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Performance Evaluation of Communication Technologies for SMART GRID Applications

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Abstarct: The initiative of Smart Grid has started to evolve more rapidly with the enhancement in Communication Technologies. Two way communication is a key feature in realizing Smart Grids and is easily possible with the help of modern day advancements in both wired and wireless communication technologies. This paper discusses understanding the communication network choices when supporting applications such as Distribution Automation, Advanced Metering, Automated Demand Response and Electric Vehicle Charging and some of the major communication technologies which include IEEE specified ZigBee, WiMAX and Wireless LAN (Wi-Fi) technologies, GSM 3G/4G Cellular, DASH 7 and PLC (Power Line Communications), with special focus on their applications in Smart Grids. The advancements, challenges and the opportunities present in these priority areas are discussed in this paper.

Keywords- component; formatting; style;styling;insert (smartgrid,power line communications(PLCS) ,ZIGBEE,WI-FI,WIMAX,GSM/GPRS,DASH7)

1. INTRODUCTION

The infiltration of communication technologies in the Power Sector has helped the concept of Smart Power Grid to take quantum leaps towards a practically realizable stage. The idea of Smart Grid which surfaced long ago, started to take concrete shape when major breakthroughs were achieved in communica-tion technologies and power electronic equipment. The power flow was there long ago but the inclusion of communica-tion technologies has enabled the aspect of bi-directional com-munication. The key features of Smart or Intelligent Grid involve monitoring, protection, automation, optimization, integration and security of the power flow from utility generators to the end user appliances. This eventually results in conservation of energy and its efficient utilization for both power and infrastructure applications.

The motivation behind this paper is to provide ample information regarding the integration, penetration and application of modern communication technologies with the existing Power Grid. Keeping in view the recent developments and research in this domain, this article gives a general overview of different support communication technologies and their applications in realizing Smart Grids. Some of these technologies included in this survey are IEEE 802.11 based wireless LAN, IEEE 802.15 based ZigBee, IEEE 802.16 based WiMAX, 3G/4G GSM, DASH 7 and Power Line Communication (PLC). These technologies are selected because of their penetration and ongoing research activities for the realization of Smart Power Grids.

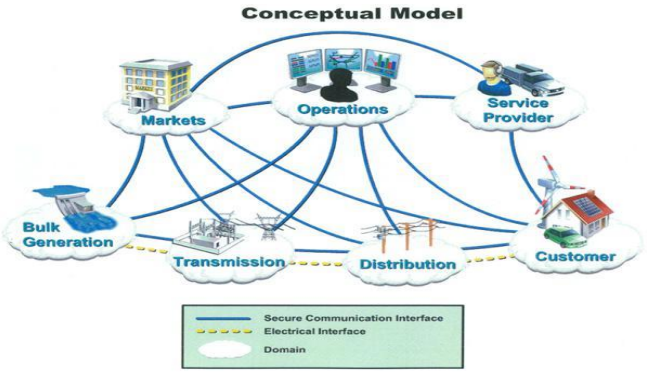
The organization of this paper is as follows: Section 2 discusses the a conceptual architecture of a Smart Power Grid network. Section 3 discusses the above mentioned communication tech-nologies and their potential applications in Smart Grid and Section 4 concludes the discussion.

2. CONCEPTUAL ARCHITECTURE FOR SMART POWER GRIDS

Different conceptual models and architectures have been proposed for the Smart Grids' implementation. One such con-ceptual architectural model is proposed to National Institute of Standards and Technology (NIST) in the Smart Grid Interpret-ability Standards Roadmap [1]. The main purpose of this archi-tecture is to be used as a guideline for describing, discussing, analyzing and developing smart grid architecture and standards. The top level abstraction of this architecture is shown in Fig. 1.

The key domains in developing a complete Smart Power Grid are shown. The interfacing and communication between these domains is also given in Fig. 1. These domains may contain multiple domains as well. Inter domain communication and Intra domain communication may or may not have similar requirements [1].

