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Smart Electric Meter Utilizing Embedded System

A Thesis
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By

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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 general, two-way communication between the central system and the meter is provided by the smart meters. This function of two-way communication between the supplier and the meter sets this Advanced Metering Infrastructure (AMI) apart from the Automatic Meter Reading (AMR). Since conventional meters operate via knowing the electricity consumption of households every month, there is a need for electric utilities to find new developments for the benefit of both providers and consumers. The thesis indicates that the smart electric meter has been simulated by using the hybrid system based on the Zigbee protocol. Besides, the protocol is used to communicate between the smart meter and electric center. In proposed method, a designed system using a cooperative communication system with Time Division Multiple Access (TDMA) worked together in hybrid system. The outcomes of performance Zigbee are measured by utilizing standard units that are known as performance metrics. Several performance metrics have selected for performance assessment: throughput, average End-to-End (E2E) delay, and Packet Delivery Ratio (PDR).

A web application is designed to allow users to register info like meter number, first name, last name, and email. The database is receiving the information from nodes that are connected with it by the hybrid system after split data which comes out from network simulator. Every end-user should be login to the web application to register their information. The web application can send a notification to all users by email that tells them about consumption.

Results appear that the average of E2E delay is 5.01*ms*, the average throughput is 42.63 kbps, and PDR is 97.19%. Use Zigbee protocol with a cooperative communication system, through the network simulator, has successfully facilitated the reading and wireless transmission of power consumption of the consumer. The thesis is a smart meter by using a hybrid technical and web application design for notification of users.

Keywords:* *Advanced Metering Infrastructure, Smart Grid (SG), Smart Meter (SM), Zigbee, TDMA, NS2, Web application.

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2020

Dedication

To God Almighty my creator, my strong pillar, my source of inspiration, wisdom, knowledge, and understanding.

To the great teacher, prophet "Muhammad" peace be upon him.

To the light that illuminates my path of success, "My Father" who has taught me everything. For my mother, who gave me my life and to be wherever I am to overcome the difficult circumstances.

To my brothers and my sisters for their support and love.

To my husband, who encourages and supports me in the way of success, and his effort that makes me finish what I have started.

To my kid, Yamen, who is my life.

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List of Abbreviations

Abbreviations	***Details***
AMI	Advanced Metering Infrastructure
AMM	Automatic Meter Management
AMR	Automated Meter Reading
AODV	Ad hoc On-Demand Distance Vector
AOMDV	Ad hoc On-demand Multipath Distance Vector
CSS	Cascading Style Sheets
DMPs	Data management points
DMS	Distribution Management System
DSR	Dynamic Source Routing
E2E	Average End-to-End Delay
EHS	Electromagnetic Hypersensitivity
EMS	Energy Management System
GPRS	General Packet Radio Services
HTML	HyperText Markup Language
IHP	In-House-Display
MAC	Media Access Control
MIMO	Multiple-input-Multiple-output
NAM	Network Animator
ns-2	Network Simulator version two
PDR	Packets Delivery Ratio
PHP	Hypertext Preprocessor
PLC	Power Line Communication
RERRs	Route error messages
RF	Radio Frequency
RREPs	Route replies
RREQs	Route requests
SG	Smart Grid
SM	Smart Meter
SQL	Structured Query Language
TDMA	Time Division Multiple Access
WSN	Wireless sensor network

CHAPTER ONE

INTRODUCTION

Chapter One

Introduction

1.1 Introduction

Currently, electricity serves as an ecological resource and social necessity. Consumers are affected by the effects of any electricity disruption, with the degree varying from critical to low depending on the activity nature. Nevertheless, decreased non-renewable resources and other ecological side effects impact of the electricity usage. As such, it is necessary to introduce conservative measures [1]. Recently, there has been growing interest in the development of improved feedback and control mechanisms for the power grid. Generation, transmission, distribution, retail, and consumers make up the power supply chain. Conventionally, historical consumption data is used to project electricity grid requirements; demand is projected to rise annually. Electricity providers make investments into additional infrastructure only to sustain requirements during peak periods, in order to prevent brownouts and blackouts. This approach is an inefficient and costly operating model [2]. Also, there is an absence of information flow between network elements of conventional grids, and the only data available for consumers is the cumulative consumption over a period. Power grids are experiencing a drastic alteration to enhance network operation's efficiency and for data exchange between the grid's elements. The introduction of the smart metering system is one of such efforts [3].

Smart meters are basically digital meters that provide records of short time intervals consumption and communicate to and from the provider of an electric utility. Billing and monitoring data are sent by the smart meter, which also controls information to and from provider. These meters are now being promoted to retrieve remote consumption data for billing purposes and to regulate control demand [4]. Real time data from the power grid can be provided by the smart meter to consumers. Instantaneous data on power usage can be displayed to users via devices such as In-House-Display (IHD) that are attached to smart meters. It can also show control signals such as price signals that are sent from the provider to the smart meter. The smart metering system has been reported to provide plenty of advantages to consumers [5]. The research question for this thesis is: what is a technique that provides a reliable wireless connection between nodes with a model that can provide a service for users?

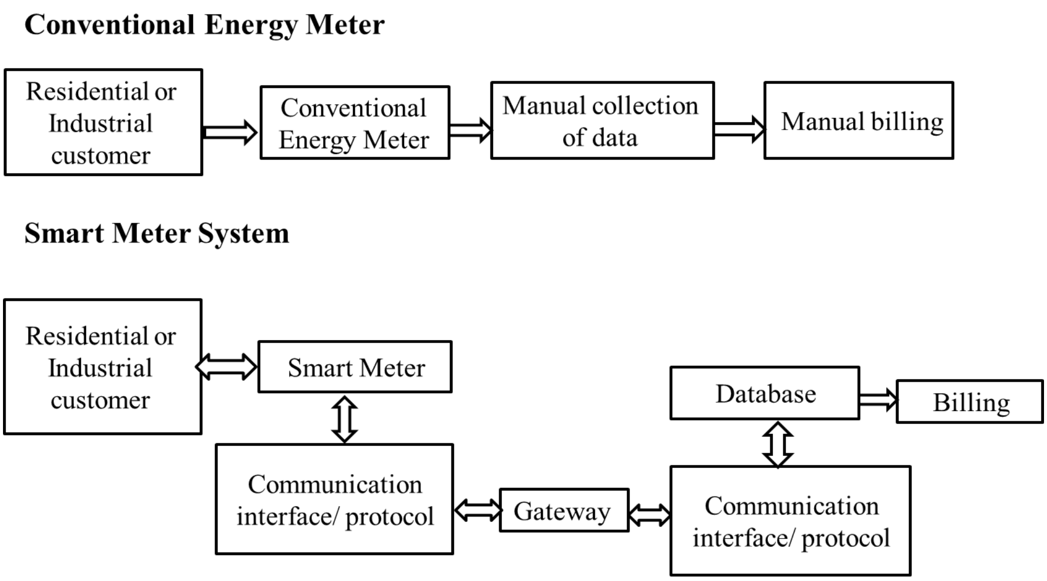


Figure 1.1: Architectures of conventional energy meter and smart meter [4].

Smart meters can be programmed such that, only power consumed from the utility grid is billed, while the power consumed from the distributed generation sources or storage devices owned by the customers are not billed. Smart meters can limit the maximum electricity consumption and can terminate or reconnect electricity supply to any customer remotely [6]. Figure 1.1 shows an architectural model of a conventional energy meter and a smart meter [4].

1.2 Motivation

The increase of the possibility of lowered consumption by utilizing smart meter information motivated us to conduct this research work to enable the lowering of energy expenditures. There is a high wastage of energy to manpower during the utilization of conventional meters. Since conventional meters operate via knowing the electricity consumption of households every month, the consumption data is not stored, the reading it provides is not accurate and does not contain a time and date for data, there is a need for electricity utilities to find new developments for the benefit of both providers and consumers. However, the study aims to reduce drawbacks occurred by consumers by attempting to replace electricity meter in respective households. The daily electrical utilization fluctuates according to the behavior and habits of consumers. Conventional meters deprive consumers of the information of sump of consumption over an hour or any particular 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.

1.3 Literature Review

Mohammad *et al*. analyzed the performance of ZigBee topologies in 12, 20, 30, 40, and 50-node scenarios for node deployment in underground environments [7]. PDR, energy consumption, Average end-to-end (E2E) delay, packet delivery security, and throughput are some of the metrics utilized for the evaluation of performance. They use deferent topology which are mesh and cluster tree topology, where their result in mesh topology which are PDR was 79 %, energy consumption was 100 (mWb), E2E delay was 34 (ms) and throughput was 3000 (bits/s), and their result in cluster tree which are PDR was 25 %, energy consumption was 60 (mWb), E2E delay was 11 (ms) and throughput was 1000 (bits/s). The mesh topology's prioritization in WSNs design confirms by the evaluation of the results, which attributes to PDR, network security, and higher throughput. In the case of lower energy consumption and lower E2E delay, cluster tree topology is preferable. The drawback in their work is that the comparison was only in the mesh and cluster tree topology, they did not use star topology in comparison.

Mohd Zubairuddin *et al*. presented a simple inexpensive Global System for Mobile Communications (GSM) based Automatic Energy Meter Reading system (AEMR) [8]. The suggested system provides a remote access approach for the energy provider and consumer. It provided the consumers and suppliers a chance to remotely oversee the energy meters, thus enabling a convenient collection of energy reading. **Tom Wilcox *et al.*** proposed a new core-broker-client system architecture for big data analytics [9]. Smart Meter Analytics Scaled by Hadoop (SMASH) is the name of the platform that is run. Work experiences confirm the SMASH's ability to run a query, data storage, visualization, and analysis tasks on vast sets of data at a scale of 20 TB.

Haya Salah *et al*. presented an experimental evaluation of ZigBee and DigiMesh networks; two well-known and widely used wireless mesh network architectures [10]. Round Trip Time, throughput, Mesh Routing Recovery Time, and Received Signal Strength Indication are the performance metrics utilized. Their results which are throughput was 3.6 in digimesh and 2.9 in Zigbee, delay was 0.14 in digimesh and 0.16 in Zigbee, Received Signal Strength was -65 in digimesh and -50 in Zigbee, Mesh Routing Recovery Time was 0.115 in digimesh and 0.109 in Zigbee. DigiMesh shows by the experiments to have relatively higher throughput than Zigbee networks. Nevertheless, Zigbee supersedes Digimesh based networks in terms of greater Received Signal Strength Indication, less recovery time needed from a failure node and lower Round Trip Time. As a result, Digimesh based networks are more suitable for networks requiring a high throughput, while Zigbee adapts for applications that need a more extended range of communication and less delay. The drawbacks in their work are that they will not do the network robustness against external interference and noise, and the power consumption and network lifetime will not be investigated for both types of networks.

A taxonomy on distinct security protocols targeted at Smart Grid (SG) environment was built by **Ashok Kumar Das *et al*.** This taxonomy makes the inclusion of trust computing, authentication, key management, intrusion detection systems, and privacy preservation [11].

Advanced Metering Infrastructure (AMI) analyzed by **Asad Masood Khattak *et al*.** from the security perspective; possible weaknesses linked with distinct attack surfaces in the smart meter has discussed. Threat implications and security also give consideration. Finally, better countermeasures and security controls have recommended by them [4]. **Bilgin and Gungor** evaluated performance of ZigBee in terms of network throughput, end-to-end delay, energy consumption, and packet delivery ratio in different smart grid environments, including an indoor power control room, an outdoor 500 kV substation environment, and an underground network transformer vaults [12]. Their result which are throughput were 23 (kbps), 17.578 (kbps), 17.089 (kbps), E2E delay were 2 (ms), 5 (ms) and 9 (ms), PDR were 15%, 20%, and 55% and energy consumption were 0.01% ,0.01% and 0.04%. Overall, our performance evaluations show that the ZigBee is ideal to use for low power and low data rate smart grid applications not having very high reliability requirements and real time deadlines. The drawback in their work is that the comparison between deferent environment was only in 15 node, this number is few.

Syeda Aimal *et al*. proposed an Efficient Convolutional Neural Network (ECNN) and Efficient K-nearest neighbour (EKnn) in which the parameters are tuned to make a smart grid cost efficient by predicting electricity price and load [13]. The management of an enormous quantity of load data originating from the electricity market may be a challenging task. They included three modules within the suggested methodology in order to address this issue. Feature engineering and classification make up the suggested model. Feature engineering is essentially a two-step process (feature selection and feature extraction). Mutual Information (MI) utilizes for the feature selection in order to eliminate redundancy among features. Recursive Feature Elimination (RFE) utilizes for feature extraction in order to retrieve principle features from the chosen features and eliminate feature dimensionality. Lastly, EKnn and ECNN run load prediction, following the training of data set and elimination of duplicate features. EKnn and ECNN have better performance compared to K-nearest neighbor (Knn) and Convolutional Neural Network (CNN).

Lu Wang *et al*. proposed a compensating method based on neural network approximate modeling to increase the accuracy of electric energy measurement among the whole range of operational temperature [14]. Following data measurement and the smart electricity meter's internal structure, a MATLAB/Simulink model of the meter, develops to assess the power measurement's consistency at varying levels of temperature. In order to collect the smart meter's temperature contours under various operating parameters, the Finite Element Method (FEM) thermal simulation model of the metering device runs in ANSYS Icepak. Subsequently, based on the simulation data, the component temperature in the metering circuit is evaluated according to the approximation model built by the Radial Basis Function (RBF) neural network. Finally, metering accuracy is adjusted using a temperature compensation program that is realized in the Micro-Controller Unit (MCU). Based on the results of the final tests, the suggested approach has tremendously improved the metering accuracy among the full temperature range.

Elliptical Curve Cryptography (ECC) is deployed by **Shijo Mathew T. *et al*.** Its performance sets in comparison with the current Advanced Encryption Standard (AES) Security protocol in Zigbee or wireless devices in a mathematical manner and in real time via utilization of the Raspberry Pi3 processor for fluctuating meter data in terms of Key Generation and Execution time [15]. Furthermore, the secured energy meter data has securely routed via SAODV routing, which is effective against Denial of Service attack, and which is Grey Hole and Black Hole attack. Thus accordingly, performance validation via the implementation of ECC and AES security protocol have carried out in order to ascertain its performance against Denial of Service attacks related to the Grey Hole and Black Hole attacks. It has been confirmed via ns-2.

The Wireless Sensor Home Area Network (WSHAN) is developed and run by **Mustafa Burunkaya *et al*.** with Zigbee interfaced smart meter [16]. Due to the rising demands for electricity, it has been necessary to substitute conventional electric grids with robust, intelligent, cost effective, and reliable SG applications. Their system can record usage of energy, display Time Of Use (TOU) values, and logs data in real time. The system is also able to regulate any device that is linked to power outputs. The smart meter provides the correct power usage, which then relays the data with Zigbee towards the Personal Computer. The user can monitor power data and run remote system navigation. The drawback in their work is that they will not work on security and privacy data.

V. Preethi *et al*. presented a smart energy meter for an automatic metering and billing system [17]. Within this meter, any energy that utilizes and its corresponding amount continuously shows on the LCD and relays to the control base station. The feedback from the user helps in identifying the usages between authorized and unauthorized users which helps in controlling the power theft. Zigbee allows communication between household/user with the substation. Any SMS to be sent to the local authorities with regards to cases of theft is made via the GSM network. This meter may function as a postpaid or prepaid meter.

Dariush Abbasinezhad-Mood *et al.* proposed an authentication scheme that can both provide the desired security features and offer better efficiency in communication and computational costs than several recently published schemes

[18]. Lastly, but most significantly, the suggested scheme's security has received validation via the recognized ProVerif tool. Moreover, the cryptographic elements have been carried out on appropriate hardware for smart meters. Results suggest that the proposed scheme is well suited for real world applications.

Marco Pau *et al.* presented a smart metering infrastructure that unlocks a large set of possible services which aimed at the automation and management of distribution grids [19]. The architecture suggested is based on a cloud solution. It permits communication with smart meters originating from one side and gives the required interfaces to the distribution grid services lying on the other side. At the same time, an enormous quantity of applications maybe build above the cloud. They introduce the cloud solution's significant role in getting flexibility, scalability, and interoperability. They also allow distinct services to integrate for the distribution system's automation. Furthermore, they present the automatic network reconfiguration and state estimation algorithm as an example of the coordinated operation of distinct distribution grid services via the cloud.

1.4 Problem Statement

The electric unit requires an energetic grid that can expand and evolve to address modern consumers' needs. There should be an efficient energy transaction between the grid's elements. 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. Intelligent data systems are 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. This data can also enhance the operational efficiency of an electric utility. Most of the negative feedback towards smart meter has not addressed, and smart meters are regarded as spying devices and an invasion of consumer's privacy. Health issues linked to Electromagnetic Hypersensitivity (EHS) are blamed upon radiations emitted from smart meters. They are responsible for transferring control signals and information to and from the base station. The smart meter system's mode of operation revolves around vast amounts of data transfer between a server positioned at the base station and a smart meter. The maintenance, management, and storage of data pose a challenge.

The selection of communication networks 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. 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 pose in the transmission of energy consumption information via public communication networks which include cellular networks.

1.5 Research Objectives

The research objective is simulating smart meter by using the hybrid system based on the Zigbee protocol. It is because of the benefits of the smart meter, where these meters use in automatic meter reading of power, preventing falsification information of consumption and assuring security. The primary research objectives for this thesis are:

- Designing a hybrid system for meters based on Zigbee.
- Simulation of the hybrid system by using Network simulator version two (ns-2).
- Evaluating the hybrid system based on Zigbee and Time Division Multiple Access (TDMA) with three protocols: Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), and Ad hoc On-demand Multipath Distance Vector (AOMDV).
- Using a cooperative system in all communication between nodes

1.6 Contributions

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. In this thesis, a hybrid system for smart meter system is introduced. The system depends on the Zigbee protocol. Contributions to this thesis are listed below:

- A cooperative system proposed with use TDMA and Zigbee makes from the hybrid system a transformation noticeable in communication.

- It is contributed a high throughput with the Packet Delivery Ratio (PDR) of the performance hybrid system in smart meter. However, it gives the best values in routing between nodes. A combination of TCP/IP layers gives a system high performance, it makes the physical, data link and network layers work together to achieving the best route and a high value of data rate.
- The research also contributes to enabling the interface for us to manage electricity resources in their homes in addition to a cycle that will reduce the cost of electricity use.

1.7 Thesis Outline

This thesis provides a description and reports on the effort during the research's duration to meet the scope and objectives of the thesis. Five chapters that cover the entire thesis make up this entire research.

Chapter two explores a review of the SG. A brief introduction to SG, specifically the wireless communication technologies, smart measurement, and metering was given in this thesis. In this chapter also explores the techniques which are used in this thesis which include review about routing protocol and explain cooperative communication system, TDMA, and ns2.

