available to its stakeholders through the network interface. There exist two main types of smart meters: Automatic Meter Reading (AMR) and Automatic Meter Infrastructure (AMI). AMR use only one-way communication and act primarily as digital “meter readers”. While AMI can use two-way communication to both transmit usage information and perform observation and maintenance tasks.

2.3 ZigBee (802.15.4)

ZigBee is the most popular industry wireless mesh networking standard for connecting sensors, instrumentation and control systems. ZigBee is an open, global, packet-based protocol designed to provide an easy-to-use architecture for secure, reliable, low power wireless networks. ZigBee and IEEE 802.15.4 are low data rate wireless networking standards that can eliminate the costly and damage prone wiring in industrial control applications [6]. Flow or process control equipment can be placed anywhere and still communicate with the rest of the system. It can also be moved since the network doesn't care about the physical location of a sensor, pump or valve. According to a survey, the benefits of this technology go far beyond, ZigBee applications include: Home and office automation, Industrial automation, Medical monitoring, Low-power sensors, HVAC control, Plus many other control and monitoring users. Figure 3 gives more insights into the highlighted applications.

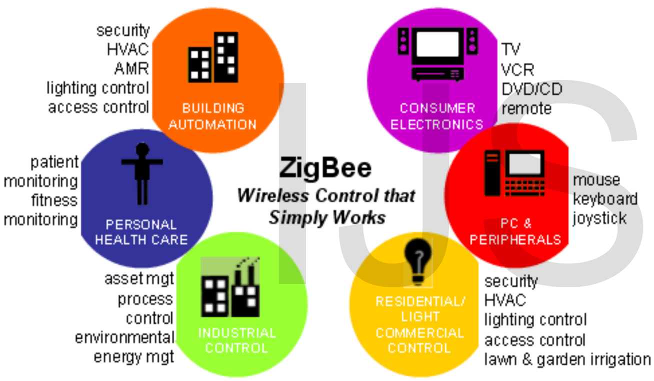

Fig 3: ZigBee Application

(Source: [7])

ZigBee targets the application domain of low power, low duty cycle and low data rate requirement devices. Figure 4 shows an example of a ZigBee network.

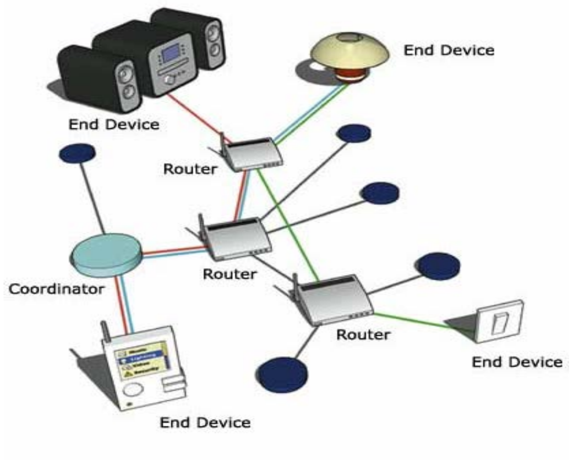

Fig 4: ZigBee Network

(Source: [7])

3. RELATED WORKS

In recent years, a wide range of smart meter research and innovations have been carried out both for small and large scale for domestic and industrial usage. Various architectural design and development methods of smart grid utility system for effectively managing and controlling the household appliances for optimal energy harvesting have also been developed [8]. Also, smart meter systems like [9] have been designed for specific use, especially in certain regions.

Different Information and Communication technologies integrating with smart meter devices have been proposed and tested at different residential areas for optimal power utilization [10][11], but individual controlling of the devices are limited to specific houses.

In the work of [12], a high-tech system that involves some means of metering, display and communication layer having a live contact with the utility was proposed. The system was effective in terms of electrical peak load management and a cost effective solution for different categories of users. [13], in their work they presented a low cost, flexible and real time smart power management system which can easily integrate with home monitoring systems. In another research conducted by [7], a smart grid for home utility was design and developed. The system utilizes wireless power monitoring devices and control units to monitor electrical parameters such as voltage, current and power of household appliances. In this framework, a low-cost, flexible and real time smart power and temperature monitoring system which can easily integrate with electrical appliances is presented.