The Consumer Domain refers to the user of electricity (and other utilities). The consumer can generate, store and use the electricity. We have only considered domestic, industrial and commercial consumer aspects for this discussion. The ‘‘Market’’



3. COMMUNICATION TECHNOLOGIES FOR SMART GRIDS

3.1 Power Line Communication (PLC)

One of the earliest initiatives for the automation of the electricity grid was taken using the Power Line Communication (PLC) Technology. The Power Line Communication technology involves introduction of a modulated carrier signal over the existing power line cable infrastructure for two way communication. PLC is classified into two major categories i.e. Narrowband PLC and Broadband PLC.The Narrowband PLC has an operating range of 3–500 kHz. This operating range includes CENELEC, ARIB and FCC specified bands. Narrowband PLC is further classified as Low Data Rate Narrowband PLC and High Data Rate Narrowband PLC. The Low Date Rate Narrowband PLC is a single carrier based technology having data rate up to 10 kbps..

The Broadband PLC technology has an operating range of 2–250 MHz with data rates up to several hundred Mbps. The standards developed for this includes IEEE 1901, TIA—1113 (HomePlug 1.0), ITU-T G.hn (G.9960/G.9961), HD-PLC, etc [2].The Narrowband PLC technology is more suited to the sensing and communication purposes in Smart Grid environments while the broadband PLC is more inclined towards end user entertain-ment and Internet applications in addition to the Smart Grid Applications. Power Line Communication technology has found its applications in nearly all aspects of the Smart Grid Environ-ment. From Generation to the End User, Power Line Communication can be considered as a viable solution

The PLC technology is considered to be the most mature communication technology for Smart Grid applications. One of the main reasons behind this is the availability of the power line infrastructure and amount of the research conducted in this area. The development of software defined PLC modems has made the implementation and up-gradation cost of the overall solution quite low as compared to other viable and proposed solutions.

3.2 IEEE 802.15.4 (ZigBee)

IEEE 802.15.4 is a standard which specifies the physical layer and media access control for low-rate wireless personal area networks.The IEEE 802.15.4 standards adopt beacon and non-beacon mode for communication. In beacon mode communication, the device searches for the network beacon for data transmitting interval, while in non-beacon mode the device simply sends the data to the network coordinator node [18,19].The ZigBee enabled devices use the same functionality in a slightly different way. They have two types of devices. One is the Full Function Device (FFD) and the other is the Reduced Function Device (RFD). The network formed on the basis of ZigBee devices consists of both these devices. The establishment and manage-ment of the network, along with routing of the data lies with the FFD. The RFDs are there to support the functions of the FFDs [18,19].

Electrical power networks are required to be scalable in order to support the new and the future set of functions characterized by the Smart Grid requirements. These are also required to be highly pervasive in order to support the deployment of last-mile communications (i.e. from a backbone node to the customer location) [20,21]. ZigBee can serve as a right technology enabling wireless networking between the different devices connected in the Power Grids. The robust nature of ZigBee networks also makes these ideal for hostile environments where node failures may be common [18,22].

3.3 IEEE 802.11 (Wireless LAN (WLAN) or Wi-Fi)

Wireless LAN (WLAN) or Wi-Fi is the most popular among the wireless standards developed by Wi-Fi Alliance under the IEEE 802.11 standards. The Physical Layer and the MAC layer of the Wi-Fi

Technology are governed by the IEEE 802.11 standards. The IEEE 802.11 is a family of standards. The most popular among these versions are IEEE 802.11b and IEEE 802.11g. The latest release is the IEEE 802.11n.

Wi-Fi provides robust performance in shared spectrum and noisy RF channel environments. It supports all IP based protocols and numerous applications including Smart Energy Profile 2.0. A wide range of data rates is supported along with point-to-point and point-to-multipoint communications. Security features for secure and authentic data communication are also implemented, making it a strong contender for communication technologies for Smart Grids [41].The Automatic Metering Infrastructure (AMI) involves relaying information from the energy meters back to the utility central database. This involves a Neighborhood Area Network (NAN) scenario where different meters in the locality relay information to the nearest collector station (access points-APs) in their region. This involves municipality level deployment of Wi-Fi mesh network. The performance and range of Wi-Fi degrades in dense mesh environment and research is going on is this area. A Wi-Fi based remote meter reading application has been presented in [42].NIST has approved IEC 61850 standards for Substation Auto-mation applications [1]. IEC 61850 supports Ethernet (LAN) based communication network for intelligence purposes on a Substation Environment [44–46]. Wi-Fi technologies which are inherently Wireless LAN Technologies are equally applicable for deploying substation automation schemes [43].