Chapter three elaborates on the thesis methodology for this study and how the study is conducted to make sure the objectives of the thesis can achieve. Chapter Four describes the simulation setup, results, and discussion of the results. Lastly, Chapter Five concludes the thesis with a summary of the research findings and limitations of the thesis.

CHAPTER TWO

THEORETICAL BACKGROUND

Chapter Two

Theoretical Background

2.1 Introduction

Although electrical grids were introduced in the late 1800s, power grids in developed nations only began to spring in the 1960s [20]. At this stage, there was an excellent distribution of load delivery capacity and the network's penetration rates. The delivered power's quality and reliability were only at a satisfactory level. Centralised power generators in hydro, nuclear and fossil plants were technically and economically developing. There was a rise in electric demand during the end of the 20th century as there was an emergence of a new wave of consumers, including the entertainment industry. Dependency on electricity as the primary fuel of ventilation and heat also contributed to electric demand. The latter is the result of rising prices of fossil fuels [20].

There are unavoidable challenges in the electrical system. There were many issues in the energy and other emerging hurdles during the 21st century. New ways of generating, transmitting and distributing power posed new hurdles. Some of the energy hurdles include consumer's data security, environmental effects, quality enhancement of delivered power, centralized approaches of power generation, consumer's data privacy, system security against potential external physical or cyber-attacks, economics of power system, introduction of the Distributed Energy Resources (DER), necessity of better control schemes for complex system, and cost of maintenance for equipment renovation and network expansion [21].

2.2 Smart Grid

Smart Grid (SG) refers to the communication and control facilities incorporated into the conventional grid during the 21st century. Despite other applications such as intelligent grid, inter-grid or Intelli-grid being utilized, the term Smart Grid is commonly utilized for the grid which includes wireless communication infrastructure and wireline [22]. Despite the electrical grid to date being perhaps the best engineering work in the twentieth century, it is increasingly overburdened and outdated, which caused expensive burnouts and blackouts [23]. Thus, transformation measures are on track to increase the efficiency of the current electrical grid. The SG can be considered an improvement of the current electric grid in order to permit bidirectional flow of data and electricity. It also helps to reach several aims such as providing several options to consumers on the amount, method and time of electrical consumption. The SG has a self-repair ability in times of emergency such as cyber and physical attacks, or environmental disasters. Also, the infrastructure of the SG can connect and use various sources of energy, including renewable energy producers and mobile energy storage. Moreover, this infrastructure has the objective of giving enhanced electricity delivery in terms of power, quality and effectiveness. Indeed, these aims can only achieve with excellent communication technology facilities that can assemble, synthesize and gather information emitted from sensors, smart meters, electric vehicles, computers, and information technology operating systems [23].

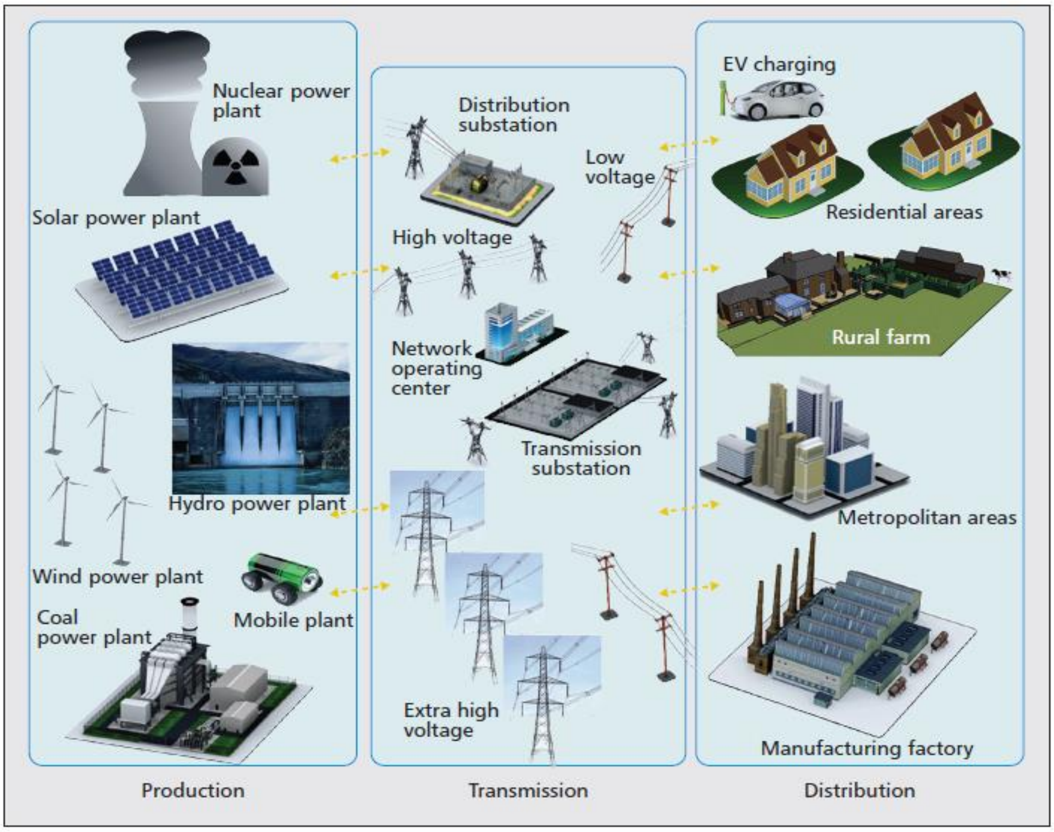


Figure 2.1: Smart grid architecture [23].

The upcoming electric grid possesses a tiered architecture to facilitate the generation of energy supply to consumers, as shown in Figure 2.1. In this case, energy originating from power generation transfers via transmission systems towards distribution units and finally to consumers. Utilization and coordination of several generations and production processes are the aim of the SG.

Besides, specific architectures influence whether generation plants can be fixed or mobile. In terms of transmission, an extensive network of operating centers and substations manage this aspect. A high volume of mixed voltage power lines conducts the generated electricity from various sources to the distribution architecture. Then, electricity is delivered by a set of complex distribution topologies to regions, neighbors, and localities for consumption.

The widespread communication and control substructure allows the SG to respond to the alterations that take place within any area of the customer substation, generation, and transmission and distribution (T&D). Such function originated from sensor networks and agent centered observations of the whole grid. There is an immediate translocation of information between integrated controllers with energy conversion units including generators, converters, inverters and transformers, and each substation. Furthermore, this observation method permits detection of load side and source demands, which allows the handling of the flow of energy in an extended decision scenario [24].

Conversely, a few problems in the centralized and conventional grid are listed by the SG concept lists as it is dependent on Distributed Generation (DG) and to improve the traditional grid [25]. A report cited in [26] suggests that the fossil fuels that result in the greenhouse gas impact, environmental impacts and climate changes make up more than 80% of the energy generated around the world. Another contributing factor to SG is the degrading issues and centralization of traditional grids. More challenging restorations against peak load demands are caused by these weaknesses [26].

Bidirectional energy and data flow are provided by the smart infrastructure, depending on its intelligence, communication infrastructures, and energy. The traditional unidirectional grid follows the basis of the generation of energy and supply to load sites over T&D lines. However, the SG permits load sites or customers use micro-generation sources allowing bidirectional energy flow in generating energy and supplying to the utility grid. The micro-generators may be conventional or alternative sources that function in the micro-grid structure and help the utility grid [24].

The smart management systems require demand profile, pricing, cost, energy loss prevention, energy efficiency, control services, machine learning, and few optimization processes like optimize the energy production and consumption systems and provide highest level of accuracy. The intelligence subsystems and smart communication are linked to management systems as well as infrastructural components. Thus, the latest area of research of SG is the smart protection covering reliability, prediction, localization and security issues. The measurement and monitoring requirements are conducted in this perspective. Smart metering systems measure consumption and other linked billing parameters in pre-determined intervals. The measured data are modulated following communication protocol and then transmit to management systems over wireless or wireline networks. The developed version of the conventional Automatic Meter Management (AMM) and Automated Meter Reading (AMR) system could be taken as the AMI. That is because it involves several improved technologies, including Wide Area Networks (WANs), Home Area Networks (HANs), neighbor networks, or Smart Meters (SMs) [27].

2.3 Smart Measurement and Metering

Besides smart energy infrastructure and power electronics, SG's improvement also attributed to the high level information infrastructure, measurement, monitoring, and metering functions that offer ample communication substructure. As such, it is vital to emphasize that energy and consumption heavily depending on the bidirectional flow that SG is reliant upon. As such, the SG wholly construct with its distributed that information system connected to power generation, transmission, distribution, and consumption nodes. This chapter also investigates smart metering solutions which include AMM, AMI, and AMR, as well as smart measurement prerequisites for instance networks, sensors and Phasor Measurement Units (PMUs) [22].

2.3.1 Electricity Meters

Electricity meters install at the customer's premises for billing purposes. It makes accurate measurement of energy consumption by the customer. The billing unit is kilowatt-hour (kWh), and the value is read once a billing period. These meters are initially of accumulation type. In many places, these accumulation meters replace by interval meters. Meters can mainly classify as accumulation and interval type meters. Accumulation meters only have the option to record the accumulated usage. Electromechanical meters and earlier digital meters are of this type. The total consumption for the billing period calculates by taking the difference between the current and previous meter reading. For the electromechanical meters, the displays are mostly a dial or a cyclometer. The electronic meters had a digital display that showed the accumulated kWh. These meters were also referred to as 'Flat Rate' meters as only a single rate could be applied to the consumed electricity to calculate the bills [28].

Interval meters can record consumption over a time interval that programs into the meter. Each interval data will be associated with a time stamp, and this enables the use of variable tariff rates on the power consumed. Advanced interval meters are also capable of recording other data related to power quality [28].

There are various ways in which the meter data could retrieve. In the traditional set-up, a meter reader would go to the customer's premises and read the data on the meter's display. With later generation meters, other data retrieval mechanisms could be introduced. The meter data retrieval methods can mainly classify as on-site meter reading and remote reading [29]. There are prepayment meters that operate by inserting cards. These cards have the amount of energy encoded on them. When the amount on the card is exhausted, the energy flow through the meter will be blocked. This method does not require consumption data to be retrieved as these types of consumers do not need to be billed [30].

For on-site reading, a technician or a meter reader from the utility company has to go to the premises where the meters are located to note the readings. For older version meters, the technician either writes down the value or enters the data into a hand held device. Advanced meters have an optical port, and the hand held meter reading devices are connected to the meter using an optical probe. For interval meters, the readings include billing data and load profile data. Remotely read meters will have a communication module. These meters also refer to as AMR meters [31]. The distribution service provider can read consumption data and other meter data remotely using various communication technologies. Power Line Communication (PLC), Radio Frequency (RF) mesh technology, General Packet Radio Services (GPRS), and Wi-Fi are some of the commonly used communication methods [32]. Some of the initial models of AMR were also referred to as Encoder Receiver Transmitter (ERT) devices, 'wake-up' meters, etc. The meter reading vehicle would transmit a wake-up signal as it drove past an area. The ERT's receiver detects the signal and transmits the needed data. Another type of AMR meters refers to as 'bubble-up' meters. These meters do not require a wake-up signal and transmit frequently or at specific intervals as programmed [33]. For prepayment meter, consumers can add credit into the meter using cards that have a specific amount of energy encoded into it. After the credit runs out, energy is wholly blocked or reduced to the bare minimum. This method is used where the consumers are considered a credit risk and when the customer preference this method, and often refer to as a useful budgetary tool [30]. Apart from the flat rates, these meters also support Inclining Block Tariff (IBT). IBT introduces in many countries to protect the people. In IBT, the electricity price has several blocks. The first block of electricity purchased in a month has the lowest price and the price increases in the subsequent purchases done during the same month [34]. At the end of each month, the history gets reset, and the consumer starts again from the lowest price. Prepayment meter provides direct feedback to the consumers on their consumption. It can help them manage their bills and save by limiting their purchase to what is sufficient for a month [34].

2.3.2 Smart Metering

The AMR meters evolved to become AMI meters or 'Smart Meters'. AMR meters only utilized one-way communications to collect meter data for the utility whereas AMI meter has two-way communication. Apart from receiving data from the meter, the distributor and retailer can also send information to the meter. Smart meters capture data on power consumption and quality of supply. This data is transferred and stored in the distributor's back-end. The data is processed to generate energy management decisions. Useful information to the consumer is then transferred through the system to the users to help them in making intelligent choices [35]. A smart meter mainly consists of a metering unit, communication unit, and control (connect/disconnect) unit. A high-end smart meter has a micro-controller with an Analog to Digital (A/D) and the meter firmware performs various data processing and calculations. Some sensors measure the current and voltage of the power supply.

Smart measurement is carried out by utilizing a SM that measures any customer's energy consumption. As such, SMs are required to be able to detect rates of energy consumption in real time by collecting phase angle, frequency, and voltage. As illustrated in Figure 2.2, a usual smart metering system is made up of communication and metering infrastructures. Data management system, AMR framework, and time-of-use pricing control are the three metering sections of an SM. SG's communication component potentially consists of wireline methods including wireless communication and PLC. Bidirectional data flow should be enabled by the communication infrastructure to allow the SM to receive information about the utility grid and customer [4]. Thus, a SM's communication section is made up of control infrastructure and a network connection which assists the meter in running control demands and convey information to remote centers. In addition to the two main sections, a SM's modules include control module, metering module, power supply module, indicating module, timing module, communication module and encoding module [36].

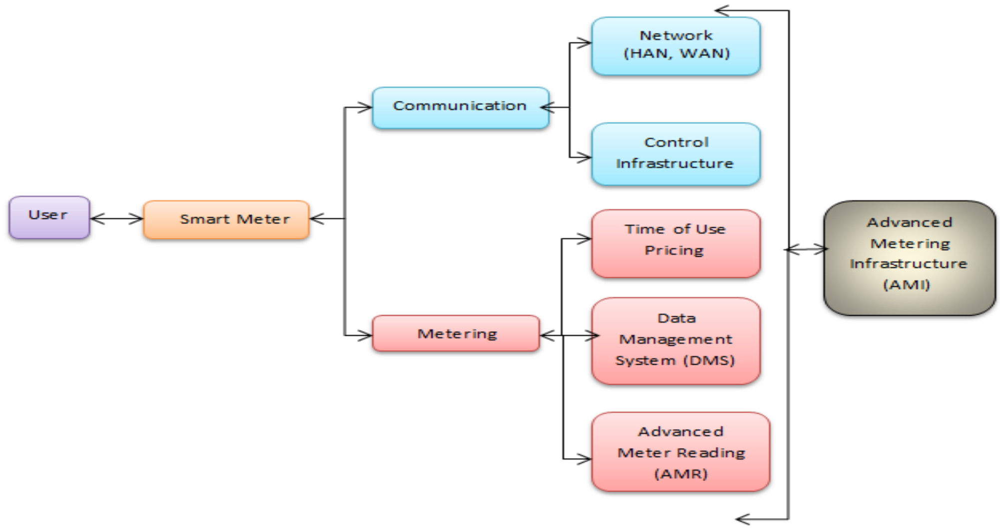


Figure 2.2: A smart grid perspective with all components [22].

Apart from the features of SM that are previously shared, the logging module holds the user's data including date, power factor, consumption of energy and more. Voltage and current values are instantly acquired and measured by the metering module. It achieves this by separating the SM from the utility grid. The billing module generates electricity bills by taking into account the timestamps, whereas the timing module makes provision for reference points to this section. Figure 2.3 illustrates the two common approaches which can be set to form bills based on energy consumed from the utility grid or billed by taking into account the contribution of the user's DG resources which feed the utility grid. In addition, the SMs can regulate a customer's energy demand by setting a limit to the consumption or remotely disconnecting and connecting other supplies [4]. There is a suggestion that SM will be significant in SG applications of the future considering their real time management, security features, and scalability. Communication with hundreds of SMs in a particular area requires access point architecture, similar to cell structures. Thus, considerations should be made for security matters to protect billing data and SMs [36]. There is a growing focus on monitoring SMs remotely to enhance metering security and grid management. In addition, monitoring SMs remotely allows utility companies to monitor illegal use of electricity, which is detectable via statistical data obtained from SMs.

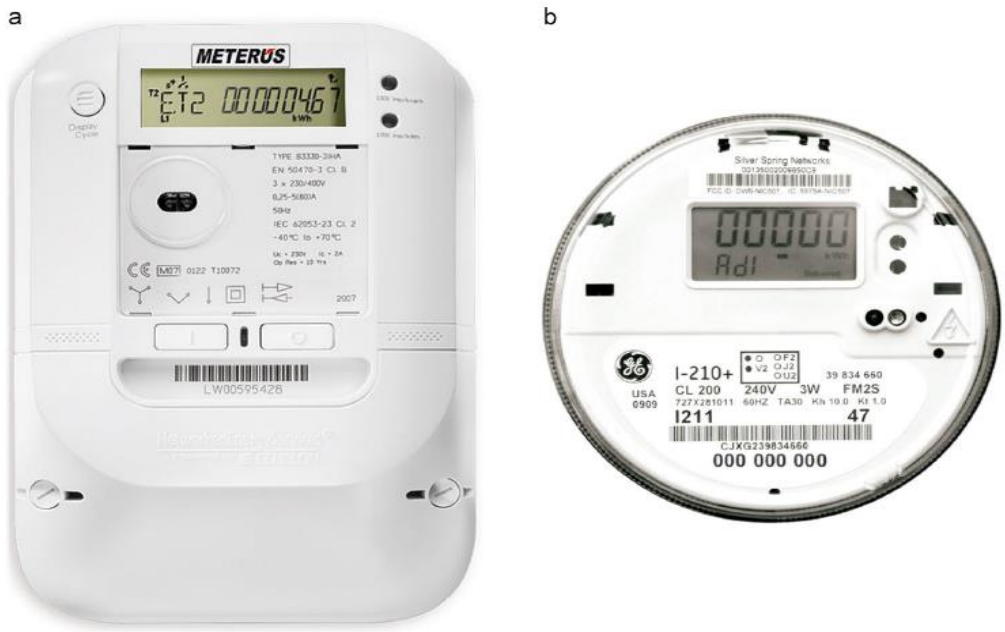


Figure 2.3: Commercial smart meters (a) SM utilized by EVB Energie AG which promotes two-way communication, (b) reliable and high accuracy in a solid-state kWh meter platform package of general electric [22].

The AMI aspects of SM allow management of bidirectional communication that enables the SM to operate control commands transmitted by a utility company [37]. In opposite to SM's opportunities, they address a few threats of unauthorized access on safety, privacy and security problems. The SG is vulnerable to malicious applications as a result of unauthorized access and attack. Extensive investigation is carried out on several scenarios, cyber warfare practices, and protection researches to avoid SMs from posing new risks in smart grids [38]. Apart from security issues, unauthorized access to SM may lead to bill losses and manipulation. The SMs need to prevent all these ill-intended access by employing trusted software. This necessity can define by Secure Signal Processing (SSP) term, which protects sensitive data via encryption of algorithms and attending to security weaknesses in SM [38]. The latest studies suggest security data acquiring and privacy preserving billing in smart grids [39]. One of these active communication steps that are based on the prevention of authorized access to private information is the SSP. The security operation follows an encryption approach which processes data in a cryptographic manner instead of plain texts [39].

