Wireless Sensor Networks and Advanced Metering Infrastructure Deployment in Smart Grid

O. M. Longe, K. Ouahada, H. C. Ferreira, S. Rimer
Dept. of Electrical & Electronics Engineering Science,
University of Johannesburg,
Johannesburg, South Africa.
wunmigrace@yahoo.com, {kouahada, hcferreira, suvendic}@uj.ac.za

Abstract. The increasing demand for electricity has necessitated the introduction of information and communication technologies (ICT) in the development of the smart grid. Advanced Metering Infrastructure (AMI) and Wireless Sensor Networks (WSNs) are contributing technologies. In this paper, a review on AMI and WSN in the smart grid is carried out. Also, the introduction of WSNs with AMI in the in-home energy management system of the smart grid is also presented with challenges faced in the deployment of WSNs for the smart grid. The low power and low-cost nature of WSN has presented WSN as a technology that can be used with AMI and smart home appliances in achieving home energy management within the great goal of the smart grid.

Keywords: Wireless sensor network; Advanced Metering Infrastructure, Smart Grid.

1 Introduction

The rapid global growth in science and technology has greatly increased the number of gadgets and cities to be electrically powered, but the present power generation cannot meet this growing demand for electrical energy; hence, the need to introduce information and communication technologies to the present power grid to give birth to a smart grid. The smart grid is expected to provide energy efficiency, reliability, security and economic savings. To achieve this paradigm every stage of the power system namely: generation, transmission, distribution and consumption would have information and communication technologies incorporated into it. Four major steps have been pointed out as necessary for the actualization of a smart grid, but the foremost is Advanced Metering Infrastructure (AMI) [1]; while others are Advanced Distribution Operations (ADO), Advanced Transmission Operations (ATO) and Advanced Asset Management (AAM). The smart grid will include the use of smart appliances, switches and plugs at consumer premises. In South Africa, the industry specification for AMI is set as NRS049. This specification was prepared on behalf of the Electricity Suppliers Liaison Committee (ESLC) and approved for use by supply authorities. The first iteration of NRS049 was published in 2008 by the South African Bureau of Standards (SABS). Eskom, the national electricity utility provider intends implementing the AMI solution for its qualifying customers in a phased approach [2].

3 Advanced Metering Infrastructure

AMI is defined as the communications hardware and software; associated system and data management software that create a network between advanced meters and utility business systems and which allows collection and distribution of information to customers and other parties such as competitive retail providers, in addition to providing it to the utility itself [3]. The meter data is received by the AMI host system and sent to the Meter Data Management System (MDMS) that manages data storage and analyses data to provide the information in useful form to the utility. AMI enables two-way communications between utility and the meter. Communication media for AMI are wired, wireless and/or cellular.

3.1 Benefits of AMI

The benefits of AMI can be categorized basically into two namely: system operational benefits and customer service benefits.

System Operational Benefits. These include eradication of personnel for meter reading and monthly bills dispatch, elimination of errors in reading and missing meter readings, increased consistency in billing periods, theft reduction, provision of detailed data to inform energy advisors actions, better troubleshooting can be done by grid operations engineers, reduced fuel and maintenance cost on meter reading and maintenance, less labour cost to service providers, improved cash flow budgeting and management, provision of monitoring tool for demand and line losses etc.

Customer Service Benefits. These include energy savings and a lowered bill, accurate bill as consumer, payment of electricity bill at convenience, no arbitrary high bill to the consumers etc.

3.2 Components of AMI System

An AMI system is comprised of a number of technologies and applications that have been integrated to perform as one:

- Smart meters
- Wide-area communications infrastructure
- Home (local) area networks (HANs)
- Meter Data Management Systems (MDMS)
- Operational Gateways

Smart Meters. These are solid state programmable devices that perform many functions, including time-based pricing, consumption data for consumer and utility, net metering, loss of power (and restoration) notification, remote turn on or turn off operations, load limiting or demand response purposes, energy prepayment, power quality monitoring, tamper and energy theft detection and communications with other intelligent devices in the home [1][4]. The AMI communications infrastructure supports continuous interaction between the utility, the consumer and the controllable electrical load.

Home Area Networks (HAN). HAN interfaces with a consumer portal to link smart meters to controllable electrical devices. Its energy management functions may include in-home displays so the consumer always knows what energy is being used and what it is costing, responsiveness to price signals based on consumer-entered preferences, set limits for utility or local control actions to a consumer specified band, control of loads without continuing consumer involvement and consumer over-ride capability, security monitoring. [4][5].

Meter Data Management System (MDMS). MDMS is a database with analytical tools that enable interaction with other information systems such as Consumer Information System (CIS), billing systems, utility website, Outage Management System (OMS), Enterprise Resource Planning (ERP), power quality management, load forecasting systems, Mobile Workforce Management (MWM), Geographic Information System (GIS) and Transformer Load Management (TLM) [4][6]. One of the primary functions of an MDMS is to perform validation, editing and estimation (VEE) on the AMI data to ensure that despite disruptions in the communications network or at customer premises, the data flowing to the systems described above is complete and accurate.