3.4 IEEE-802.16 (WiMAX)

WiMAX, Worldwide Interoperability for Microwave Access is a communication technology developed under the IEEE 802.16 standards for Wireless Broadband. Among the family of IEEE 802.16 standards, the most used standard is the IEEE 802.16e 2005. The IEEE 802.16 specifies the Physical and MAC layer for the WiMAX technology. The Physical layer involves OFDMA with other features including MIMO based antenna systems used in order to provide the Non-Line of Sight capability. WiMAX technology uses two frequency bands, one for line-of-sight (11–66 GHz) and other for the non-line-of-sight operation (2–11 GHz). WiMAX involves Data Encryption Standard (DES) and AES encryption techniques for secure and reliable data communication [38,48,49]. WiMAX is more seen as a backbone solution in Smart Grid environments. Its long communication range, inherent interoperable nature and ability to support high data rates and point-to-multipoint capability make it much likely to be used as a reliable back-end communication link. It can be further considered as a viable option for communication between the distributed energy resources at remote locations. Other than these options it can also serve as a redundant high data rate link at the backbone of the utilities.

WiMAX technology provides reliable, high data rate and automatic network connectivity along with low overall installation costs and large coverage area for the Smart Grid Applications. A hybrid wireless communication system for power line monitoring in Smart Grid is proposed in [51]. The solution integrates the Wi-Fi and WiMAX technologies to support dual directional broadband communications. The WiMAX system modification for spectrum sensing and sharing with other sys-tems is also proposed in this scheme.Performance Analysis of WiMAX polling service for Smart Grid Meter Reading Applications has been shown in [52]. The analysis of different variables in WiMAX network designed to serve Smart Grid Applications is shown. It was revealed by the results that the polling services are able to support and fulfill the needs of metering application [52]. The size of the network affects the used capacity and the number of admitted smart meters that could be connected to the network. Further work is still required in this domain to improve the QoS related issue when using WiMAX form Smart Grid Applications.

