PAPER • OPEN ACCESS

Monitoring Consumption System via Web Server for Hybrid Transport Protocol based on Smart Meter

To cite this article: Dhuha Shamil Mustafa *et al* 2020 *J. Phys.: Conf. Ser.* **1530** 012039

View the article online for updates and enhancements.

Monitoring Consumption System via Web Server for Hybrid Transport Protocol based on Smart Meter

Dhuha Shamil Mustafa[1], Abd Al-Karim Al-Aloosy[2,] and Khattab M Ali Alheeti[3]
[1]College of Computer and Information Technology, Computer Sciences Department, University of Anbar, Iraq
[2]College of Computer and Information Technology, Computer Networking Systems Department, University of Anbar, Anbar -Iraq
[3]College of Computer and Information Technology, Computer Networking Systems Department, University of Anbar, Anbar -Iraq

duhashamel@gmail.com

Abstract. A smart meter refers to an electronic device that makes an accurate record of electrical energy consumption, and then relays this data to the electrical supplier for billing and monitoring purposes. In this paper, several performance metrics have been selected for performance assessment: Throughput, Average End-to-End Delay and Packet Delivery Ratio. Results showed that the average of end to end delay is 4.896ms, the average throughput is 42.63 kbps and the Packet Delivery Ratio is 97.19%. Use Zigbee protocol with a cooperative communication system, through the Network Simulation ns-2, it's successfully facilitated the reading and wireless transmission of the voltage and power consumption of the users. A website is designed by using four languages: HTML, CSS, PHP, and SQL, to allow users to register his info like meter ID, first name, last name, and email. The database is receiving the data from nodes that are connected with it's by Zigbee after split data which is come out from ns-2. Every node is representing a user. Every end-user should be login to the website to register his number of meters, with other details. The website is sending notification to all users by email that tells him about consumption.

1. Introduction

Smart meters are set to transform how people understand and manage their energy usage. It is a manifestation of modern technology that governments have begun to regulate and manage electricity consumption by reducing excessive consumption [1]. The daily electrical utilization fluctuates according to the behaviour and habits of consumers. Conventional meters deprive consumers of the information of the sump of consumption over an hour or any particular time period of the day. Consumer's poor knowledge regarding the Smart meter and its installation also leads to falsification of the customers' uncertain perception. Lastly, this study is also motivated to initiate change and address market concerns [2].

The smart management systems require demand profile, pricing, and cost, energy loss prevention, energy efficiency, control services, machine learning, and few optimization processes. The intelligence subsystems and smart communication are linked to management systems as well as infrastructural components. Thus, the latest area of research of smart grid (SG) is the smart protection covering reliability, prediction, localization and security issues. The measurement and monitoring

requirements are conducted in this perspective. Consumption and other linked billing parameters are measured by smart metering systems in pre-determined interims. By protocol used in communication is modulated the data that measured to send it to management system over wireless or wireline in networks. A developed version of conventional automatic meter management (AMM) and automated meter reading (AMR) system could be taken as the advanced metering infrastructure (AMI). This is because it involves several improved technologies including wide area networks (WANs), home area networks (HANs), neighbor networks or smart meters (SMs) [3].

The wireless technologies have been proposed to be significant networks for the SG by the national institute of standards and technology (NIST). Selection of the most suitable communication technologies to process the management influences management of the demand, which is the key component to give SG's reliability with efficiency. Technological and economic feasibilities are the major aspects of selecting accurate technology [4, 5]. One of the most frequently studied topics related to power systems involved in the concept of SG is the wireless communication network. Despite the coverage and installation benefits of wireless networks, their disadvantages include their sensitivity to interference and limited bandwidth [4].