Operational Gateways. AMI interfaces with many system-side applications to support Advanced Distribution Operations (ADO), Distribution Management System with advanced sensors, Advanced Outage Management for real-time outage information from AMI meters, Distributed Energy Resources (DER) Operations (using Watt and VAR data from AMI meters), Distribution automation (including Volt/VAR optimization and fault location, isolation, sectionalization and restoration (FLISR)), Distribution GIS and also application of AMI communications infrastructure for microgrid operations (AC and DC), Hi-speed information processing, Advanced protection and control and Advanced grid components for distribution [4].

AMI has many challenges which include interoperability, non-standard protocols and multiple open protocols such as DLMS/COSEM, ANSI C12, Modbus, IEC 1107, legacy meters with limited communication functionalities, data security and integrity, handling of huge volume of data and real-time data update, commercial losses due to theft and tampering of smart meters [6][7].

4 Wireless Sensor Network Enabling AMI Communications

WSN technology addresses two-way communication efficiently by providing low-cost and low-power wireless communications. With the invention of low-cost, low-power radio sensors, wireless communication is one of the most cost efficient ways to collect utility meter data.

The contribution of WSNs brings significant advantages over traditional communication technologies including rapid deployment, low cost, flexibility, and aggregated intelligence through parallel processing. The recent advances of WSNs have made it feasible to realize low-cost embedded electric utility monitoring and diagnostic systems [8][9][10]. In these systems, wireless multifunctional sensor nodes are installed on the critical equipment of the smart grid and monitor the parameters critical to equipment condition. Such information enables the smart-grid system to respond to the changing conditions in a more proactive and timely manner. In this regard, WSNs play a vital role in creating a highly reliable and self-healing smart electric power grid that rapidly responds to online events with appropriate actions.

However, the realization of these currently designed and envisioned applications directly depend on efficient and reliable communication capabilities of the deployed WSNs. A typical WSN topology in a HAN is shown in Fig. 1.

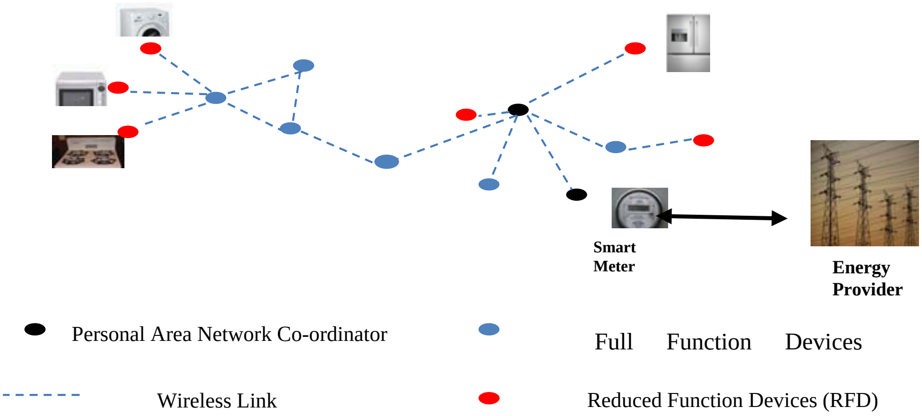

Fig. 1. A Typical WSN Topology in a HAN

5 Challenges of WSNs in Smart Grid

In WSN-based smart grid applications, a good link quality metric is essential for a reliable and energy-efficient system operation. Some of the challenges faced in WSNs deployment in the Smart Grid are described below [9][10].

Harsh Environmental Conditions. Sensors may also be subject to radio frequency interference, highly caustic or corrosive environments, high humidity levels, vibrations, dirt and dust, or other conditions that challenge performance [8]. These may lead to malfunctioning of sensor nodes.

Reliability and Latency Requirements. The wide variety of applications envisaged on WSNs for smart grid will have different quality-of-service (QoS) requirements and specifications in terms of reliability, latency, network throughput, etc while it is important to receive the data at the controller node in a timely manner.

Packet Errors and Variable Link Capacity. In WSNs, the bandwidth of each wireless link depends on the interference level perceived at the receiver and wireless links exhibit widely varying characteristics over time and space due to obstructions and noisy environment in electric power systems.

Resource Constraints. The design and implementation of WSNs are constrained by three types of resources namely: energy, memory and processing. Therefore, communication protocols for WSNs are mainly tailored to provide high energy efficiency.

5 Conclusion

The impact that AMI and WSNs would have in smart grid cannot be over-emphasized as energy management has grown beyond generation, transmission and distribution, but has moved right into the consumer premises, be it an individual home or commercial and industrial premises. AMI and WSNs are therefore very promising technologies for the success of the smart grid even as their introduction would bring benefits to both utility and energy consumers including energy efficiency, saving, reliability and security.

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