Literature has provided some researches on SM's privacy and secure billing [40]. Some privacy issues from consumers, data experts and media are met by SM [39]. 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*.** [41] to enhance SM's security by keeping particular data hidden. This approach is based on fixed size databases for a fixed term billing time-frame and depends on the simplification of the regular differential privacy protocol. The testing of the experimental study is achieved by the addition of several corrupted data to the stored measurements and examining the accuracy of the billed consumption [41].

The AMI system serves as a significant achievement in SG. It functions to acquire, measure and analyze data of power quality of each consumer and energy consumption. Communication facility with metering devices on-demand occurs in an SM adapted with AMI facilities [40]. Enhancement of maintenance, panning of the capability of supplier and demand management is achieved via bidirectional communication between consumer and utility supplier.

IEEE 2030-2011 standard defines the smart grid's communication architecture, in which apprehension of applications and infrastructures at a hierarchical arrangement is significant [43]. The purpose of the standard is to address several confusing descriptions by making clear indications of a logical structure for the SG networks, which includes the three sub-networks. The first network is linked to user properties is known as private networks which include Industrial Area Network (IAN), Building Area Network (BAN) and HAN. The second network which situates 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 [44]. 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 Network (VPN), GIS, local Area Network (LAN) and voice over internet protocol (VoIP) [45]. Smart grid's communication technologies give descriptions with regards to bandwidth properties as broadband and narrowband.

2.4 Smart Grid Networks

The wireless technologies propose to be significant networks for SG by the National Institute of Standards and Technology (NIST). Selection of the most suitable communication technologies to process the management influences demand management, which is the key feature to provide SG's reliability and efficiency. Technological and economic feasibilities are significant aspects of selecting accurate technology [46]. 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 [47].

An SG utilizes four types of communication networks namely HANs, NANs, Vehicle-to-Grid (V2G) connections, and WANs. Each one has a different coverage range, data rate and consequently, requires deferent communication technologies [48]. SG utilizes these networks to exchange information about users' demands and grid conditions. Three of these networks utilize to connect the customers with the power utility. The first network is HAN, which connects smart household appliances to the smart meter inside the house. The second network utilized is NANs which is responsible for forwarding the electricity consumption reports for all HANs in the area to the utility company. WAN is utilized by NANs to forward the electricity reports to the main utility center [44].

HANs is a local area network which facilitates the connection between smart devices inside or close to the house; HAN represents the communication network between smart appliances and smart meter. There are two other networks which can be considered as HANs: Building Area Networks (BANs), and IANs. BAN is a connection between several HANs within the same residential area while IAN connects some HANs in the same industrial area [44].

NANs connect HANs in a particular area to the main. It forwards the electricity consumption reports for the area to the service provider. Moreover, it sends the payment value for electricity from the utility to all HANs in the area. NAN's applications, for instance, smart metering and demand response, require a higher data rate from 100 kbps to 10 Mbps and more considerable coverage distance up to 10 km. Therefore, Zigbee mesh networks, Wi-Fi, PLC, and cellular can be suitable for NAN [44].

V2G Connections is the optimal utilization of generated power and reduction of electricity losses which is one of the significant objectives of SG. This objective needs storage units that can save extra electricity in case of high power generation and provide the electricity back to the grid in case of high power consumption.

WANs can be utilized by NANs to forward the electricity reports from their local regions to the main center in utility companies. WAN applications such as wide area control, protection, and monitoring require a higher data rate from 10 Mbps to 1 Gbps but have an extended coverage distance up to 100 km. Technologies especially WiMAX and cellular are most commonly utilized between transmission/distribution substations and the utility center due to their high capacity, wide coverage range and low latency [44].

2.5 Wireless Communication Technologies

The smart metering system requires robust communications technologies. Choosing the right communication technology is still a challenge. Ideally, the communication solution should have minimal investment and should be easy to install, operate and maintain. The energy consumed should also low. Though a smart meter consumes little power, it adds up when many meters are connected point-to-point. The communication network chosen should be able to operate reliably for the same span of time. It must be able to survive extreme environmental conditions (temperature, humidity, corrosion, etc). The system should assure interoperability even if the components are changed. It should also have the functional capacity and low latency. The system should also be secure. Confidentiality, integrity, and authenticity of the data should be assured, and the availability of data should be guaranteed [49]. RF Mesh, a cellular network, and PLC are the most commonly used communication technologies. All technologies have authentication and confidentiality over the air links, but application-layer security mechanisms have to be applied for end-o-end security [50].

Hierarchical mesh networks that utilize wireless LANs in order to provide interaction with electrical devices make up the wireless network. The cheap installation cost of HANs and NANs for wireless deployment makes them the most appropriate AMI infrastructures [46]. The Data Management Points (DMPs) and internet based communication infrastructures can install as either wireless or wireline, in which the communication between DMPs and NANs can cover a range of kilometers. Hundreds of SMs can be linked and managed by any DMP, in which a wide area of coverage may be fixed with mesh networking or have the DMPs relayed. SG application's innovative studies depend on highly scalable and communication networks that are widely spread and can easily constitute by utilizing wireless sensor networks (WSNs).

Besides, a reliable infrastructure should be provided by the WSNs by lowering the latency against demand requirements [46]. Compared to commercial broadband communication, the latency requirements for Open SG is more eased as it is fewer than 1 sec for NANs. A smaller coverage area compared to NANs is required for HANs to conduct energy management and demand planning.

Compared to NANs, HANs commonly permit latency to fewer than 5 sec which is quite facilitated [46].

The IEEE 802.22 standards, Universal Mobile Telecommunications System (UMTS)/ Long-term evolution (LTE) and worldwide interoperability for microwave access (WiMAX) form the basis of unique communication technologies utilized within NANs. In addition, wireless SGs also adopt WPAN and Wi-Fi technologies following IEEE 802.11 and IEEE 802.15. The primary mechanism that permits connectivity between SMs and DMPs is the WiMAX, which is a product of the IEEE 802.16 standard for metropolitan area networks (MANs). A regular Orthogonal Frequency Division Multiplex (OFDM) digital modulation scheme’s multi-user format called Orthogonal Frequency Division Multiple Access (OFDMA), is utilised by the WiMAX. A concurrent transmission of data from a large section of consumers in low data rates is enabled as the OFDMA gets a multi-user structure by making arrangements of subsets of several subcarriers to unique customers [51]. WiMAX’s subcarrier based multi-user structure avoids interference among users’ information and raises the spectral efficiency of the entire system. Despite the less complicated structure of WiMAX compared to cellular standards, it is still not commonly utilized as a wireless platform in SG applications. Nonetheless, its DMP interaction allows the situation as mentioned earlier to not limit its competitive ability against other competing platforms [46].

The reference that defines the PHY layer for low cost network, low data rate and low power consumption is the IEEE 802.15.4 standard namely WPAN. The WPAN’s basic PHY layer gives 256 kbps data rate within the area of coverage starting from 10 m to 1600 m in the star topology for cluster tree, single-hop and as well as mesh topology for multi-hops. The PAN coordinator that regulates the entire network lies within each type of topology. Also, tree and mesh topologies have extra router notes to provide interaction between devices and coordinators to develop multi hop connections. IEEE 802.15.4 standard forms the basis of several industry standards in control and monitor applications.

Due to their usage in industrial control processes, Wireless-HART, Zigbee and ISA 100.11a are the most prevalent standards in this classification. Nonetheless, thanks to its extended network management capabilities, the Zigbee is commonly utilized in both commercial and industrial processes [46].

Several options for NAN coverage are provided by cellular technologies namely LTE and UMTS which are based on GSM. Compared to other wireless networks, GSM-based technologies is advantageous as it has a wider area of coverage. Cellular network's evaluation is considerably rapid and novel technologies support broader data bands. The most common standard of 3G technology which is the UMTS provides data communication up to 22 Mbps in the uplink and up to 168 Mbps in the downlink. UMTS's capabilities are improved by 4G which is based on LTE and LTE Advanced standards, which are the most recent cellular technology.

Cognitive Radio (CR) is a novel wireless technology that is presumed to manage the inadequate spectrum. SG users classify into secondary and primary in CR applications, which permits the allocation of communication channels to any user at the exact time [52]. This technology drew considerable attention with its ability to alleviate the licensed spectrum requirement. Conversely, high radio bandwidths are needed to convey vast amounts of multimedia data such as monitoring and power control units which promoted by CR [53]. SG's security and traffic management issues are being heavily scrutinized with regards to wireless and wireline networks. Communication system-related cyber security threats categorize into four types which are linked to protection, availability, authenticity, and integrity [54].

2.6 Zigbee

A Zigbee protocol is proposed to communication between nodes in areas that include meters. However, A Zigbee is short range wireless communication technology based on IEEE 802.15.4 standard [55]. The range of this technology is up to100 m and provides low data rates 20–250 Kbps [56]. It operates at 868 MHz, 915 MHz and 2.4 GHz frequencies [57]. The main benefit of Zigbee is its low power consumption (up to 100 mW). It means that approximately two batteries can be utilized for up to two years [56]. It utilized a self-organization procedure to form a network [58]. Zigbee utilized Advanced Encryption Standard (AES-128 bit) for robust security [56].

The other definition of Zigbee is a low power wireless specification based on IEEE standard 802.15.4.2003 and established in 2002 by a group of 16 companies. It introduce mesh networking to the low power wireless space and is targeted towards applications such as smart meters, home automation, and remote controls [59].

The Zigbee communication is built explicitly for control and sensor networks on the IEEE 802.15.4 standard for wireless personal area networks (WPANs), and it is the product from Zigbee alliance. This communication standard defines physical and Media Access Control (MAC) layers to handle many devices at low-data rates. The data rate of 250 kbps is most suitable for periodic as well as intermediate two way transmission of data between sensors and controllers [60].

Generally, Zigbee is a cheap and low powered mesh network that used to control and monitor applications. This communication system is cheaper and simpler than other short range wireless sensor networks, for example, Bluetooth and Wi-Fi [61].

Zigbee two way data is transmitted in two modes: Non-beacon mode and beacon mode. In a beacon mode, the coordinators and routers continuously monitor active state of incoming data and therefore more power is consumed. In this mode, the routers and coordinators do not sleep because any one of the nodes can wake up and communicate at any time. Although, it needs more power supply and its overall power consumption is low since most of the devices are in an inactive state for long periods in the network [62].

In non-beacon mode, if there is no data communication from end devices, the routers and coordinators will enter into a sleep state. Periodically, the coordinator will wake up and transmit the beacons to the routers in the network. These beacon networks work for time slots whereby they operate when the communication need results in lower duty cycles and more extended battery usage. These beacon and non-beacon modes of Zigbee can manage periodic (sensors data), intermittent (Light switches) and repetitive data types [62].

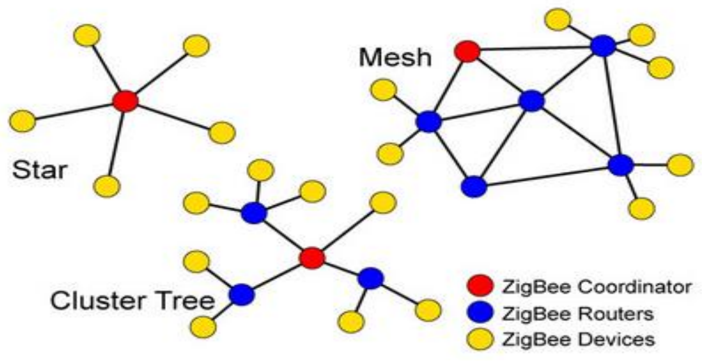


Figure 2.4: Zigbee Topologies [63].

Digital radio functions enable Zigbee to connect devices with each other. Various forms of devices make up a typical Zigbee network. A network coordinator generates the network, takes note of nodes in its network. It also oversees each node's data and information received/transmitted within the network. A network coordinator is mandatory in each Zigbee network. The network may include other Full Function Devices (FFDs) that support all of the 802.15.4 functions [64]. They can serve as network coordinators, network routers, or devices that interact with the physical world. The terminal device found in these networks is the Reduced Function Device (RFD), which usually only serve as devices that interact with the physical world. Several topologies are supported by Zigbee, including star, mesh, and cluster tree. As can be seen in Figure 2.4, star topology is most useful when several end devices are located close together so that they can communicate with a single router node. That node can then be a part of a larger mesh network that ultimately communicates with the network coordinator. Mesh networking allows for redundancy in node links so that if one node goes down, devices can find an alternative path to communicate with one another [65].

2.7 IEEE 802.15.4

802.15.4 is a packet based radio protocol. It addresses the communication needs of wireless applications that have low data rates and low power consumption requirements. It is the foundation on which Zigbee is built. The Figure 2.5 below shows a simplified Zigbee stack, which includes the two layers specified by 802.15.4: the Physical (PHY) and MAC layers [65]. It serves as the foundation of the Zigbee [27]. The combination of IEEE 802.15.4 and Zigbee provides a basis for various monitoring and management solution [28].

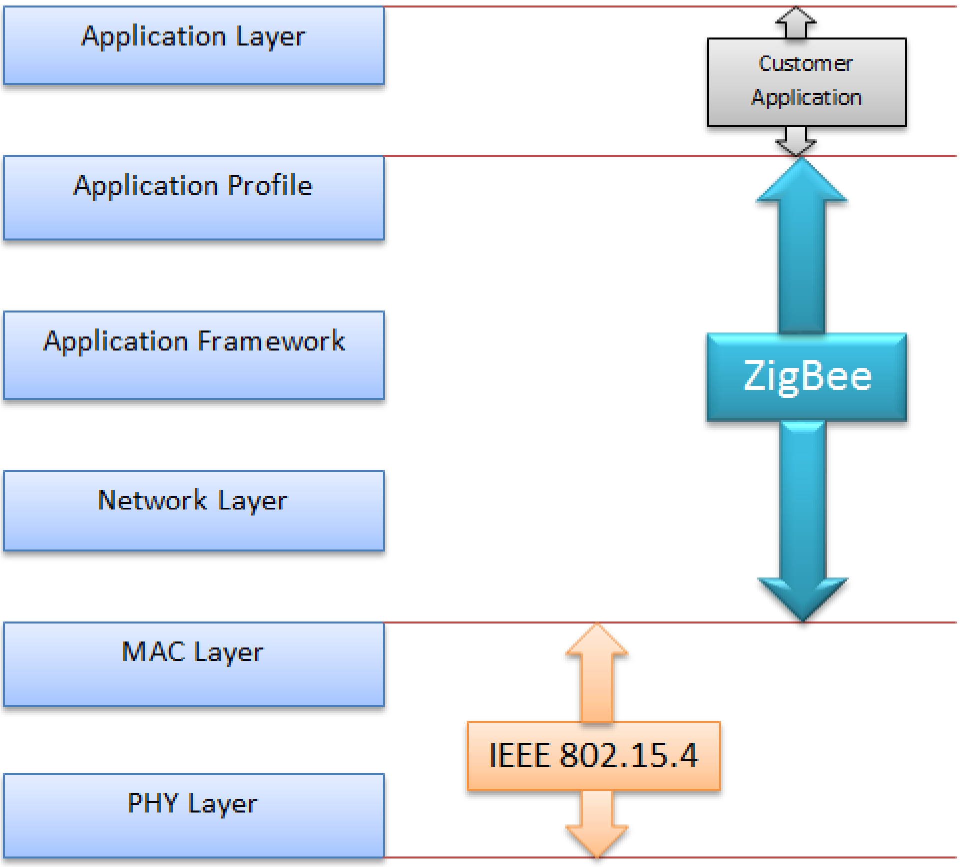


Figure 2.5: Zigbee Stack [65].

2.8 Routing Protocols in MANET

The goal of a MANET routing algorithm is to properly and capably create a route between nodes in the network to ensure messages can be delivered according to the expected QoS parameters [66]. The route's establishment should be completed with minimum overhead and bandwidth [67]. In general, routing algorithms for mobile ad hoc networks may be divided into two classes: proactive routing protocols (also known as table-driven routing protocols) and reactive routing protocols (also known as on-demand routing protocols). Classification of the routing protocols is shown in Figure 2.6.

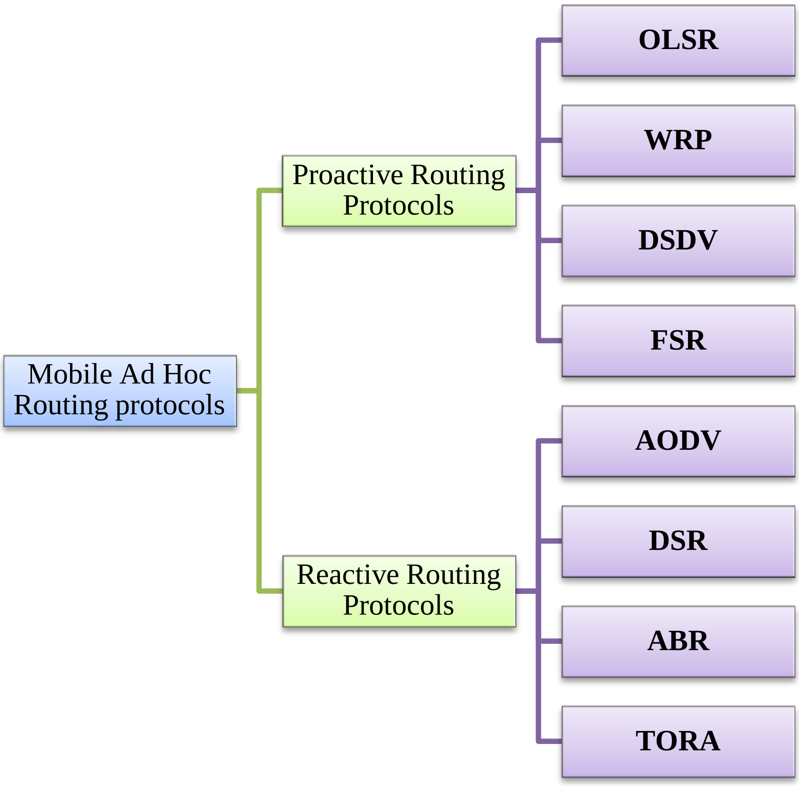


Figure 2.6: Classification of Routing Protocols.

Each network node maintains a routing table which contains information on how to reach each of the other nodes in the network. Usually generated during the discovery phase, the routing table assists network nodes to have an accurate view of the network's actual topology.

2.9 Reactive Routing Protocols

Reactive routing is also known as on-demand routing protocols. These protocols lack routing information or routing activity on the nodes in the network when communication is lacking or dismal. Unused routes are maintained with less overhead. Unfortunately, more time delays may be experienced initially [68]. A route is searched for by the reactive protocol in an on-demand manner if a node intends to pass on a packet to another node. The packet is received and transmitted after forming a connection. Then, the request packets are dispersed within the networks, leading to a discovery of routes. There are two categories of reactive protocol; source routing and hop-by-hop routing.