Based on standard IEEE 802.15.4, and requirements the sensor network and control, it's created a Zigbee for wireless personal area networks. The Zigbee communication work on Media Access Control (MAC) and physical layers, then it handles a lot of devices with a few data rates. Zigbee for wireless personal area networks can operate with these frequencies: 868 MHz, 902 to928MHz and 2.4 GHz. its two-way transmission between controllers and sensors with 250 kbps data rate so it's most suitable for periodic as well as intermediate [6]. Generally, Zigbee is a cheap and low-powered mesh network used to control and monitor applications and it can cover 10 to 100 meters range. When compared with the Zigbee communication system with another wireless sensor network like Wi-Fi and Bluetooth, the Zigbee is cheaper and simpler [7].

A common issue surrounding the energy industry is peak demand and it requires cost-effective and efficient approaches instead of increasing the number of generators [8]. An intelligent data system is required by these improvements in order to support the activities in the power grid in an efficient manner. Real-time data on the power supply's quality and consumption can be provided by smart meters to consumers and distributors [9]. The selection of a communication network may consider numerous technical issues. Moreover, it is customary for smart meter communication networks to adopt small bandwidths, thus leading to a capped quantity of transmitted information and overwhelming traffic [10]. The overall cost of deployment count would be raised by the integration of devices for demodulation, modulation and extra memory for data logs. Security risks might be posed in the transmission of energy consumption information via public communication networks which include cellular networks [11].

In this study, virtual smart meters used and the nodes were simulated inside it. However, this study aims to design a system for a smart meter based on the ZigBee protocol for analysing the data of electricity, this is because of the benefits of the smart meter, where the smart meter use in automatic meter reading of power, preventing falsification information of consumption and assuring security. Also, this study aims to notify the users of the amount of consumption through a webpage to help the user to save his power and control resources.

The paper is organized as follows: The related work on smart meter deployments presented in section II. Section III shows the proposed system design for a smart meter with a flow chart. In the end, Section VI includes the result, conclusion, and contribution.

2. Related Work
Literature has provided some researches on SM's privacy and secure billing [12, 13]. Some privacy issues from consumers, data experts and media are met by SM [12]. The privacy is linked to several factors such as transfer, measurement, and storage between the operating service and meters. If adequate privacy is not available, anyone can invade the system and manipulate any information stored inside the system. Such intrusion may lead to unintentional controls such as abuses of coolers

and heaters. An approach known as differential privacy was suggested by Danezis et. al. [14] to enhance SM's security by keeping special data hidden. This methodology depends on fixed-size databases for a fixed term billing time-frame and depends on the simplification of the regular differential privacy protocol. Testing of the trial study is done by the addition of numerous corruption of data with measurements stored in and examining the accuracy of the consumption bill [14].

Few researches aimed to enhance SMs' security [13, 15]. Rial et al enhanced a protocol of security that follows user agents that makes up a security in channel of communication within a wide network area. Also, in the research, there was an absence of requirement of additional channels while there is security in the communication. A privacy-protection approaches for SMs are enhanced by intensive investigation of the specialist and private key-based security problems [15].

The AMI system serves as a significant achievement in the smart grid. It functions to acquire measure and analyse data of the power quality of each consumer and energy consumption. Communication facility with metering devices on-demand occurs in an SM adapted with AMI facilities [16]. Enhancement of maintenance, panning of capability of supplier and demand management is achieved via bidirectional communication between consumer and utility supplier.

Communication between SM and operation centers may be practiced in few protocols via utilization of dual methods such as wireless and/or wireline. The wireline communication, also known as PLC, is carried out by utilizing transmission lines. The basic concept is utilizing the distribution and transmission lines to serve as the medium of communication in which any extra communication channel necessity is addressed this way. Despite this approach's disadvantage of losing aged electrical lines, elimination of additional system requirements is achieved via the transmission channel by lowering total cost of installations [15].