4. METHODOLOGY

Electrical power generation and distribution have been in existence for many years. The primary sources for electricity generation are coal, natural gas, oil, nuclear power and other natural resources. At present, the consumers and utility companies have continuous concerns regarding the operational efficiency of the power distribution and associated system because of magnificent power requirements [14]. Hence, the need to develop an enhanced and reliable system not only for distribution but also for proper monitoring of its consumption and equipment condition is necessary. The proposed work is mainly on the consumer side for controlling load appliances and monitoring equipment condition seamlessly through a Graphical User Interface (GUI) on a computer system and a developed mobile application to cloud based service.

The hardware unit consists of the monitoring units (Sensor nodes) and the base station being coordinated using ZigBee. While the software unit is the system GUI and mobile application to access cloud base service. At the control/monitoring unit a smart electrical appliance monitoring unit will be developed to find the use, intensity and duration of use of the appliance. Data is then transmitted to the central controller. By monitoring the load of a household in the database an individual can analyze his/her billing system at any time.

4.1 Proposed System Overview

The modular architecture for the proposed power and temperature monitoring utility system is shown in Figure 5. From the consumer point of view; electrical current and voltage consumed are the key elements to measure power consumption of various appliances in a house.

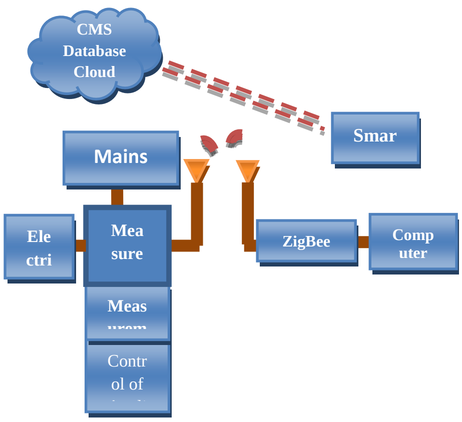

Fig 5: The proposed smart power and temperature monitoring system architecture

While the integrated temperature circuitry will measure the corresponding temperature, based on the information of system rating, a current transformer smart electrical appliance monitoring unit will be designed. The resulting signals after stepping down the values are processed using the power/energy sensing unit to get the information on the power. With the power and temperature sensing unit, an intelligent algorithm will be developed to capture and analyze appliances temperature and its corresponding power rating. The data is then transmitted to the central controller using ZigBee based wireless protocol.

4.2 Proposed System Operations

In this proposed work, a SMART component-based system of various integrated sensors all communicated via IEEE 802.15.4 wireless modules will be developed and implemented. The system will depend on a set of a selected number of wireless sensors and controller which relies on inputs from the sensors.

The power monitoring unit which houses the various sensors and power conditioning circuits are connected to the appliances or hooked around the wires powering location of space of interest as the case maybe, and connected to a wireless radio frequency transmitter. The temperature sensor circuit will have an Integrated Circuit (IC) temperature sensor for sensing temperature of equipment in degree Celsius scale. In the temperature monitoring unit, the millivolt output from the LM35 will be converted to digital temperature indicator by means of LM3914IC. The LEDs in this circuit shows the temperature levels digitally via 20 steps.

The smart temperature and smart metering circuit will be connected to a mains 240V/50HZ supply, transmits the readings to the base, a microcontroller base station/ZigBee co-coordinator cited at the office /control room. Intelligence in the sensing unit is provided to detect the activity of the particular device whether it is ON or OFF. The base will always remain powered ON at all times to ensure that data is continuously logged on the database. The base is powered by a mini-USB. As much as power is extremely critical to ensure reliability and constant availability of data on the database, the internet connectivity of the device is just as critical. A Wi-Fi adapter connected to one of the device's USB ports ensures the device is connected to the internet via wireless connection.

All components must be within close proximity of the base to ensure RF connectivity. The base is the internet gateway, relaying readings received via wireless from sensor nodes to the online platform. It is in turn powered ON and connected to the internet via Wi-Fi or Ethernet cable. The base is logged into and the feeds are created and displayed on dashboards. Data being measured are seen graphically on the dashboards and reports can be created using either the numerical values or the graphical values generated.

The ZigBee basically uses digital radios to allow devices to communicate with one another within the network. The ZigBee will operate in two different modes, FFD (Full Function Device) and RFD (Reduced Function Device). The ZigBee Coordinator always operates in FFD which means it listens to end devices. While the end devices operate in RFD mode when connected appliances are not in use, the connected sensor goes into sleep mode until the next command is sent by the coordinator. When the user selects an ON signal from the system GUI, the coordinator sends a digital signal to the appropriate digital I/O pin. The appliance will remain in the ON state until the coordinator sends a digital low signal on the chip.