A complete source to destination address is carried by the source routed on-demand protocols. The information contained in the header of each packet will be evaluated by every intermediate node when forwarding these packets. The intermediate nodes are not required to maintain updated routing data for each active route. In addition, neighbour connectivity through periodic beaconing messages is also not required in the database of the nodes. As each node has the potential to update its routing table in the presence of fresher topology information, the routes are therefore adaptable to the changing environment, which takes place dynamically, in the MANETs. The data packets are forwarded over better and fresher routes this way [69-71]. Figure 2.7 shows the reactive routing protocol's path in the discovery process

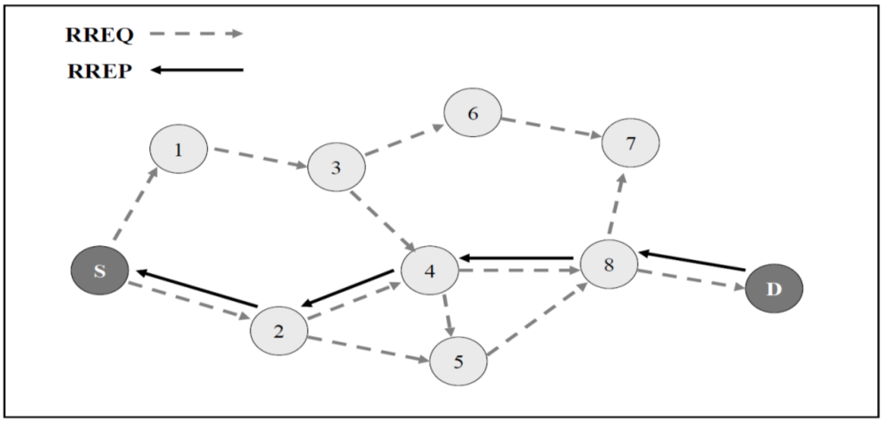


Figure 2.7: Reactive Routing Protocol's Path for Discovery Process [72].

There are several well-known reactive routing protocols, for example, Ad hoc On-Demand Distance Vector (AODV), Dynamic Source Routing (DSR), Temporally Ordered Routing Algorithm (TORA) and Area Border Router (ABR) are examples of reactive routing protocols.

The routing process of a reactive routing protocol involved two steps. These steps are explained below [73].

i. Route discovery: In a hardwired network, before the source sends a packet to another node, it must broadcast an ARP request packet to all the other nodes attached to the LAN to get the MAC address of the destination. Route discovery looks almost the same, but it works in IP layer, and it takes into consideration of the nodes out of source's transmission range. In the

MANET, if the source does not have the route towards the destination in its current routing table, a source node initiates route discovery by broadcasting route query or request messages into the MANET to find the route between itself and the destination [72].

ii. Route maintenance: As the nodes along the path may move randomly or may shut down due to power exhaustion, route maintenance is introduced to check the route's validity once the route between the source and destination is established. If there is any link failure detected along the path, notification will be sent to the source and the source may reinitiate the procedure to discover new route, or the broken link will be bypassed when the local repair is launched.

2.9.1 Ad hoc on Demand Distance Vector Routing Protocol (AODV)

AODV is a unicast routing protocol that searches for routes on-demand [74]. Using four control packets such as; traffic messages, route requests (RREQs), route replies (RREPs), and route error messages (RERRs), all nodes in AODV maintain a routing table where active route information is stored. The stored information is next hop, number of hops, destination, destination sequence number, route's active neighbors and route table entry's expiration time. A route entry's timeout reset is based on the current time and the timeout of the active route each time it is used. To safeguard against routing loop, sequence number is used, sent with RREQ and RREP, and stored in the routing table. The sequence number indicates the latest route information. For cases where there are similar sequence numbers, the number of hops is used to select a new route and the sequence number with fewer hops will be chosen [75].

2.9.2 The Dynamic Source Routing Protocol (DSR)

DSR uses source routing (SR) instead of hop-by-hop routing [76, 77]. SR is a routing technique where the complete sequence of nodes through which the packet has to pass is determined by the source node. The source route is carried by the data packets in the packet header. This means the complete hop-by-hop route to the destination is made known to the sender. These routes are stored in a route cache. DSR applies on demand schemes for both route discovery and route maintenance

2.9.3 Ad-hoc On-demand Multipath Distance Vector Protocol (AOMDV)

AOMDV is a reactive routing protocol and a multipath extension to the AODV protocol. In AOMDV protocols multiple routes are founded between the source and destination. It uses alternate routes on a route failure. In AOMDV protocols new route discovery is needed when all the routes fail. In AOMDV protocols multipath routing is the enhancement of unipath routing in which advantage is to handle the load in network and avoid the possibility of congestion and increases reliability [78].

2.10 Access Method TDMA

Within Time Division Multiple Access (TDMA) cellular radio system, a common carrier frequency is allows several users to share the same frequency channel by dividing the signal into different time slots show Figure 2.8 . Each node that transmits a low bit-rate digitized speech or other digital data, is distributed into one or more time slots that lie inside the frame in the upstream and downstream direction [79].

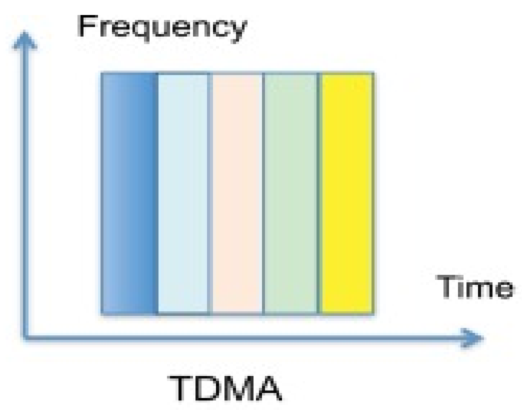


Figure 2.8: TDMA a common carrier frequency.

The transmitted variables transfer through wireless channels and limited capacity. The study has considered the fading channel with a Signal to Noise

Ratio (SNR) given by $\gamma ij=gij\cdot$ SNR between two nodes i, j. The variable gij denotes the channel gain. The channel gain is constant during a slot length Ts. There is always a slot in a different SNR. The transmit scheme is TDMA. Each transmitter has a specific transmit period Figure 2.9, which is equal to the slot length. After this transmits period, the next transmitter is scheduled. Hence, the shared channel is divided into orthogonal time slots (Figure 2.9).

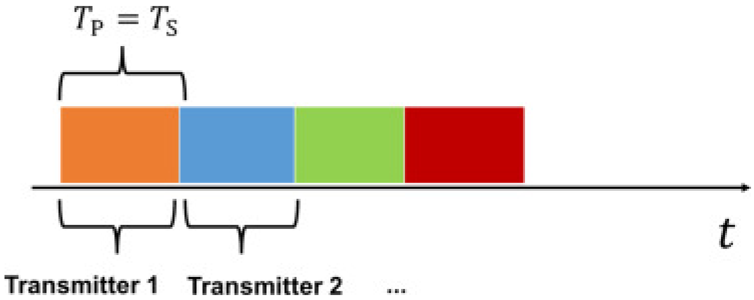


Figure 2.9: TDMA transmission.

In each slot, the transmitter can use the bandwidth B. The upper bound of the achievable rate to transmit a specific state from i to j within this slot period is given by:

$$R_{i\,j}\,(k) = B\,.\log_2(1 + SNR\;.\left|g_{i\,j}\,(k)\right|^2)\;\;\text{bit/s} \tag{2.1}$$

The transmitter can estimate the SNR of the next slot, e.g., based on the uplink signal. The rate $R_{i,j}$ is variable and depends on the SNR of each link. Therefore the number of bits that can be transmitted during a transmission period TP is changing.

2.11 Cooperative Communication System

Cooperative communication is one of the fast developing areas of research that is likely to be a key enabling technology for efficient spectrum usage. The main idea in user cooperation is resource sharing among multiple nodes in a network. The aim of exploring user cooperation is that readiness to share power and computation with neighboring nodes can pave the way to savings overall network resources. Mesh networks provide a considerable application space for user cooperation approaches to be implemented [80].

Cooperative communication allows communication terminals in a network to hear and help the information transmission of each other, by taking advantage of the broadcast nature of wireless communications. It may be utilized to enhance network connectivity, enhance reliability of communication, and enhance the power and efficiency of the spectrum. In addition, there is benefit in cooperative communication in terms of feasibility of deployment and feasibility of hardware, when compared to other potential methods that may produce same performance benefits, including Multiple-Input-Multiple-Output (MIMO). The rewarding benefits of cooperative communication make it a promising techniques for future wireless communication systems [81].

In traditional communication networks, the physical layer is only responsible for communicating information from one node to another. In contrast, user cooperation implies a paradigm shift, where the channel is not just one link but the network itself [80].

2.12 Identification of Performance Metrics

There are various parameters are available to check the performance of communication in the systems. there are several of performance metric which explain three of them below.

a) Packet Delivery Ratio (PDR) is the fraction of data packets that transfer to the sources nodes and destinations nodes. The PDR indicates the efficiency of protocol in transferring packets between the source and destination. A higher value means packet delivery will be more successful. The performance metric studies the accuracy and completeness of the routing protocol besides measuring its reliability. PDR can be computed by using the formula shown in Equation 2.2: [82].

$$PDR = \frac{\sum Number\ of\ packets\ received}{\sum Number\ of\ packets\ sent} \qquad (2.2)$$

b) Throughput is the amount of data that successfully deliver to the destination of specified time duration. It measures typically by bytes per second.

Throughput affects by several factors, including limited bandwidth and energy, inconstant network topology, and unreliable communication. Throughput can be calculated by using the formula shown in Equation 2.3: [83].

$$Throughput = \frac{Number\ of\ received * pckets\ size}{Simulation\ Time} \quad (2.3)$$

c) Average End-to-End delay indicates the delay experienced by the packets as they travel from source to destination. The total delay is an accumulation of several small delays that occurred in the network. It includes possible delays due to buffering happens in route discovery latency, lining up at the interface, MAC retransmission delays, transfer time as well as propagation. The received packet's E2E delay can calculate by getting time discrepancy between sent and received CBR packet. The sum of time differences will then be divided by the total number of CBR. This metric reveals the lower E2E delay and indicates the higher performance of the application. This metric (E2E) is computed using Equation 2.4 shown below [84].

$$E2E = \frac{\sum End\ Time - Start\ Time}{\sum Number\ of\ connections} \quad (2.4)$$

2.13 Network Simulator (ns-2)

Network Simulator is an open source network simulator implemented on Linux operating systems that is commonly utilized. Moreover, it can be implemented by the Microsoft Windows operating system [85]. However, It originates at the University of California-Berkely and has characteristics of being object oriented, driven by discrete events. Programming language C++ and OTcl have been utilized to develop ns-2. Although C++ is a good in design and implementation, it cannot be easily portrayed graphically and visually. Hence, OTcl is used to overcome the weakness of C++. These two programming languages are integrated to form an effective ns-2. C++ is implemented in the procedure while OTcl is used in scenario control and event planning [86].

2.14 AWK Program

AWK is a domain-specific language designed for text processing and typically used as a data extraction and reporting tool. It is a standard feature of most Unix-like operating systems. It is very powerful and uses simple programming language. It can solve complex text processing tasks with a few lines of code [87].

The AWK language is a data-driven scripting language consisting of a set of actions to be taken against streams of textual data either run directly on files or used as part of a pipeline for purposes of extracting or transforming text, such as producing formatted reports [88].

CHAPTER THREE

DESIGN AND IMPLEMENTATION

Chapter Three

Design and Implementation

3.1 Introduction

The overall methodology applies, including the proposed method for the hybrid system used in the smart meter meant to explain in this chapter. The next sections of this chapter explain the proposed methodology followed by the block diagram of activities. Moreover, this chapter introduces a method and designs for hybrid systems and its component. The performance of the method is compared in terms of accuracy. Web application is explained to notify the user about the amount of electricity consumed.

3.2 A Proposed Method

A block diagram in Figure 3.1 shows the step by step for the system design which is proposed to make more than layers in TCP/IP to execute by using ns-2 simulation and the web application.

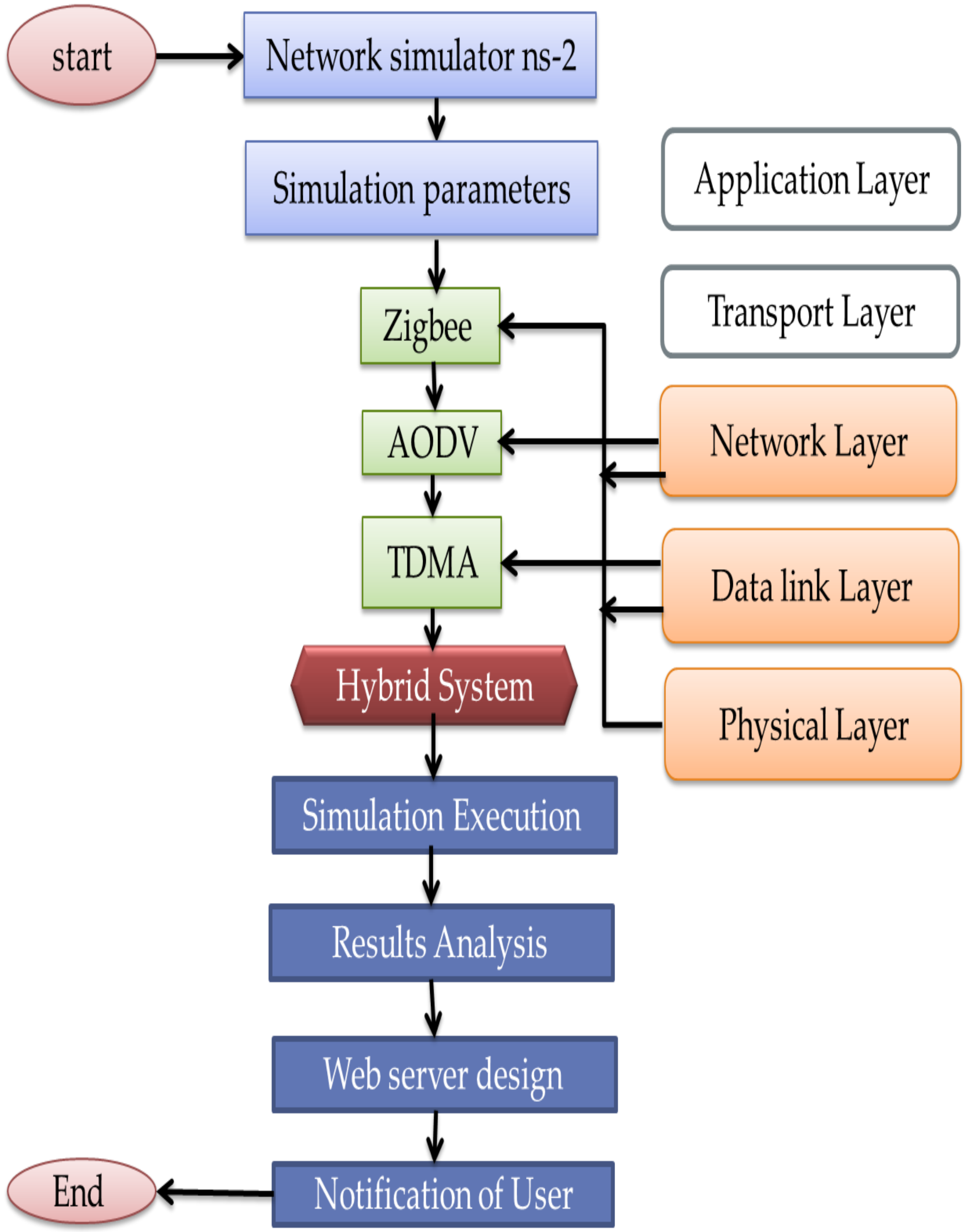


Figure 3.1: A block diagram for system design.

3.3 Simulation Setup

In this stage, the study aims to indicate how can an appropriate environment, simulate smart meters be created. That identifies the necessary parameters for the simulation and the software and hardware requirements for simulation smart electric meter, which is illustrated in table 3.1. Network Simulation tool ns-2 version 2.35 is utilized for this purpose.

Table 3.1: Simulation Parameters

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

The smart electrical meter has been read and monitored by the use of the Zigbee communication technology, where Zigbee places in both the electric meter and the central electric. Due to the advantages of Zigbee technology like low cost and low power operating modes and its topologies, this short range communication technology is best suited for several applications compared to other proprietary communications, such as Bluetooth, Wi-Fi, etc [61]. Some of these comparisons such as range of Zigbee, standards, etc., are given in table 3.2.

The cooperative communication technique uses in proposed method, which allows several nodes cooperatively transmit data to a destination together. In a cooperative communication system, each node is assumed to transmit data as well as act as a cooperative agent for another node, where users share and coordinate their resources to enhance the information transmission quality. It chosen in proposed method including the benefits of the optimal exploitation of bandwidth, the cost, and less time, but the disadvantages are privacy and security. The cooperative communication technique is used with the help of TDMA for the success of the work, and routing protocol AODV that is used with Zigbee. Where the start of work is to input two files into ns-2. A scenario file contains parameters which are a Zigbee code and smart electricity meter environment code. A topology file contains the position of the node in network animator. After the files are utilized in the simulation, a trace file generates as an output. The parameters which measured by this stimulation will be analyzed by scanning of the trace file.

Table 3.2: Comparison Zigbee, Sub-GHz, Wi-Fi and Bluetooth [89].

	ZigBee	**Sub-GHz**	**Wi-Fi**	**Bluetooth**
Physical Layer Standard	802.15.4	Proprietary / 802.15.4g	802.11	802.15.1
Application Focus	Monitoring & control	Monitoring & control	Web, email, video	Cable replacement
Battery Life (days)	100-1,000+	1,000+	0.5-5	1-7
Network Size	100s to 1000s	10s to 100s	32	7
Bandwidth (Kbits/s)	20-250	0.5-1,000	11,000+	720
Range (meters)	1-100+	1-7,000+	1-30+	1-10+
Network Architecture	Mesh, Star, Cluster Tree	Point-to point, star	Star	Star
Optimized For	Reliability, low power, low cost, scalability	Long rang, low power, low cost	speed	Low cost, convenienc e

3.4 Hybrid Component for Proposed System

In developing the proposed method for high performance in sending and receiving data with reliable communication (or routing), the following two (2) steps must perform sequentially:

- The first step is to analyze, design, and establish a model of high-performance link between any two communicating nodes MANET. Once stable links are established, and then a message can be transmitted reliably between them.
- The second step is to develop a hybrid system for ability to have quick reliable and efficient data rate, i.e. routing, along a complete route/path in area connecting any two end nodes, which ultimately allows systems to be implemented successfully with acceptable service quality.