Conversely, data transmission that rates up to 200 Mbps for a single-phase system is provided by PLC applications. Few wireless communication approaches based on IEEE 802.15.4 protocol wireless personal area network (WPAN) or IEEE 802.22 protocol wireless regional area network (WRAN) may possibly be utilized. There are plenty of studies on the wireless smart grid and some of them presented in the next section are also available in literature [17-19]. Improvement of wireless networks such as Bluetooth and Wi-Fi may be attributed to digital communication approaches, in an effort to address the lack of PLC in applications of higher frequency.

IEEE 2030-2011 standard defines the smart grid's communication architecture, in which apprehension of hierarchical arrangement the infrastructures and applications are significant [18]. The purpose of the standard is to address several confusing descriptions by making clear indications of SGs networks like a logical structure, which includes the three types of sub-networks. In the first network is private networks linked to user properties are known as which includes building area network (BAN), industrial area network (IAN) and HAN. The second network which is situated at the distribution layer is known as WAN, which comprises field area network (FAN) and neighborhood area network (NAN). In order to regulate several functions, these networks are fixed with few monitoring and control mechanisms which include AMIs, PMUs and remote terminal units [19, 20]. Core network for utility sections including transmission and generation layers are the final network categories described in the standard. Some of the broadband communication architectures included in the core network are virtual private networks (VPN), GIS, local area network (LAN) and voice over internet protocol (CoIP) [19, 21]. Smart grid's communication technologies are given descriptions with regards to bandwidth properties as broadband and narrowband.

3. System Design

Figure 1 is the description of the stages of the proposed design for the smart meter. In the suggested design's specifics, the Zigbee protocol was utilized for transmission of data while synchronization purposes for smart meter nodes. The design also considers low-power and low-cost restrictions. The asynchronous measurement scheduling method was utilized to reduce the network traffic and, thus, the consumption of power while minimizing the requirement of wired connections between the nodes or the utilization of a particular radio link to enable synchronization. The proposed system is depending

on: Zigbee with MAC 802.15.4, Cooperative communication, routing protocol Ad hoc On-Demand Distance Vector (AODV) and Access Method Time Division Multiple Access (TDMA). A Simulation parameter that is used in this paper is present in table 1. After executing the simulation by ns-2 and getting the results that meant analysed and discussed in the results section. The AWK file in ns-2 separates the readings of the meters obtained from the program ns-2. So that, each message has separated that has been sent by the meter, and each message indicates its power. These results adopt web site designed where every single reading is a month's reading of the meter.
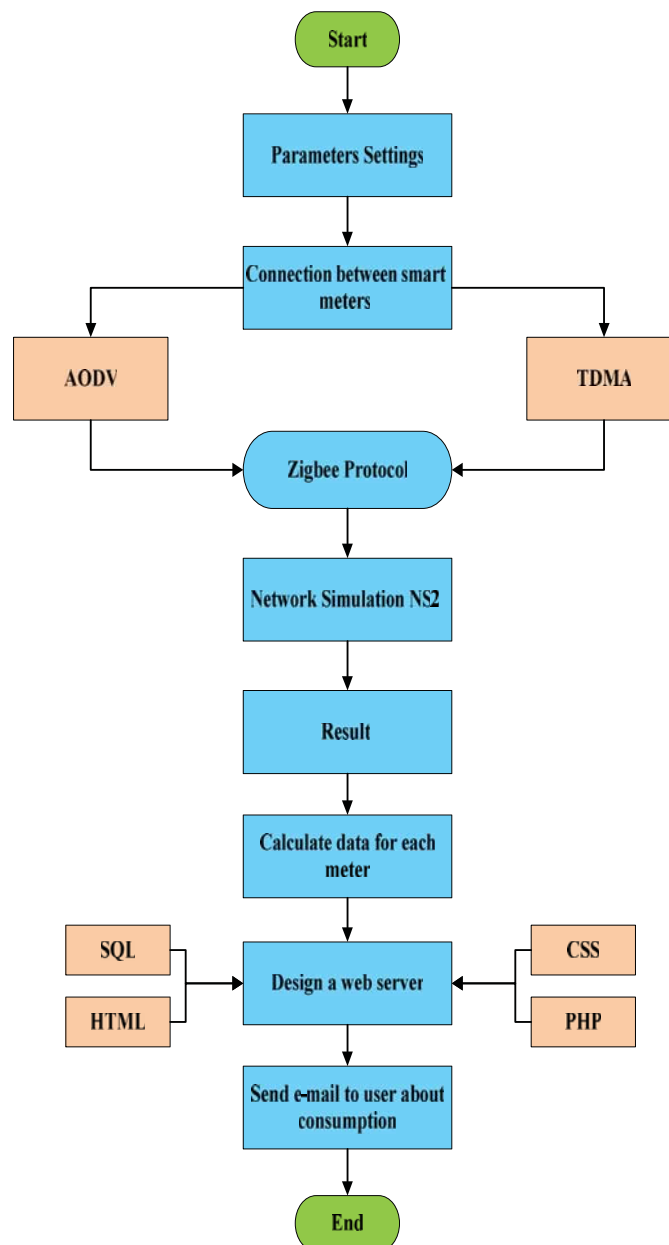