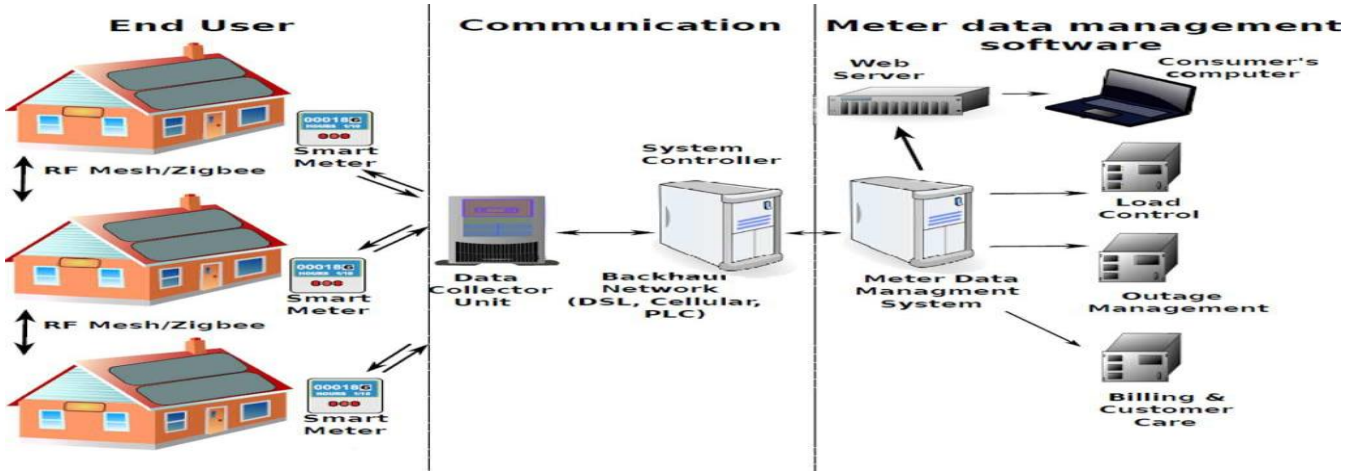
3.5 . GSM and GPRS

Global System for Mobile (GSM) is the most popular cellular network deployed all over the world. It is a circuit switched network and operates at 900 MHz and 1800 MHz. It uses Gaus-sian Minimum Shift keying (GMSK) as a modulation technique with data rates up to 270 kbps. Its architecture consists of four basic components i.e. Mobile handset, Base Station Subsystem, Network Switching Substation and Operation Support Substation. GSM is considered among the most secure communication networks.General Packet Radio Service (GPRS) employs packet based transfer of data over the circuit switched GSM network. This allows it to run IP based network applications over the GSM network. The data rate is much larger as compared to the GSM. In Smart Grid applications mostly it is used for remote monitoring purposes. A remote monitoring of a substation via GPRS technol-ogy is proposed in [54] and GPRS based online power quality monitoring in [55,56].

GSM based smart meters have also found their way in the AMI infrastructure. Subscriber Identity Module (SIM) cards are embedded in the meters and the recorded data is relayed to the backend database via GPRS or SMS. Other than metering pur-poses,

GSM based devices can also be used for Substation Automation and Protection purposes. These can be used to monitor distributed energy resources as well.

Detailed architecture of an AMI.:



4. CONCLUSION

The global trend is towards conservation of energy and discovering new energy resources. Smart Energy Grid plays an significant role in this effort and Communication Technologies are considered the backbone for its realization. The conventional and non-conventional generation finds the penetration of GSM/GRPS technology for smart communications. Other technologies are finding it hard to penetrate this sector. It is mainly because of the robust nature of the solutions available using the GSM/GPRS communication technology. Although the standardization and interoperatibility issue are still prevailing, the smart information sharing from this end is mostly done using the GSM/GPRS. Technologies and standards like IEEE 802.11 (Wi-Fi) and IEEE 802.16 (WiMAX) have good potential and efforts are going on towards developing and maturing these standards for this domain. Power Transmission Network along with the Power Distribution Network have more penetration of Power Line Communication (PLC) as a technology for smart information sharing. The solutions based on PLC are quite mature and considered among the oldest available.

REFERENCES

[1] T. Basso, J. Hambrick, and D. DeBlasio, "Update and review of IEEE P2030 smart grid interoperability and IEEE 1547 interconnection stan-dards," *Proc. IEEE PES Innovative Smart Grid Technol. Conf.*, pp. 1–7, Jan. 2012.

[2] T. Basso and R. DeBlasio, "Advancing smart grid interoperability and implementing NIST's interoperability roadmap," in *Proc. Grid Interop Conf.*, Denver, CO, Nov. 2009.

[3] F. Bouhafs, M. Mackay, and M. Merabti, "Links to the future: Commu-nication requirements and challenges in the smart grid," *IEEE Power Energy Mag.*, vol. 10, no. 1, pp. 24–32, Jan.–Feb. 2012.

[4] F. Benzi, N. Anglani, E. Bassi, and L. Frosini, "Electricity smart meters interfacing the households," *IEEE Trans. Ind. Electron.*, vol. 58, no. 10,

[5] Hu Z, Geng X, Xiao J, Hu X. Research and realization of on-line monitoring system for high voltage circuit breaker based on ZigBee technology. In: IEEE international conference on control and automation, ICCA, 2009; 2009.190–5.

[6] ong H, Zhang L, Pang J, Li C, Song T. Design of substation temperature monitoring system based on wireless sensor networks. In: Second interna-tional conference on advanced computer control (ICACC), vol. 1; 2010.127–30.

[7] ei C, Yang J, Zhu W, Lv J. A design of alarm system for substation perimeter based on laser fence and wireless communication. In: International con-ference on computer application and system modeling (ICCASM), vol. 3; 2010. p. 543–6.