At this link level communication, a strong and quick link must be first established by a hybrid technology to create a hybrid system that able to establish a connection between any two communicating nodes with efficient data rate, throughput, and a small E2E delay. It needs to combine more than one technique. In this research, a hybrid method is suggested to be used inside the meters to become a smart meter. A Zigbee proposes in order to achieve wireless communication between nodes. An AODV is used to achieve the reliable routing protocol and the efficient delivery of the message. The hybrid system needs to combine work between more than layers in TCP/IP models, so a TDMA cellular radio system is also proposed in this research to carrier frequency by several users in order to establish communication with the base station. The proposed hybrid system is depended on companied between data link layer that has TDMA access method, IEEE 802.15.4, and network layer that has Zigbee and AODV routing protocol as presented in Figure 3.1.

3.5 Protocols Identification

The design of a hybrid system needs best routing protocols that can have a high performance in communication. As proposed in the thesis, a hybrid system is depended on Zigbee for wireless with a TDMA for share frequency. Then, a final system has a reliable and fast communication by record a high data rate. This point gives a system a strong connection because the hybrid system combines between two layers of TCP/IP models. The hybrid system needs one more step to become perfect as much as possible. This step is a routing protocol, so for this design a reactive routing protocol is used in this design. AODV was chosen in the hybrid system and compared with two protocols within the same family of the reactive routing protocol, DSR and AOMDV. The comparison was made to clarify the performance of each of the protocols, and which is better in increasing the number of nodes, which will be clarified in the four chapter.

3.6 Simulation Execution

In this step; a real simulation by using ns-2 is accomplished by adding in two input files. The first file, which is also a scenario file describes the code of work. On the other hand, the second file is for topology as it contains the positioning node.

After the execution process, two files generate as output. The first one is a trace file which is useful in the data processing. The second file is Network Animator (NAM), a platform that visualizes simulation. A NAM employed to presented connection environment of nodes. Figure 3.2 showed NAM as a graphical display tool for simulation, Where it shows the number of nodes in the simulation that was 58 nodes distributed in topology 100 x 100 (m), as 56 of them represented the smart meter and two represented the electricity centers.

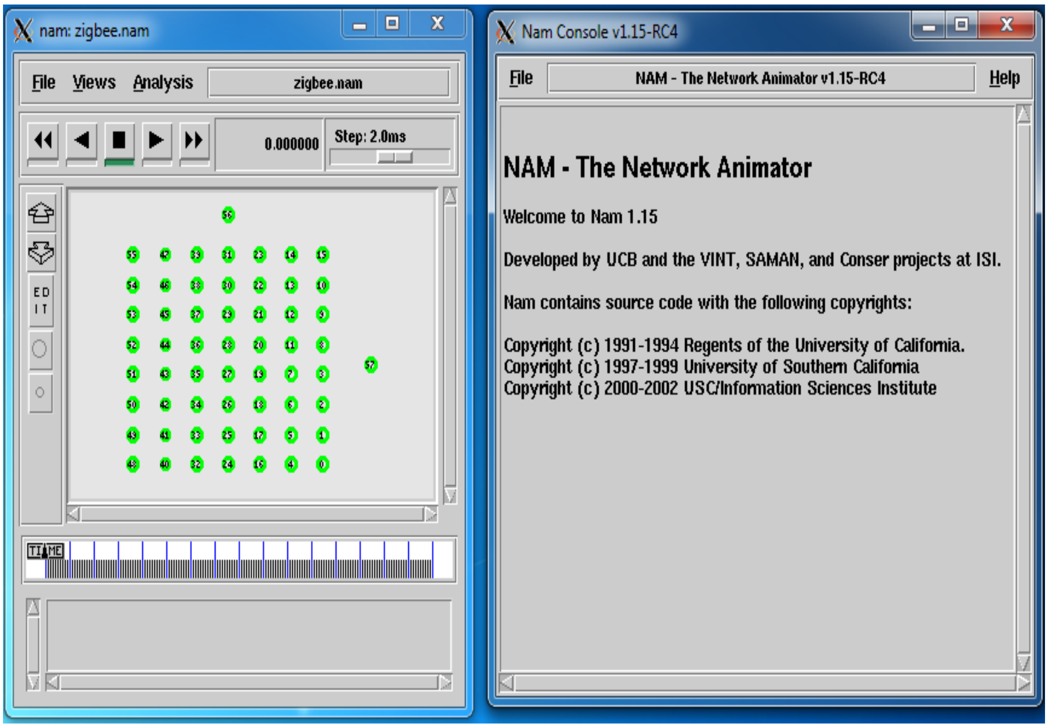


Figure 3.2: Screenshot of Network Animator (NAM) in ns-2

The outcomes of the hybrid system are measured. The result will be evaluated by using performance metrics. In proposed method, three performance metrics are chosen to evaluate the performance of the system. the performance metrics that intend to be measured and evaluated PDR, Throughput, and E2E

The analysis stage involves the use of the AWK Program. This program uses the trace file produced from the simulation as an input. From the input, it then accesses the values of the performance metrics, which is an essential part of this research.

3.7 Web Application Design

The second level of the proposed system is to notify the user. It can be accomplish after getting the trace file from ns-2; where each meter information separate from the trace file by AWK in the ns-2 program and store in the program file in which the work designs the sites. However, that can use as each user electricity consumption information. Then, a Web page makes to monitor the use of electricity. A database creates in which each user's information can store. Through the web application, the user will get information about the amount of electricity consumption. The flowchart in Figure 3.3 describes how the user gets the notification from the smart meter.

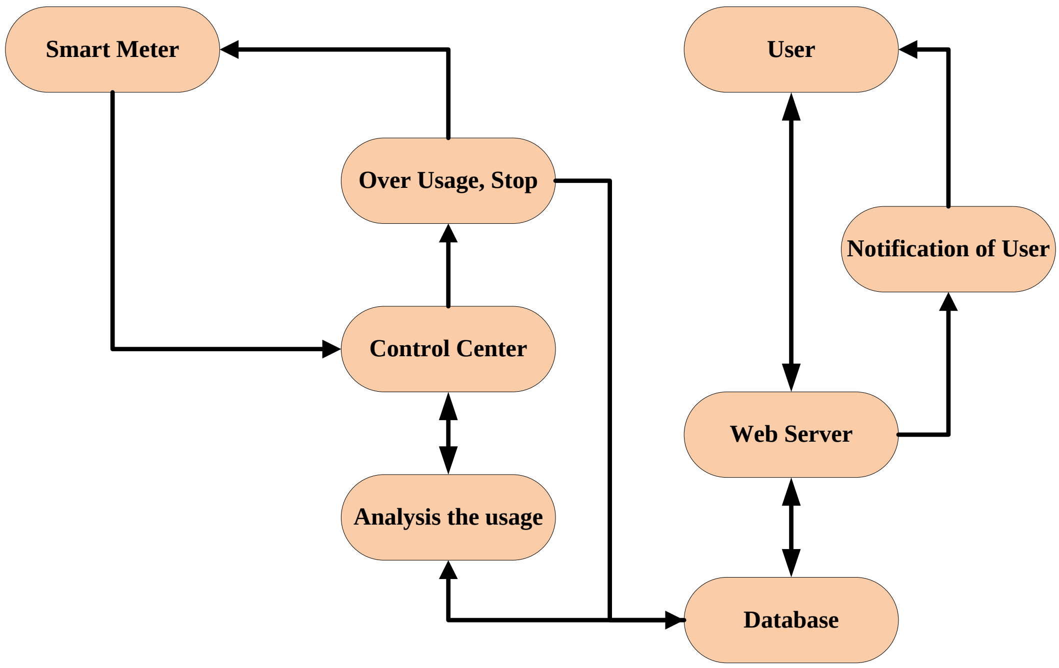


Figure 3.3: A flowchart for notification users.

CHAPTER FOUR

RESULTS AND DISCUSSION

Chapter Four

Results and Discussion

4.1 Introduction

The chapter aims to introduce the results obtained by the proposed method. The steps performed in this thesis elaborate and discuss with the output that is achieved. However, evaluating the proposed method plans to use the performance metrics.

The hybrid system was simulated by using ns-2. Moreover, its performance intends to be presented and discussed. Combining a function taken from a network layer with a technique use the data link layer in the TCP/IP model makes a Zigbee protocol has a new performance, and the system name becomes a hybrid system. The Simulation of the hybrid system achieves by Zigbee protocol and uses a cooperative communication system technique. The TCP/IP layers play the main effect when they use a routing and wireless connection. The evaluating of the hybrid system is measured by using three performance metrics which are; an E2E delay, PDR, and throughput. The second part of the proposed method of the thesis is the interface design by a web application. The database that is created by the store data meters and it sends back notification to the user by email. The web application to monitor the electrical readings by HTTP server.

4.2 Main steps of Proposed System

The flowchart in Figure 4.1 describes the workflow of the study in details. The work focuses on choosing the best routing protocol with the Zigbee protocol. The simulation parameters play an important issue to prefer better protocols. The second purpose of the flowchart focuses on the results and design of the web application to notify users.

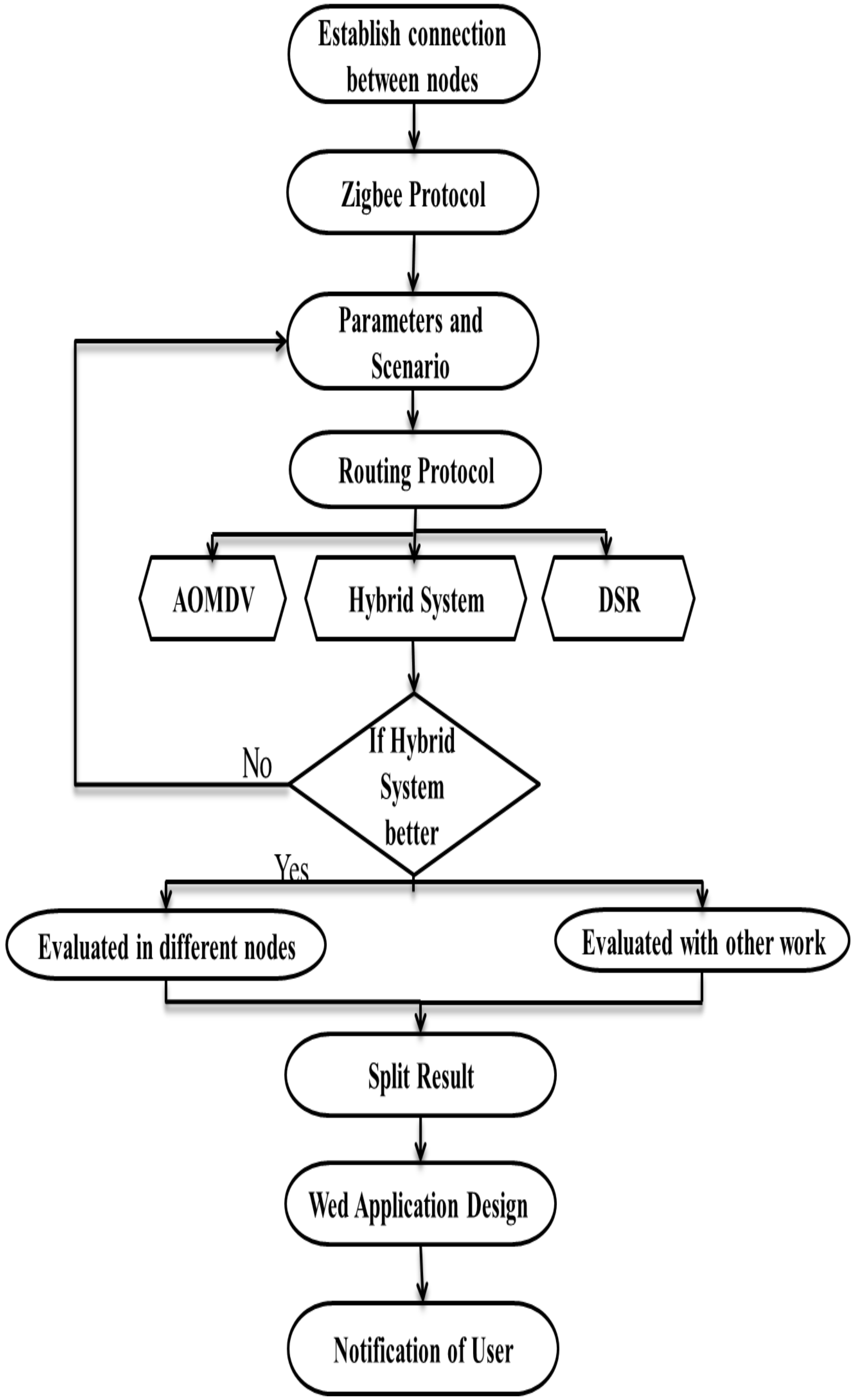


Figure 4.1: Steps by steps description the workflow

4.3 Simulation and Parameters for a Hybrid System

A simulation of our modulation methods via ns-2 is run. The selection of this method is based on the fact that the simulation is specifically useful in the system design when a real life hardware is unavailable for measurement, and in scenarios that requiring reasonable accuracy.

Information can exchange among the meters by using Zigbee technology as a network backbone. Hence, data arrives to the server node is being shared over the internet on a specific portal, and the owners can access the same and get the readings. The Zigbee part develops as well as meters portal. That portal makes by using local webserver which dispenses the use of embedded devices due to resource shortage.

In the proposed method specifics, the hybrid system utilises for transmission of data for smart meter nodes which by synchronization purposes. The design also considers low power and low cost restrictions. The asynchronous measurement scheduling method utilise to reduce network traffic. Thus, the consumption of power while minimizing the requirement of wired connections between the nodes or the utilisation of a particular radio link to enable synchronization. The hybrid system depends on Zigbee with MAC 802.15.4, cooperative communication, and Access Method TDMA. Figure 4.2 illustrates NAM of a program ns-2 which shows the process of communication between the meters and the electricity center, where 58 nodes used, two of them represents the electricity centers and the rest represents the meters. The simulation time is the 50s; transport protocol is UDP, the routing protocol is AODV, the time interval between packets is 0.01, and energy is100.

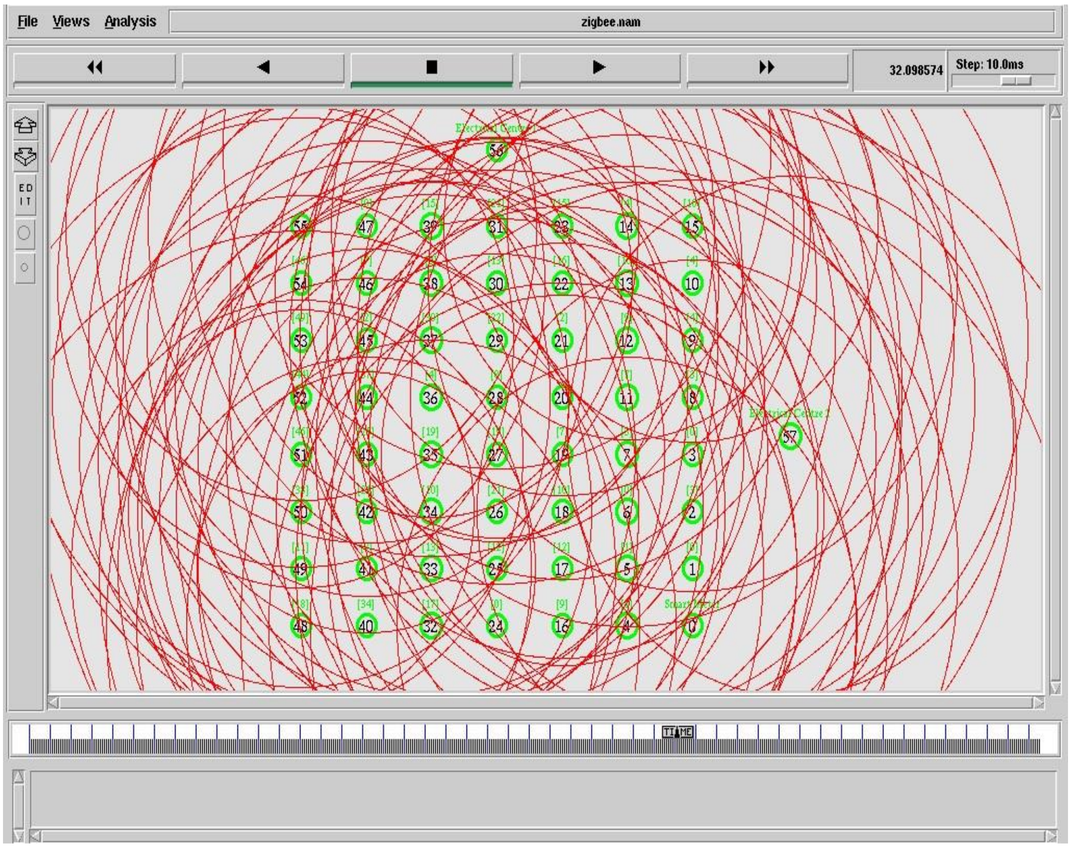


Figure 4.2: The process of communication between nodes.

The Figure 4.2 shows the nodes which are distributed on the area that proposed in a scenario were mention in chapter three. Every node is connected with the center node to send and receive the data. The red line in the Figure 4.2 is presenting the possible way for node to create way with other node or center node.

4.4 The Performance Analysis

Standard units called performance metrics are used to measure outcomes of simulations. The performance evaluates by choosing performance metrics, throughput, E2E delay, and PDR, as presented in chapter three.

The routing protocols used with the hybrid system are three protocols: AODV, DSR, and AOMDV. The simulation parameters for the comparison of evaluating the performance are shown in Table 4.1.

Table 4.1: Simulation parameters for comparison three protocols in Zigbee.

Parameter Name	Parameter Value
Number of Nodes	10, 20, 30, 40, 50, 60 nodes
Simulation Time	50 s
Map Size	100 m ×100 m
Traffic Type (Application)	Constant bitrate (CBR)
Energy	100 Joule
Time interval	0.01 s
Bandwidth of links	2 Mbit
MAC layer type	IEEE 802.15.4
Routing Protocols	AODV, DSR, AOMDV

The comparison between protocols with proposed hybrid system is come out after running simulation by ns-2. Figures 4.3, 4.4 and 4.5 show the results for throughput, PDR, and E2E delay. Figure 4.3 below shows the throughput of a hybrid system with DSR and AOMDV protocols.