Figure 1. Flow chart for proposed design.

Table 1. Simulation Parameter.

Parameter Name	Parameter Value
Channel Model	Wireless
No. of nodes	58
Bandwidth	2 Mbit
Simulation Time	50 sec
MAC Protocol	IEEE 802.15.4
Transport Protocol	UDP
Routing Protocol	AODV
Application	CBR
Access Method	TDMA
Time Interval between Packets	0.01 sec
Energy	100 Joule

Zigbee work in two modes for transmitted with two-way, Beacon and Non-beacon modes. With the beacon mode, when there is non-data come from devices, the coordinators and routers make a sleep state. Then the coordinator makes a wake-up state to transmit the beacons to the routers in the network. So, this mode will make the coordinators and routers continuously monitor the active state of incoming data and therefore more power is consumed. on the other hand, the coordinators and routers not sleep and can wake up and communicate at any time.[22]. These beacon and non-beacon modes of Zigbee can manage periodic (sensors data), intermittent (Light switches) and repetitive data types [22]. Figure 2 shows the ZigBee topologies.

The second level of this method is to notify the user. This is will done after getting the result from the first step by calculating performance matrices, then spilled the result to know the packet sent by each node. The web page is suggested in this paper to allow to user enter to the web and know their information by login to email. The languages for design websites are HTML, CSS, PHP, and SQL.
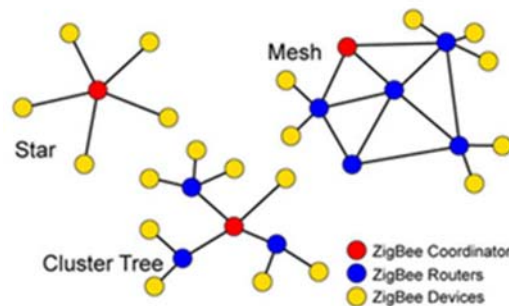
Figure 2. Zigbee topologies [23].

4. Experimental Results and Discussion

The reading and monitoring will be done by ZigBee protocol and using a cooperative communication system. The evaluating is measured using three performance metrics which are average end-to-end delay 4.896 (ms), throughput 42.6369 (kbps) and packet delivery ratio 97.192%. It has been noticed that when the results come out from the research experiment and compare with the result published by Moridi et al. [24], the research results are still the best. Where Moridi et al. [24] analysed the performance of Zigbee in deferent topologies with 50 node scenario. The metrics used for the performance evaluation include throughput, PDR, and E2E delay. Moreover, their results in deferent topology in throughput are 2.9296 (kbps) and 4 (kbps), PDR is 85% and 25%, and E2E delay are 33 (ms) and 4.9 (ms). The result in three parameters is generally better than the system as proposed by [24].