4.3 Database Design

The CMS (Customer Management System) database is an online cloud service on which data will be logged and graphed and viewed real-time. A write API key will be used to link the Base to the CMS account. Data stored will be made private due to log-in session. Also, restricted access would be given to the account as data can be altered and deleted once access is gained into the portal. Information showing real-time power being consumed and the total electrical energy consumed on that day can also be accessed by a mobile user through the use of mobile application (Power App) which serves as a link to the CMS after the API key has been configured thereby enabling one to view the data on the go. Access would be restricted to the Base as configurations can be altered, which alters the feed values among other settings. Access would be done strictly on the connection to the Wi-Fi network.

5. CONCLUSION

In this paper, architecture for power and temperature monitoring utility system using the wireless sensor network technology has been discussed. Protocols and algorithms are important guidelines that drive the design of WSN's. Application and areas of improvement have been discussed such that, systems can be integrated with co-systems like smart home behavior recognitions systems to determine the wellness of the inhabitant in terms of energy consumption. For massive arrangements, a cost-effective power monitoring system is necessary, this requires a reliable and low-cost WSN mote plan. This system can be expanded to include smart home automation and smart metering applications. Furthermore, complete distribution system monitoring with the monitoring of transformers' temperature, oil levels amongst several others is also a potential area. The noticed area for further research is the complete implementation of the proposed system.

REFERENCES

[1] Y. Shu, L. Kang, L. Peter and J. Fan, "Internet of Things: Wireless Sensors Networks", IEC White Paper, 2014.

[2] B. Sebastian, "Enabling Autonomous Environmental Measurement Systems with Low – Power Wireless Sensor Networks, A degree Thesis of Mid Sweden University, 2011.

[3] A. Broring, "New generation sensor web enablement. Sensors", 11, pp. 26522699. ISSN1424-8220. Available from: DOI: 10.3390/s110302652, 2011

[4] M. McGranaghan, D. Von-Dollen, P. Myrda and E. Gunther," Utility experience with developing a smart grid roadmap,‖ in Proc. Power EnergySoc. Gen. Meeting—Conversion and Delivery of Electrical Energy in the 21st Century", Pittsburgh, pp. 1–5, 2008.

[5] J. Ojo, O. Owoeye, O. Lawal and A. Logunleko,"A Transparent and Sustainable Mobile Framework for Multiple Source Electric Power Metering, Billing and Administration". In Book of Proceedings of International conference on Mobile e-Services, pp7 - 23, 2015

[6] H. Dae-Man and L. Jae-Hyun," Smart home energy management system using IEEE802.15.4 and zigbee" *IEEE Transactions on Consumer Electronics*, Vol: 56, Issue: 3, Page(s): 1403 – 1410, 2010.

[7] M. Mahmood, Aamir, and M. I. Anis," Design and implementation of AMR Smart Grid System, in Proc". EPEC, Vancouver, BC, Canada, pp. 1–6, 2008

[8] L. Li, X, Hu., J. Huang, K .He.."Design of new architecture of AMR system in Smart Grid", *Proceedings of the 6th IEEE Conference on Industrial Electronics and Applications* (ICIEA)- 2011, Page(s): 2025 – 2029, 2011

[9] E. Andrey and J. Morelli, "Design of a Smart Meter Techno-Economic Model for Electric Utilities in Ontario", *Proceedings of the IEEE Electric Power and Energy Conference* (EPEC), Page(s):1– 7, 2010

[10] F . Benzi, N. Anglani, E. Bassi and L. Frosini,"Electricity Smart Meter Interfacing the Households", *IEEE Transactions on Industrial Electronics*, Volume: 58, Issue: 10, 2011

[11] I. Kunold, M, Kuller., J. Bauer, N. Karaoglan,”A system concept of an energy information system in flats using wireless technologies and smart metering devices” *Proceedings of the IEEE 6th International Conference on Intelligent Data Acquisition and Advanced Computing Systems* (IDAACS), Page(s): 812 – 816, 2011

[12] F, Azhar, N.A, Ahmad., R. Muhammad., M. K, Nik., A. Salman and M. Ashad. “A smart energy management system for monitoring and controlling time of power consumption”. *Scientific Research and Essays* Vol. 7(9), pp. 1000-1011. 2012

[13] S.P.S. Gill, N. K, Suryadevara and S.C. Mukhopadhyay,”. Smart Power Monitoring System Using Wireless Sensor Networks” *Sixth International Conference on Sensing Technology*, 2012