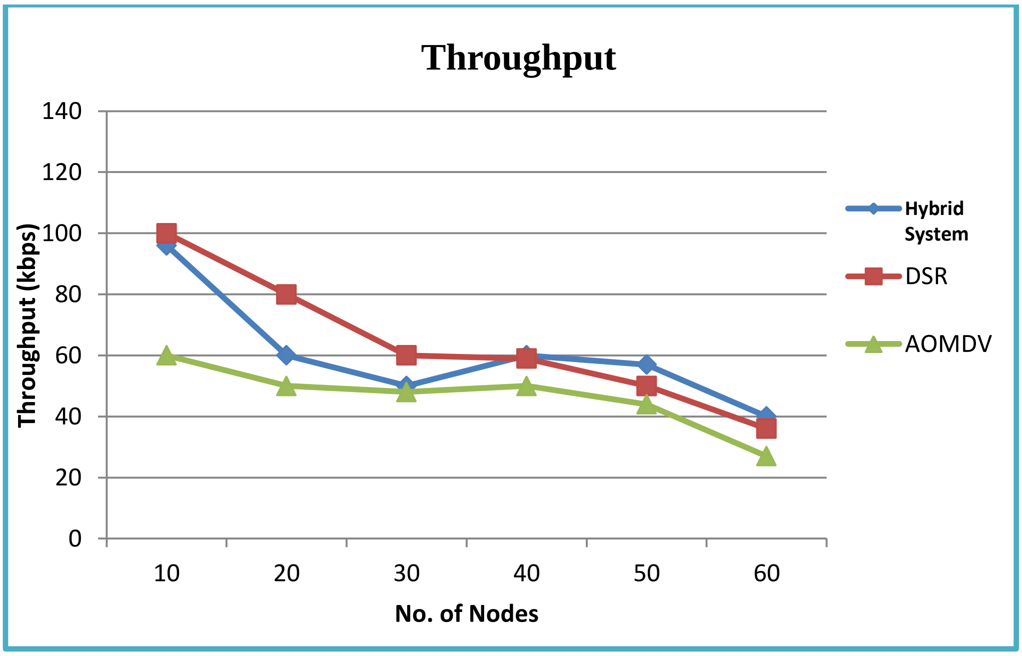


Figure 4.3: Throughput of hybrid system with DSR and AOMDV.

Figure 4.3 shows the throughput after compared between hybrid system, DSR, and AOMDV. The run evaluates in different numbers of nodes from 10 to 60 nodes. The results showed that is the DSR better than others in throughput for nodes 10 to 40, but the hybrid system is better than DSR for nodes 50 to 60. That means the proposed hybrid system, which depends on many layers works together for Zigbee protocol make routing in a high number of nodes with AODV protocol better than others when it evaluates. On the other ways, the throughput records high value when the number of nodes increases.

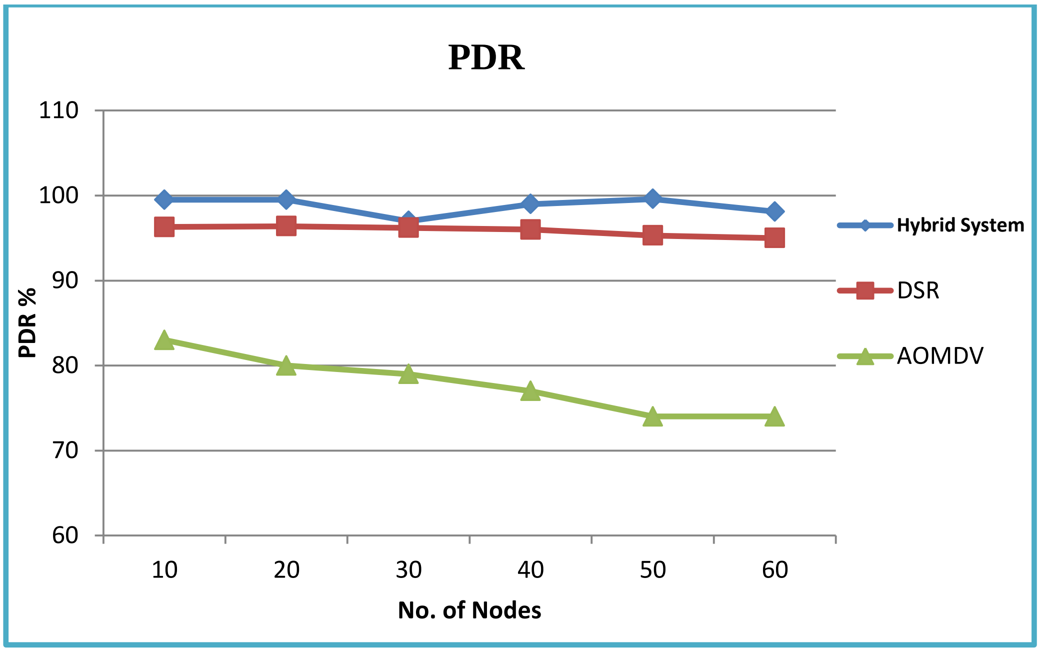


Figure 4.4: PDR of the hybrid system, DSR, and AOMDV.

The result in Figure 4.4 above shows that the hybrid system is superior in all terms of the test. It the best in different numbers of nodes that are proposed to test the protocols with the hybrid system. The PDR records more than 98%; where the hybrid system can work in a different number of nodes with high PDR.

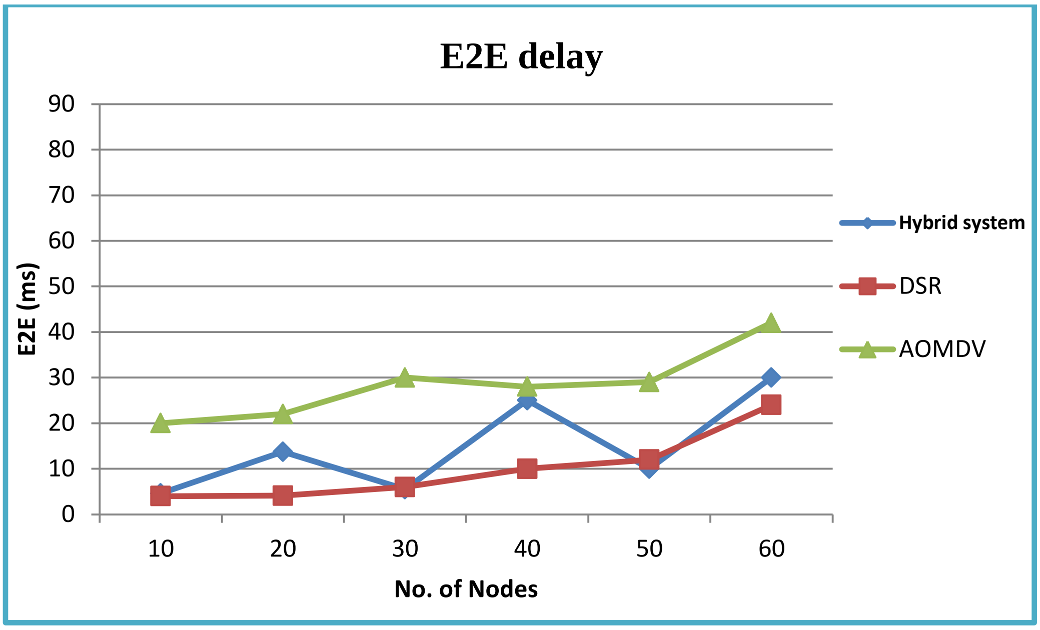


Figure 4.5: E2E delay for Hybrid System with DSR and AOMDV.

The results that come out from the run simulation is presented in Figure 4.5. The E2E delay that shows the DSR protocol is the best in all tests. Besides, the hybrid system records the values from 4 to 30 (ms) in different numbers of nodes. However, it is due to the weakness of AODV, which is used in the hybrid system.

Due to the results and performance of the hybrid system, DSR, and AOMDV for three performance metrics; throughput, PDR and E2E delay, provides better performance in terms of PDR and in most of the cases in terms of throughput. The Zigbee with AODV routing protocol and cooperative communication gives results in terms of PDR, throughput, and E2E delay that can use it in smart meters for high performance.

4.5 A Hybrid system Performance with 58 nodes

The Zigbee with AODV protocol and cooperative system (TDMA) is proposed in simulation scenario as presented in chapter three for test a smart meter with 58 nodes. The performance of Zigbee protocols is shown in Table 4.2. The 58 node for a hybrid system which is used a Zigbee protocol represent a best number of nodes. The 58 nodes is a best performance for a hybrid system based on the experimental which tested on a Zigbee protocol. These numbers of node 58 are maximum number that can handle with our system to record exchanging data between control center and smart meter without loss in packet and time.

Table 4.2 shows the average E2E delay, the average throughput, and PDR, after run simulation by using ns-2 with our scenario which mentions in chapter three.

Table 4.2: Performance metrics for hybrid system in case of 58 nodes.

NO	Performance metrics	Value
1	End to End delay	5.01 (ms)
2	Throughput	42.63 (kbps)
3	Packet Delivery Ratio	97.19%

Table 4.2 shows the average result for 58 nodes which is connected by Zigbee protocol, the MAC protocol is IEEE 802.15.4, the access method is TDMA, routing protocol is AODV with energy 100 and time simulation 50. The AWK file is used to calculate the results for the simulation run, by giving an average value for each performance metric. The average E2E delay is 5.01ms, the average throughput is 42.63 kbps, and PDR is 97.19%. The sent packet is 748 and drop packet is 21, so the packet loss rate is 2.807% between nodes with energy 99.99%.

The performance data in Table 4.2 shows the average output within an SG environment. In general, average throughput is 42.63 kbps. The values based on our network are excellent due to the performance of Zigbee protocols with routing AODV and TDMA access method; gives a high value of throughput. Table 4.2 also shows that the average E2E delay is 5.01ms. In general, E2E delay within the network is significantly stable because the techniques of connection between nodes which was used. Finally, the PDR, in the performance assessments is 97.19 % which means that there is a loss less than 3 %.

The average E2E delay in 58 node was obtained from several delays occurring in the nodes, and the values will be shown in Table 4.3.

Table 4.3: The E2E delay for each node in case 58 nodes

No of Node	E2E delay (ms)	No of Node	E2E delay (ms)
1	4.460	30	3.937
2	3.854	31	2.890
3	4.490	32	2.303
4	2.463	33	2.120
5	3.230	34	3.185
6	4.010	35	14.430
7	4.190	36	6.176
8	2.310	37	2.850
9	2.701	38	5.430
10	7.801	39	5.407
11	6.215	40	3.902
12	2.534	41	6.540
13	3.256	42	2.216
14	4.430	43	3.560
15	2.106	44	5.504
16	9.182	45	2.561
17	4.100	46	6.835
18	10.010	47	4.259
19	8.040	48	5.640
20	7.072	49	3.512
21	8.110	50	7.839
22	4.180	51	3.550
23	6.448	52	3.430
24	6.032	53	3.873
25	7.890	54	2.550
26	9.625	55	3.890
27	3.210	56	3.842
28	5.020	57	10.559
29	6.622	58	4.130

.

4.6 The Evaluation of the Hybrid System with other work

The result that comes out from the proposed method is better than those published by Bilgin and Gungor [12]. Where Biligin and Gungor [12] evaluate the performance of Zigbee in smart meter in terms of network throughput, E2E delay, energy consumption, and PDR in different SG environments which are an outdoor 500KV substation, underground transformer vault and main power room. They used number of nodes was 15, traffic type was CBR and MAC protocol was CSMA, their results come out in three deferent environments; throughput are 23 (kbps), 17.578 (kbps), 17.089 (kbps), E2E delay is 2 (ms), 5 (ms) and 9 (ms) and PDR are 15%, 20%, and 55%. The result in three parameters is generally better than the system as proposed by [12]. Figure 4.6 shows the comparison results of the hybrid system compared with Bilgin Author.

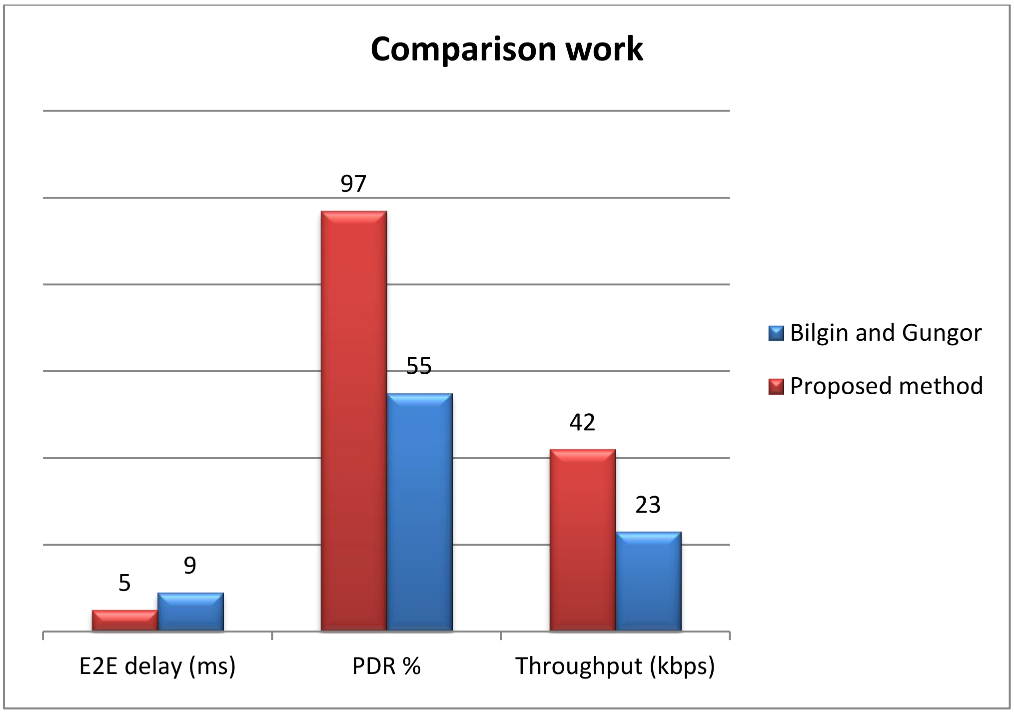


Figure 4.6: Results of hybrid system compared with Bilgin Author.

Moreover, The result that comes out from the proposed method is better than those published by Fadlullah *et al*. [90] in term of PDR. Where Fadlullah *et al*. [90], compared the PDR for the conventional and the improved (i.e., intelligent) systems based on Zigbee in the SG with number of nodes from 10 to 100, where the PDR for the intelligent system in 50 is 93% while the our result is

97.192%. Figure 4.7 shows the comparative results of the hybrid system and Fadlullah work.

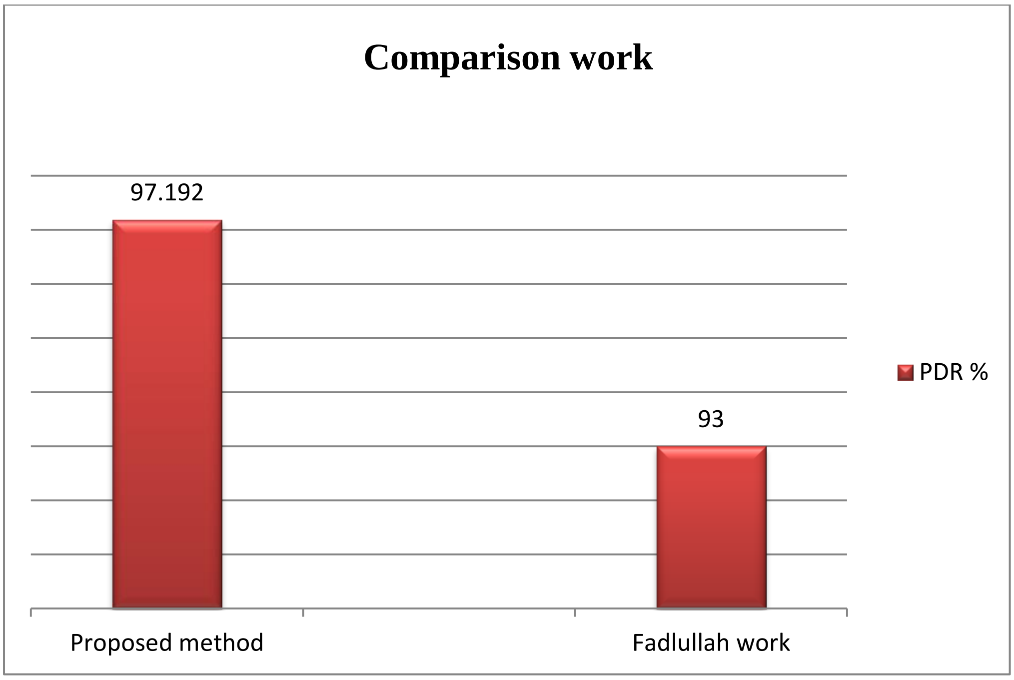


Figure 4.7: Compared the hybrid system with Fadlullah's work.

It has been noticed that when the results come out from the proposed method and compare with the result published by Moridi *et al*. [7], the proposed method results showed better result. Where Moridi et al. [7] analyses the performance of Zigbee in deferent topologies with 50 nodes scenario, network topology in mesh and cluster tree, area of simulation is 1000 * 1000(m), routing protocol is AODV. 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 [7]. Figure 4.8 shows the comparison of the hybrid system and Moridi's work.

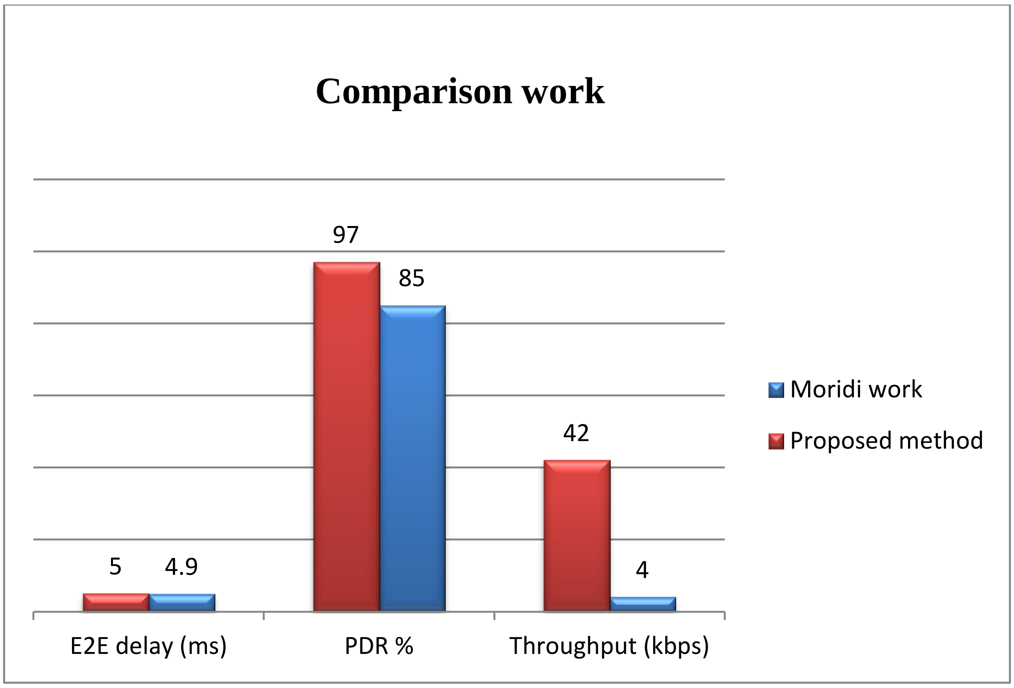


Figure 4.8: Compared the hybrid system with Moridi work.