The readings of the meters obtained from the program ns-2 were separated by the AWK file in the program ns-2, where the readers were separated by each meter, the figure 3 shows the packet messages were sent for each node. The final energy is 99.99 for all nodes where it's suggested in the proposed scenario were 100 sent. These results are adopted in the xampp program where every single reading is a month's reads of the meter. A figure 3 and 4 show the number of nodes with the packet sends after split the result from ns-2.
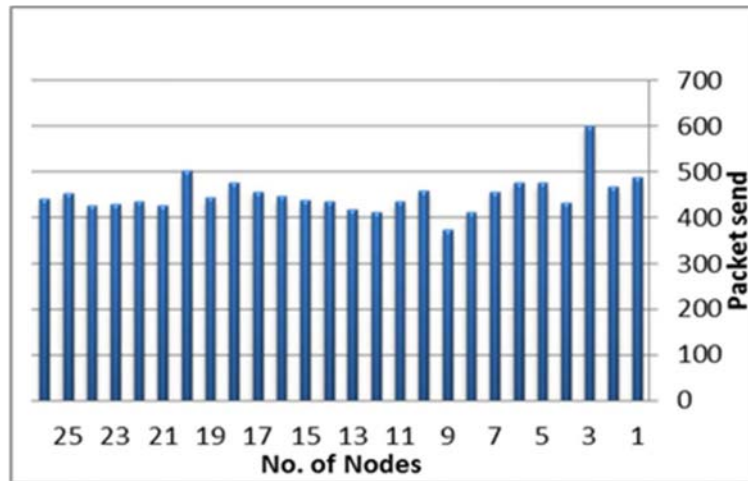

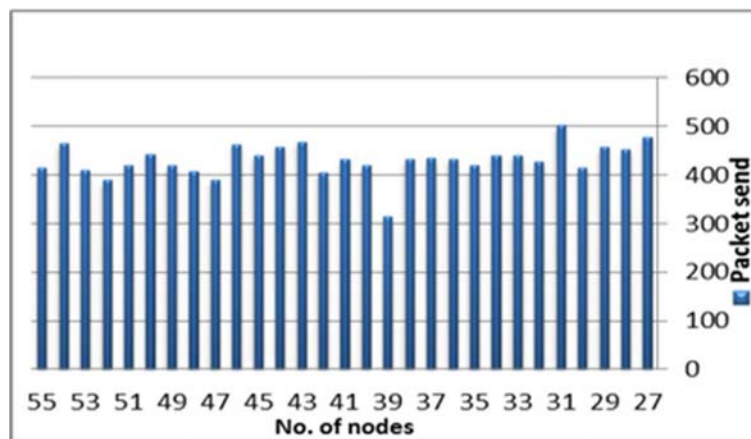**Figure 3.** No of nodes with packet send 1 to 26.

Figure 4. No of nodes with packet send 27 to 55.