After comparing the result come out from the hybrid system with others, the other authors use different scenario, so that the research results are generally better in most of the terms. Using AODV protocol in Zigbee with TDMA access method by combining layers in TCP/IP make hybrid system result almost good in PDR and throughput in different nodes which is used to test. However, the E2E delay for Zigbee with AODV needs more to improve the issue, but generally, the hybrid system is superior.

4.7 The Split Result

The AWK file 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; are shown in Table 4.4. These results adopt in web application designed where every single reading is reading of the meter for a given time. Figures 4.9 and 4.10 show the number of nodes with the sent packet after the split of the result from ns-2.

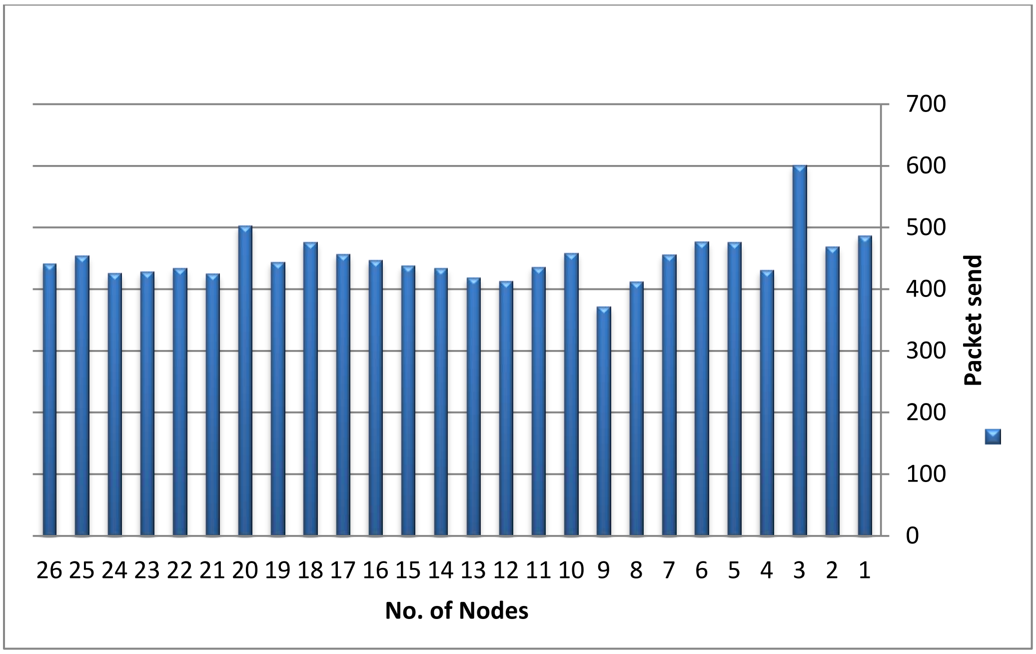


Figure 4.9: No of nodes with packet send from Node 1 to Node 26.

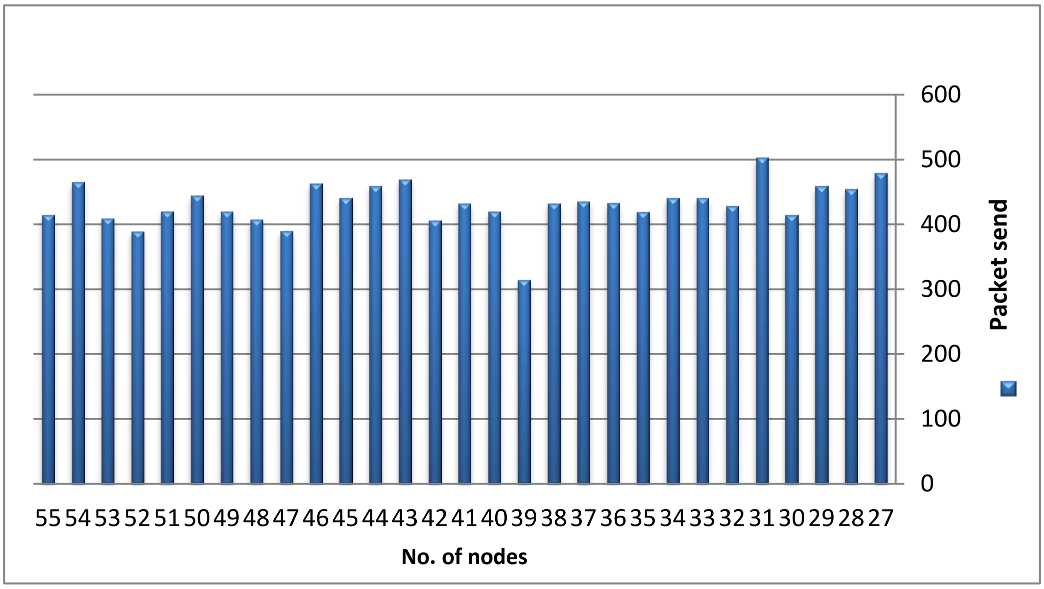


Figure 4.10: No of nodes with packet send from Node 27 to Node 55.

Table 4.4: Packet sends for every meter.

Meter no.	Packet send	Meter no.	Packet send
0	21820	29	459
1	487	30	414
2	469	31	503
3	601	32	428
4	431	33	441
5	476	34	441
6	477	35	419
7	456	36	433
8	412	37	435
9	372	38	432
10	459	39	314
11	436	40	420
12	413	41	432
13	419	42	406
14	434	43	469
15	438	44	459
16	447	45	441
17	457	46	463
18	476	47	390
19	444	48	407
20	503	49	420
21	425	50	444
22	434	51	420
23	428	52	389
24	426	53	409
25	454	54	465
26	441	55	414
27	479		
28	454		

4.8 Web Interface Design

The second step for the hybrid system is interfacing the data. After completing the test of the hybrid system in different cases, the result is ready to present for users. The web application is designed to allow the users to enter the web and knowing their information by logging in to email. The HTTP server is used to design web application. The languages for design web application are HTML, CSS, PHP, and MySQL. A database creates to store user information. The user enters the web application and inputs his / her information: first name, last name, meter number, and email, then enters each personal's information into a database as shown in Figures 4.11.

The database is designed depends on the results that obtained from ns-2. Every node represents the user, maybe home or anything related. The center node receives the data from nodes that are connected with it by Zigbee. The center node sends the reading for the node to the database which is ready to calculate the used energy for a given time. Every end user should be login to the web application to register his number of meter, first name, last name, and email as shown in appendix A. When a person input his information correctly, a page appears as shown appendix B. If the user input the wrong email or password, the page appears, as shown in appendix C.

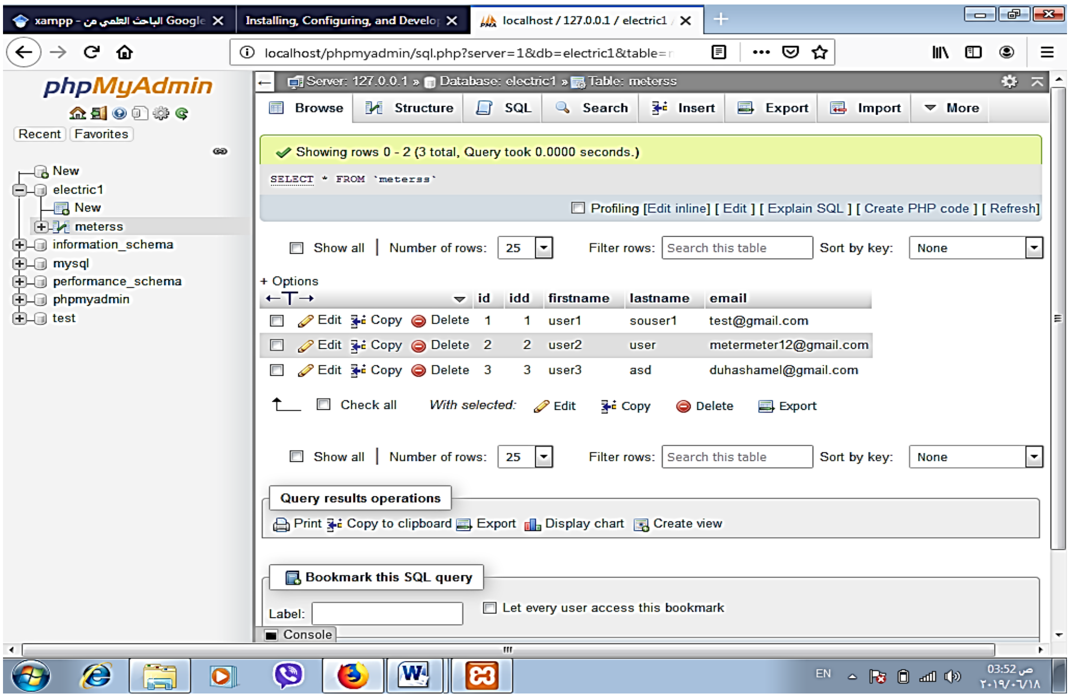


Figure 4.11: MySQL admin.

Each user can know his / her consumption for the previous month. The page is designed by the person to input the meter number and email only as shown in appendix D, where it appears the name of the user, the number of meters, email, and consumption information for each month, as shown in appendix F.

A page makes for the admin through which he can monitor the readings of the meters, where it appears before the user information such as; the first and last name, meter number and e-mail.

The admin can know the user's electricity consumption every month. He can input the number of the meter and the number of months he wants to know and then see the details, as shown in Figure 4.12. The web application can send an e-mail to the users, when the user reached the consumption of all the balance and notify him automatic about consumption by e-mail. The web application can notify all users or single users.

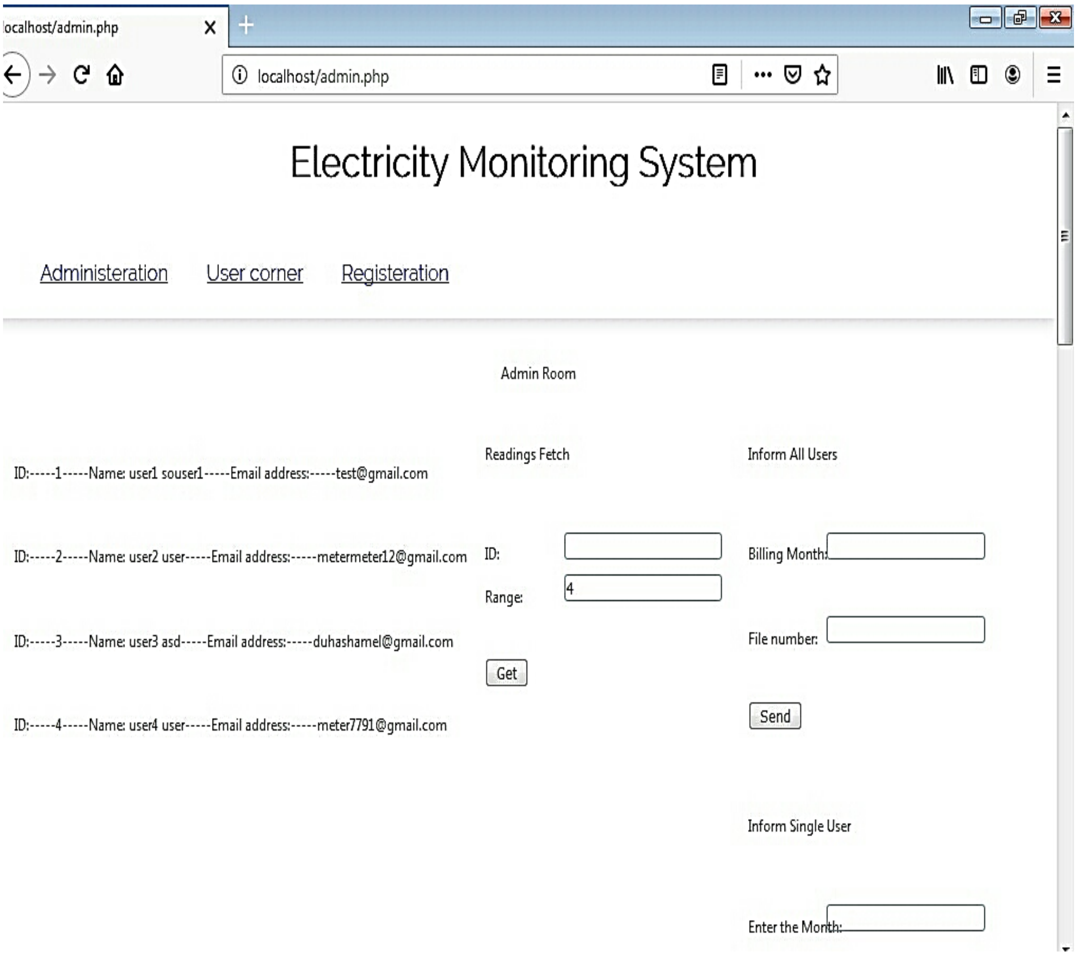


Figure 4.12: web application for admin for proposed design.

CHAPTER FIVE

CONCLUSIONS AND FUTURE WORKS

Chapter Five
Conclusions and Future Works

5.1 Introduction

This chapter presents a set of the conclusions that derives from the work of implementing the proposed method. Besides, ideas for future works presented to give a possible enhancement. Finally, the limitations have shown in this chapter.

5.2 Conclusions

The most important conclusions of this thesis are:

- A hybrid system based on Zigbee was used in a smart meter to connect the network by using ns-2 software, which is a high performance record in this thesis.
- The system evaluation based on performance metrics such as throughput, E2E delay and PDR was performed.
- From the result which is come out in simulation for smart meters technique. The zigbee technics showed a high value in throughout, small value of E2E delay and lower power used.
- A web application designed in this thesis to notification of user. It stores information about consumption electricity and sends to all users after completing their requirement register.

5.3 Future Works

A smart meter is a part of SG. The researchers still developing and publishing a lot of paper day by day. Developing techniques that provide a secure and reliable connection stills an issue. The organization is paying a lot of many to develop a smart meter because of the increased demand by governments. The current race on using smart meter is based on providing the best services at the lowest prices. Besides, providing a service of a user is necessary to satisfy a customer. There is a list of future works that can be applied in this thesis. some of them are:

- Develop a method that is self-send to a web application without a central node. This is because a center node plays a significant role and holds out a burden to receive and transmit data to the web.
- Designing an application used by a smartphone with number mobile to receive a notification.
- Because of the disadvantage of cooperative communication system technology, which is security and privacy, it is possible in future works that we develop a method that provides and guarantees security and privacy.
- Because of in this work, a simulation has only used, so in future work, real work is used to design a smart meter and apply that in the real area.

5.4 Limitations

In this thesis, a hybrid system based on Zigbee with TDMA access method was proposed to connect 58 nodes. Zigbee can connect among nodes about 58 nodes with energy 100, this is because the increase in the number of nodes leads to an increase in delay and a decrease in throughput. The final energy can calculate after transmitting 99.99%. So, the limitation of this research depends on the scenario which has been made and mentioned in chapter three. The designed web application in this thesis, is to register the critical information of the user to complete a hybrid system.

REFERENCES

REFERENCES

[1] L. Lugaric, S. Krajcar, and Z. Simic, "Smart city—Platform for emergent phenomena power system testbed simulator," in *Innovative Smart Grid Technologies Conference Europe (ISGT Europe), 2010 IEEE PES*, 2010, pp. 1-7.

[2] G. Strbac, "Demand side management: Benefits and challenges," *Energy policy*, vol. 36, pp. 4419-4426, 2008.

[3] H. Farhangi, "The path of the smart grid," *IEEE power and energy magazine*, vol. 8, 2010.

[4] A. M. Khattak, S. I. Khanji, and W. A. Khan, "Smart Meter Security: Vulnerabilities, Threat Impacts, and Countermeasures," in *International Conference on Ubiquitous Information Management and Communication*, 2019, pp. 554-562.

[5] T.-S. Choi, K.-R. Ko, S.-C. Park, Y.-S. Jang, Y.-T. Yoon, and S.-K. Im, "Analysis of energy savings using smart metering system and IHD (in-home display)," in *Transmission & Distribution Conference & Exposition: Asia and Pacific, 2009*, 2009, pp. 1-4.

[6] S. S. S. R. Depuru, L. Wang, V. Devabhaktuni, and N. Gudi, "Smart meters for power grid—Challenges, issues, advantages and status," in *2011 IEEE/PES Power Systems Conference and Exposition*, 2011, pp. 1-7.

[7] 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.

[8] M. Zubairuddin and P. Thakre, "Automatic Meter Reading using Wireless Sensor Module," 2018.

[9] T. Wilcox, N. Jin, P. Flach, and J. Thumim, "A Big Data platform for smart meter data analytics," *Computers in Industry*, vol. 105, pp. 250-259, 2019.

[10] H. Salah, S. Alouneh, A. Al-Assaf, and K. Darabkh, "Performance Evaluation of DigiMesh and ZigBee Wireless Mesh Networks," in *2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)*, 2018, pp. 1-6.

[11] A. K. Das and S. Zeadally, "Data Security in the Smart Grid Environment," in *Pathways to a Smarter Power System*, ed: Elsevier, 2019, pp. 371-395.

[12] B. E. Bilgin and V. Gungor, "Performance evaluations of ZigBee in different smart grid environments," *Computer Networks*, vol. 56, pp. 2196-2205, 2012.

[13] S. Aimal, N. Javaid, T. Islam, W. Z. Khan, M. Y. Aalsalem, and H. Sajjad, "An Efficient CNN and KNN Data Analytics for Electricity Load Forecasting in the Smart Grid," in *Workshops of the International Conference on Advanced Information Networking and Applications*, 2019, pp. 592-603.

[14] L. Wang, G. Zhai, X. Ye, M. Lv, and S. Yu, "Optimization on metering accuracy of smart electricity meter by temperature compensation," in *Tenth International Symposium on Precision Engineering Measurements and Instrumentation*, 2019, p. 1105317.