A database was created to store user information. The user allows to open a web page and enters his / her information: first name, last name, meter number and e-mail, then enter each person's information into a database this is shown in Figures 5 to 8. The database which is designed depends on the result were come out from ns-2. Every node is representing the user, maybe home or anything related. The center node is receiving the data from nodes that are connected with it's by ZigBee. The center node will send the reading for node to database which is ready to calculate the used from energy for month. Every end-user should be login to the website to register his number of meters, first name, last name, and email. The website will send notification to user by email that tells him about consumption.
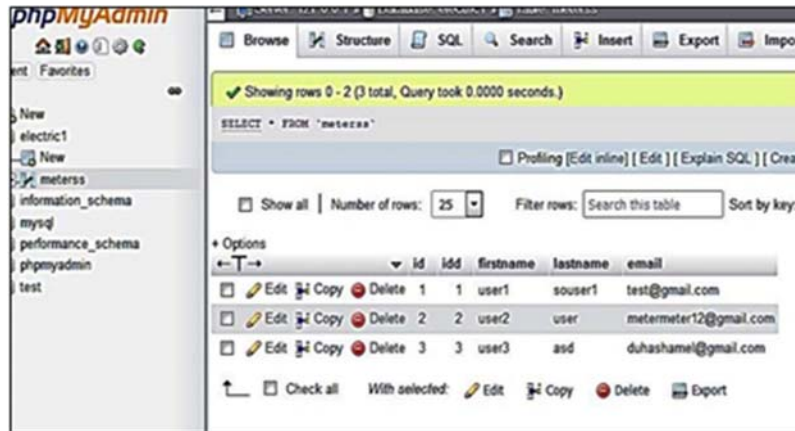
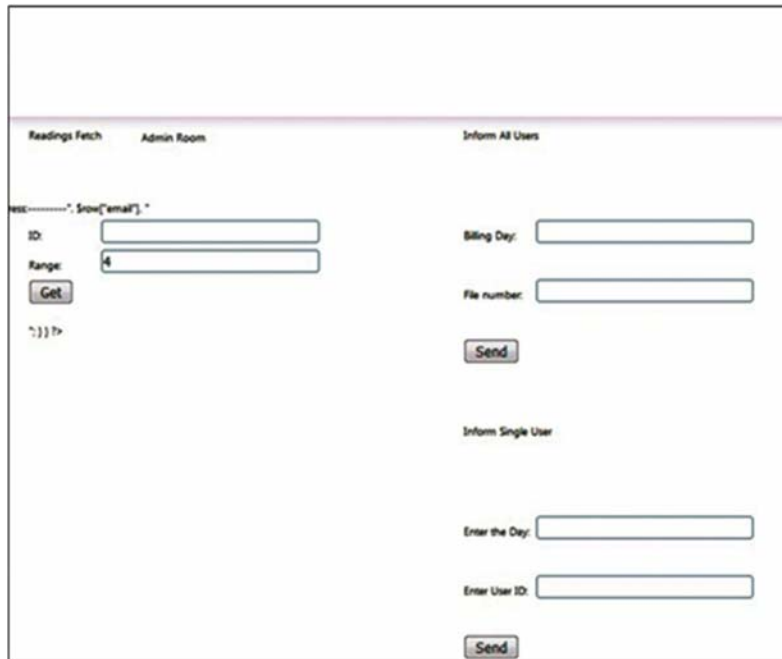**Figure 5.** webpage for the database.
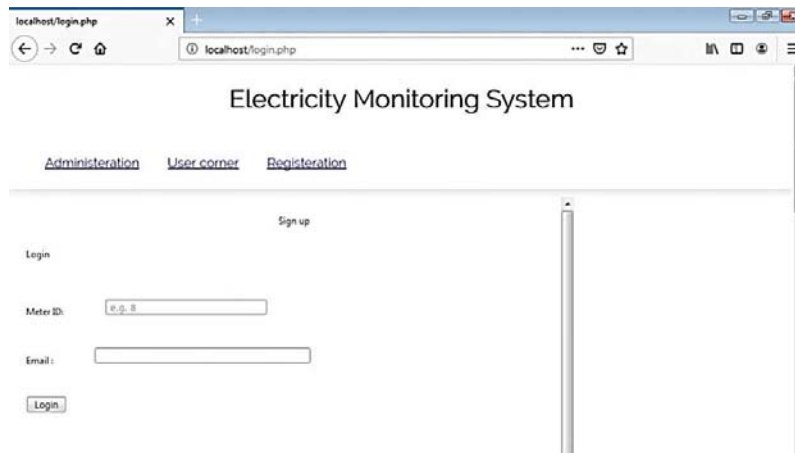

Figure 6. webpage for admin in the proposed design.

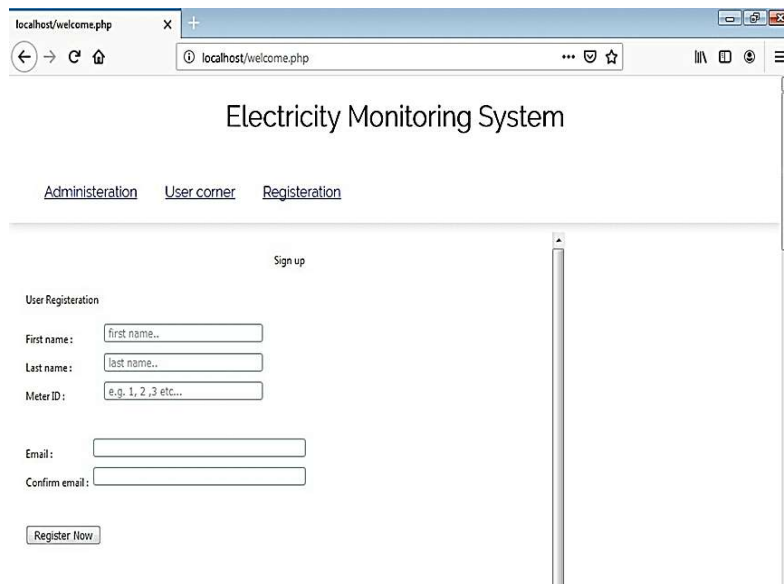**Figure 7.** webpage for user registration.

Figure 8. webpage for entering meter ID and email.

5. Conclusion

Smart meters are basically digital meters that provide records of short time-intervals consumption and communicate to and from the provider of the electric utility. There are many techniques used for measurement and present a smart metering solution which includes AMI, AMR, and AMM, as well as smart measurement requirements which include networks. A Zigbee used in a smart meter to connect the network by used ns-2 software. The system evaluation based on performance metrics such as throughput, Average end to end delay and packet delivery ratio. A website is designing to send to all users' notification data that tells about consumption per month. In this research, it successfully builds and proposed a method between nodes. A ZigBee is a high-performance record in this research. A website which design here is active working after testing it. It's store info and send email to all users after completing his requirement register.

6. Contribution

This paper is contributed a high connection between nodes which are representing a user's meter. It is contributed a high throughput with Packet Delivery Ratio (PDR) of performance Zigbee in smart meter. However, it gives the best value in routing between nodes. A website that displayed the use of consumption energy is helping the user to save his power and control resources. The research also contributes to enable the user to manage electricity resources in his home in addition to a cycle that will reduce the cost of electricity use.

References

[1] T. Krishnamurti, D. Schwartz, A. Davis, B. Fischhoff, W. B. de Bruin, L. Lave, et al., "Preparing for smart grid technologies: A behavioral decision research approach to understanding consumer expectations about smart meters," Energy Policy, **vol. 41**, pp. 790-797, 2012.

[2] J. Kelly and W. Knottenbelt, "The UK-DALE dataset, domestic appliance-level electricity demand and whole-house demand from five UK homes," Scientific data, **vol. 2**, p. 150007, 2015.

[3] F. Li, W. Qiao, H. Sun, H. Wan, J. Wang, Y. Xia, et al., "Smart transmission grid: Vision and framework," IEEE transactions on Smart Grid, **vol. 1**, no. 2, pp. 168-177, 2010.

[4] Y. Xu and W. Wang, "Wireless mesh network in smart grid: Modeling and analysis for time critical communications," IEEE Transactions on Wireless Communications, **vol. 12**, no. 7, pp. 3360-3371, 2013.

[5] Z. Zhu, S. Lambotharan, W. H. Chin, and Z. Fan, "Overview of demand management in smart grid and enabling wireless communication technologies," IEEE Wireless Communications, **vol. 19**, no. 3, 2012.

[6] S. Farahani, ZigBee wireless networks and transceivers: Newnes, 2011.

[7] O. G. Aju, "A survey of zigbee wireless sensor network technology: Topology, applications and challenges," International Journal of Computer Applications, **vol. 130**, no. 9, pp. 47-55, 2015.

[8] J. I. Chowdhury, Y. Hu, I. Haltas, N. Balta-Ozkan, and L. Varga, "Reducing industrial energy demand in the UK: A review of energy efficiency technologies and energy saving potential in selected sectors," Renewable and Sustainable Energy Reviews, **vol. 94**, pp. 1153-1178, 2018.

[9] D. Alahakoon and X. Yu, "Smart electricity meter data intelligence for future energy systems: A survey," IEEE Transactions on Industrial Informatics, **vol. 12**, no. 1, pp. 425-436, 2015.

[10] R. Siqueira de Carvalho, P. Kumar Sen, Y. Nag Velaga, L. Feksa Ramos, and L. Neves Canha, "Communication System Design for an Advanced Metering Infrastructure," Sensors, **vol. 18**, no. 11, p. 3734, 2018.

[11] P. Ozoh and M. Apperley, "Simulating electricity consumption pattern for household appliances using demand side strategies: a review," in Proceedings of the 15th New Zealand Conference on Human-Computer Interaction, 2015, pp. 65-71.

[12] M. Jawurek, M. Johns, and F. Kerschbaum, "Plug-in privacy for smart metering billing," in International Symposium on Privacy Enhancing Technologies Symposium, 2011, pp. 192-210.

[13] A. Rial and G. Danezis, "Privacy-preserving smart metering," in Proceedings of the 10th annual ACM workshop on Privacy in the electronic society, 2011, pp. 49-60.

[14] G. Danezis, M. Kohlweiss, and A. Rial, "Differentially private billing with rebates," in International Workshop on Information Hiding, 2011, pp. 148-162.

[15] M. Beye, Z. Erkin, and R. L. Lagendijk, "Efficient privacy preserving k-means clustering in a three-party setting," in Information Forensics and Security (WIFS), 2011 IEEE International Workshop on, 2011, pp. 1-6.

[16] J. Zhou, R. Q. Hu, and Y. Qian, "Scalable distributed communication architectures to support

advanced metering infrastructure in smart grid," IEEE Transactions on Parallel and Distributed Systems, **vol. 23**, no. 9, pp. 1632-1642, 2012.

[17] Y. Kabalci, "A survey on smart metering and smart grid communication," Renewable and Sustainable Energy Reviews, **vol. 57**, pp. 302-318, 2016.

[18] R. H. Khan and J. Y. Khan, "A comprehensive review of the application characteristics and traffic requirements of a smart grid communications network," Computer Networks, **vol. 57**, no. 3, pp. 825-845, 2013.

[19] E. Ancillotti, R. Bruno, and M. Conti, "The role of communication systems in smart grids: Architectures, technical solutions and research challenges," Computer Communications, **vol. 36**, 17-18, pp. 1665-1697, 2013.

[20] M. Kuzlu, M. Pipattanasomporn, and S. Rahman, "Communication network requirements for major smart grid applications in HAN, NAN and WAN," Computer Networks, **vol. 67**, pp. 74-88, 2014.

[21] T. Khalifa, K. Naik, and A. Nayak, "A survey of communication protocols for automatic meter reading applications," IEEE Communications Surveys & Tutorials, **vol. 13**, no. 2, pp. 168-182, 2011.

[22] I. Traore, I. Woungang, and A. Awad, Intelligent, Secure, and Dependable Systems in Distributed and Cloud Environments: First International Conference, ISDDC 2017, Vancouver, BC, Canada, October 26-28, 2017, Proceedings vol. 10618: Springer, 2017.

[23] T. Jamil, "A performance analysis of multimedia traffic over zigbee network," BRAC University, 2017.

[24] M. A. Moridi, Y. Kawamura, M. Sharifzadeh, E. K. Chanda, M. Wagner, and H. Okawa, "Performance analysis of ZigBee network topologies for underground space monitoring and communication systems," Tunnelling and Underground Space Technology, **vol. 71**, pp. 201-209, 2018.