[15] S. Sankaranarayanan, "Performance Analysis of Security Protocols in Smart Energy Meter System," *International Journal of Applied Engineering Research*, vol. 12, pp. 8294-8315, 2017.
[16] M. Burunkaya and T. Pars, "A smart meter design and implementation using ZigBee based wireless sensor network in smart grid," in *2017 4th International Conference on Electrical and Electronic Engineering (ICEEE)*, 2017, pp. 158-162.
[17] V. Preethi and G. Harish, "Design and implementation of smart energy meter," in *2016 International Conference on Inventive Computation Technologies (ICICT)*, 2016, pp. 1-5.
[18] D. Abbasinezhad-Mood and M. Nikooghadam, "Design and hardware implementation of a security-enhanced elliptic curve cryptography based lightweight authentication scheme for smart grid communications," *Future Generation Computer Systems*, vol. 84, pp. 47-57, 2018.
[19] M. Pau, E. Patti, L. Barbierato, A. Estebsari, E. Pons, F. Ponci, *et al.*, "A cloud-based smart metering infrastructure for distribution grid services and automation," *Sustainable Energy, Grids and Networks*, vol. 15, pp. 14-25, 2018.
[20] R. R. Mohassel, A. Fung, F. Mohammadi, and K. Raahemifar, "A survey on advanced metering infrastructure," *International Journal of Electrical Power & Energy Systems*, vol. 63, pp. 473-484, 2014.
[21] M. Di Somma, G. Graditi, E. Heydarian-Forushani, M. Shafie-Khah, and P. Siano, "Stochastic optimal scheduling of distributed energy resources with renewables considering economic and environmental aspects," *Renewable energy*, vol. 116, pp. 272-287, 2018.
[22] Y. Kabalci, "A survey on smart metering and smart grid communication," *Renewable and Sustainable Energy Reviews*, vol. 57, pp. 302-318, 2016.
[23] E. Bou-Harb, C. Fachkha, M. Pourzandi, M. Debbabi, and C. Assi, "Communication security for smart grid distribution networks," *IEEE Communications Magazine*, vol. 51, pp. 42-49, 2013.
[24] X. Fang, S. Misra, G. Xue, and D. Yang, "Smart grid—The new and improved power grid: A survey," *IEEE communications surveys & tutorials*, vol. 14, pp. 944-980, 2012.
[25] S. E. Collier, "Ten steps to a smarter grid," *IEEE Industry Applications Magazine*, vol. 16, pp. 62-68, 2010.
[26] C.-H. Lo and N. Ansari, "The progressive smart grid system from both power and communications aspects," *IEEE Communications Surveys & Tutorials*, vol. 14, pp. 799-821, 2012.
[27] 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, pp. 168-177, 2010.
[28] Ausgrid. (2018, 13-10). *Type of meters - Ausgrid*. Available: https://www.ausgrid.com.au/Connections/Meters/Type-of-meters#.V19UXtl96Uk.
[29] N. E. Knight and D. M. Banks, "Remote meter reading system," ed: Google Patents, 1998.
[30] R. D. Colton, "Prepayment utility meters, affordable home energy, and the low income utility consumer," *J. Affordable Hous. & Cmty. Dev. L.*, vol. 10, p. 285, 2000.

[31] T. Chandler, "The technology development of automatic metering and monitoring systems," in *Power Engineering Conference, 2005. IPEC 2005. The 7th International*, 2005, pp. 1-147.
[32] A. Usman and S. H. Shami, "Evolution of communication technologies for smart grid applications," *Renewable and Sustainable Energy Reviews,* vol. 19, pp. 191-199, 2013.
[33] I. Rouf, H. Mustafa, M. Xu, W. Xu, R. Miller, and M. Gruteser, "Neighborhood watch: security and privacy analysis of automatic meter reading systems," in *Proceedings of the 2012 ACM conference on Computer and communications security*, 2012, pp. 462-473.
[34] I. Pricing and R. Tribunal, "Inclining block tariffs for electricity network services," ed: Independent Pricing and Regulatory Tribunalfrom, 2003.
[35] A. Mohammadali, M. S. Haghighi, M. H. Tadayon, and A. Mohammadi-Nodooshan, "A novel identity-based key establishment method for advanced metering infrastructure in smart grid," *IEEE Transactions on Smart Grid,* vol. 9, pp. 2834-2842, 2018.
[36] Z. Yang, Y. Chen, Y.-F. Li, E. Zio, and R. Kang, "Smart electricity meter reliability prediction based on accelerated degradation testing and modeling," *International Journal of Electrical Power & Energy Systems,* vol. 56, pp. 209-219, 2014.
[37] B. Bat-Erdene, B. Lee, M.-Y. Kim, T. H. Ahn, and D. Kim, "Extended smart meters-based remote detection method for illegal electricity usage," *IET Generation, Transmission & Distribution,* vol. 7, pp. 1332-1343, 2013.
[38] Z. Erkin, J. R. Troncoso-Pastoriza, R. L. Lagendijk, and F. Pérez-González, "Privacy-preserving data aggregation in smart metering systems: An overview," *IEEE Signal Processing Magazine,* vol. 30, pp. 75-86, 2013.
[39] 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.
[40] 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, pp. 1632-1642, 2012.
[41] 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.
[42] 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, pp. 1665-1697, 2013.
[43] 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, pp. 825-845, 2013.
[44] 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.
[45] T. Khalifa, K. Naik, and A. Nayak, "A survey of communication protocols for automatic meter reading applications," *IEEE Communications Surveys & Tutorials,* vol. 13, pp. 168-182, 2011.

[46] 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, 2012.
[47] 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, pp. 3360-3371, 2013.
[48] W. Wang, Y. Xu, and M. Khanna, "A survey on the communication architectures in smart grid," *Computer networks,* vol. 55, pp. 3604-3629, 2011.
[49] K. M. A. Alheeti and K. McDonald-Maier, "Hybrid intrusion detection in connected self-driving vehicles," in *2016 22nd International Conference on Automation and Computing (ICAC)*, 2016, pp. 456-461.
[50] K. Ali Alheeti, A. Gruebler, and K. McDonald-Maier, "Intelligent intrusion detection of grey hole and rushing attacks in self-driving vehicular networks," *Computers,* vol. 5, p. 16, 2016.
[51] H. Wang, Y. Qian, and H. Sharif, "Multimedia communications over cognitive radio networks for smart grid applications," *IEEE Wireless Communications,* vol. 20, pp. 125-132, 2013.
[52] R. Deng, J. Chen, X. Cao, Y. Zhang, S. Maharjan, and S. Gjessing, "Sensing-performance tradeoff in cognitive radio enabled smart grid," *IEEE Transactions on Smart Grid,* vol. 4, pp. 302-310, 2013.
[53] J. Huang, H. Wang, Y. Qian, and C. Wang, "Priority-based traffic scheduling and utility optimization for cognitive radio communication infrastructure-based smart grid," *IEEE Transactions on Smart Grid,* vol. 4, pp. 78-86, 2013.
[54] C. Gentile, D. Griffith, and M. Souryal, "Wireless network deployment in the smart grid: design and evaluation issues," *IEEE Network,* vol. 26, 2012.
[55] M. Erol-Kantarci and H. T. Mouftah, "Wireless sensor networks for smart grid applications," in *2011 Saudi International Electronics, Communications and Photonics Conference (SIECPC)*, 2011, pp. 1-6.
[56] Q. Zhang, Y. Sun, and Z. Cui, "Application and analysis of ZigBee technology for Smart Grid," in *2010 International Conference on Computer and Information Application*, 2010, pp. 171-174.
[57] Z. A. Khan and Y. Faheem, "Cognitive radio sensor networks: Smart communication for smart grids—A case study of Pakistan," *Renewable and Sustainable Energy Reviews,* vol. 40, pp. 463-474, 2014.
[58] C. JordA, B. Asare-Bediako, G. Vanalme, and W. Kling, "Overview and comparison of leading communication standard technologies for smart home area networks enabling energy management systems," in *2011 46th International Universities' Power Engineering Conference (UPEC)*, 2011, pp. 1-6.
[59] P. Smith, "Comparisons between low power wireless technologies," *US Patent CS-213199-AN,* 2011.
[60] S. Farahani, *ZigBee wireless networks and transceivers*: Newnes, 2011.
[61] O. G. Aju, "A survey of zigbee wireless sensor network technology: Topology, applications and challenges," *International Journal of Computer Applications,* vol. 130, pp. 47-55, 2015.
[62] 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.
[63] T. Jamil, "A performance analysis of multimedia traffic over zigbee network," BRAC University, 2017.
[64] B. Latré, B. Braem, I. Moerman, C. Blondia, and P. Demeester, "A survey on wireless body area networks," *Wireless Networks,* vol. 17, pp. 1-18, 2011.
[65] J.-h. ZHAO, Y.-f. LI, and C.-x. XU, "Introduction of Zigbee technology [J]," *Telecommunications for Electric Power System,* vol. 7, p. 014, 2006.
[66] M. Ilyas, *The handbook of ad hoc wireless networks*: CRC press, 2014.
[67] E. M. Royer and C.-K. Toh, "A review of current routing protocols for ad hoc mobile wireless networks," *Personal Communications, IEEE,* vol. 6, pp. 46-55, 1999.
[68] M. Tokekar and R. D. Joshi, "Extension Of Optimized Linked State Routing Protocol for Energy Efficient Applications," *International Journal on Adhoc Networking Systems (IJANS) Vol,* vol. 1, 2011.
[69] M. S. Bhat, D. Shwetha, and J. Devaraju, "A Performance Study of Proactive, Reactive and Hybrid Routing Protocols using Qualnet Simulator," *International Journal of Computer Applications,* vol. 28, 2011.
[70] P. Khatri, M. Rajput, A. Shastri, and K. Solanki, "Performance study of ad-hoc reactive routing protocols," *Journal of Computer Science,* vol. 6, pp. 1159-1163, 2010.
[71] S. Mewada and U. Kumar, "Measurement Based Performance of Reactive and Proactive Routing Protocols in WMN," *International journal of advanced research in computer science and software engineering,* vol. 1, 2011.
[72] F. Maan and N. Mazhar, "MANET routing protocols vs mobility models: A performance evaluation," in *Ubiquitous and Future Networks (ICUFN), 2011 Third International Conference on*, 2011, pp. 179-184.
[73] S. Mohseni, R. Hassan, A. Patel, and R. Razali, "Comparative review study of reactive and proactive routing protocols in MANETs," in *Digital Ecosystems and Technologies (DEST), 2010 4th IEEE International Conference on*, 2010, pp. 304-309.
[74] I. D. Chakeres and E. M. Belding-Royer, "AODV routing protocol implementation design," in *24th International Conference on Distributed Computing Systems Workshops, 2004. Proceedings.*, 2004, pp. 698-703.
[75] A. A. Etorban, "The design and performance evaluation of a proactive multipath routing protocol for mobile ad hoc networks," Heriot-Watt University, 2012.
[76] D. B. Johnson and D. A. Maltz, "Dynamic source routing in ad hoc wireless networks," in *Mobile computing*, ed: Springer, 1996, pp. 153-181.
[77] D. Johnson, Y. Hu, and D. Maltz, "The dynamic source routing protocol (DSR) for mobile ad hoc networks " RFC 4728, February2007.
[78] P. Aggarwal and E. P. Garg, "AOMDV Protocols in MANETS: A Review," *International Journal of Advanced Research in Computer Science & Technology (IJARCST 2016),* vol. 32, 2013.
[79] I. Amiri, A. Shahidinejad, A. Nikoukar, M. Ranjbar, J. Ali, and P. Yupapin, "Digital binary codes transmission via TDMA networks

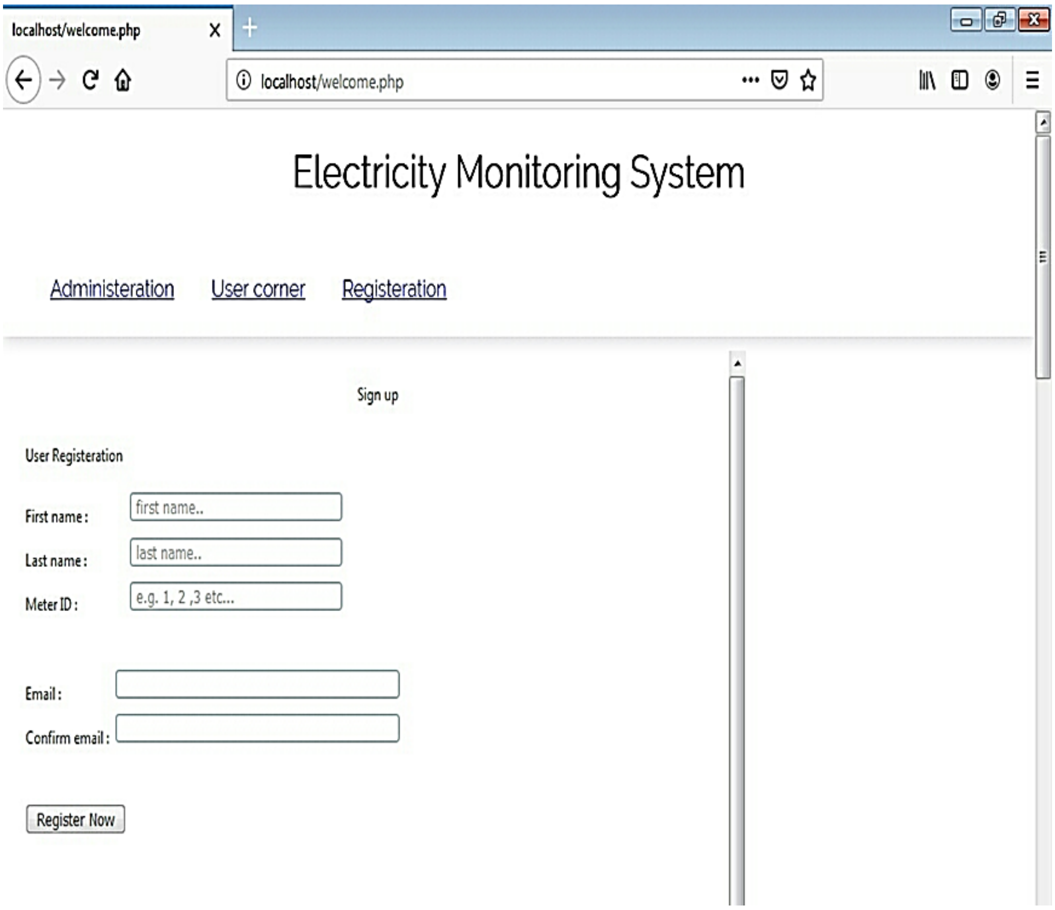
communication system using dark and bright optical soliton," *GSTF Journal on Computing (joc),* vol. 2, 2018.
[80] G. Kramer, I. Marić, and R. D. Yates, "Cooperative communications," *Foundations and Trends® in Networking,* vol. 1, pp. 271-425, 2007.
[81] Q. Li, R. Q. Hu, Y. Qian, and G. Wu, "Cooperative communications for wireless networks: techniques and applications in LTE-advanced systems," *IEEE Wireless Communications,* vol. 19, pp. 22-29, 2012.
[82] G. Anastasi, E. Borgia, M. Conti, and E. Gregori, "IEEE 802.11 ad hoc networks: performance measurements," in *Distributed Computing Systems Workshops, 2003. Proceedings. 23rd International Conference on*, 2003, pp. 758-763.
[83] F. Bai and A. Helmy, "A survey of mobility models," *Wireless Adhoc Networks. University of Southern California, USA,* vol. 206, 2004.
[84] S. Sinha and B. Sen, "Effect of Varying Node Density and Routing Zone Radius in ZRP: A Simulation Based Approach," *IJCSE, ISSN,* pp. 0975-3397, 2012.
[85] T. Issariyakul and E. Hossain, *Introduction to network simulator NS2*: Springer Science & Business Media, 2011.
[86] J. Pan and R. Jain, "A survey of network simulation tools: Current status and future developments," *Email: jp10@ cse. wustl. edu,* vol. 2, p. 45, 2008.
[87] S. Kalkhanda, *Learning AWK Programming: A fast, and simple cutting-edge utility for text-processing on the Unix-like environment*: Packt Publishing Ltd, 2018.
[88] C. A. Prawastiyo, "Membaca Dan Input File Dalam Bahasa Pemrograman AWK," 2019.
[89] J.-S. Lee, Y.-W. Su, and C.-C. Shen, "A comparative study of wireless protocols: Bluetooth, UWB, ZigBee, and Wi-Fi," *Industrial electronics society,* vol. 5, pp. 46-51, 2007.
[90] Z. M. Fadlullah, M. M. Fouda, N. Kato, A. Takeuchi, N. Iwasaki, and Y. Nozaki, "Toward intelligent machine-to-machine communications in smart grid," *IEEE Communications Magazine,* vol. 49, pp. 60-65, 2011.

APPENDICE

Appendices

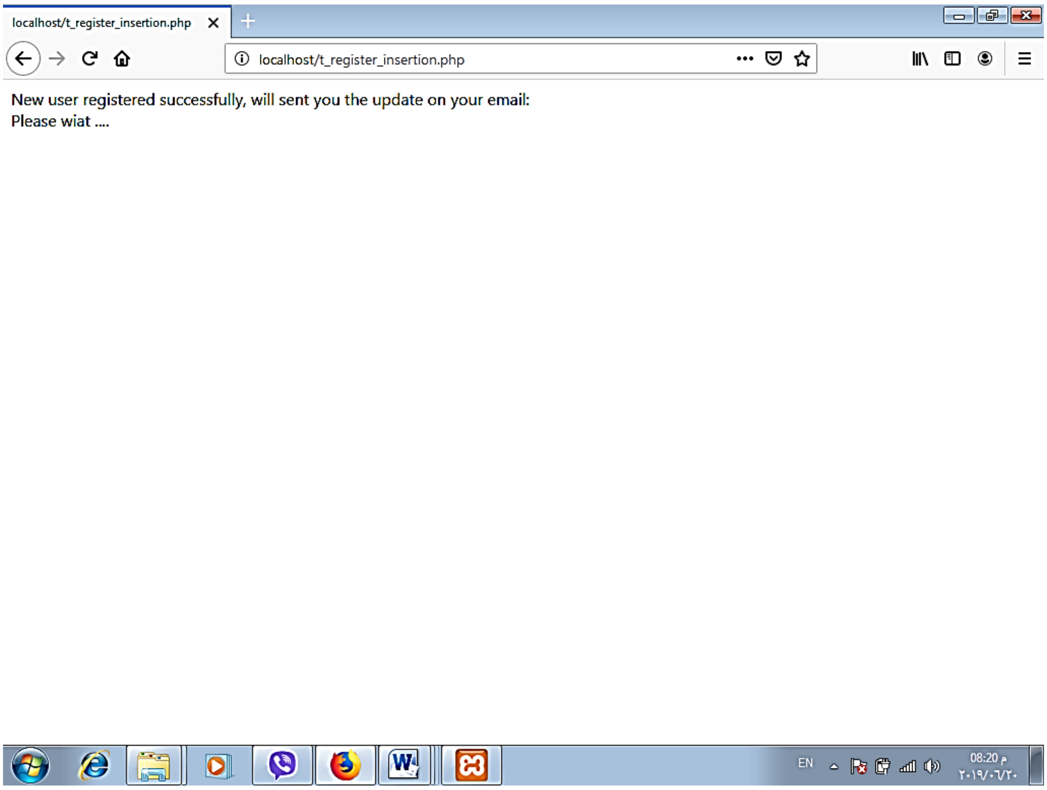
Appendix A

Figure showed register user in web application.



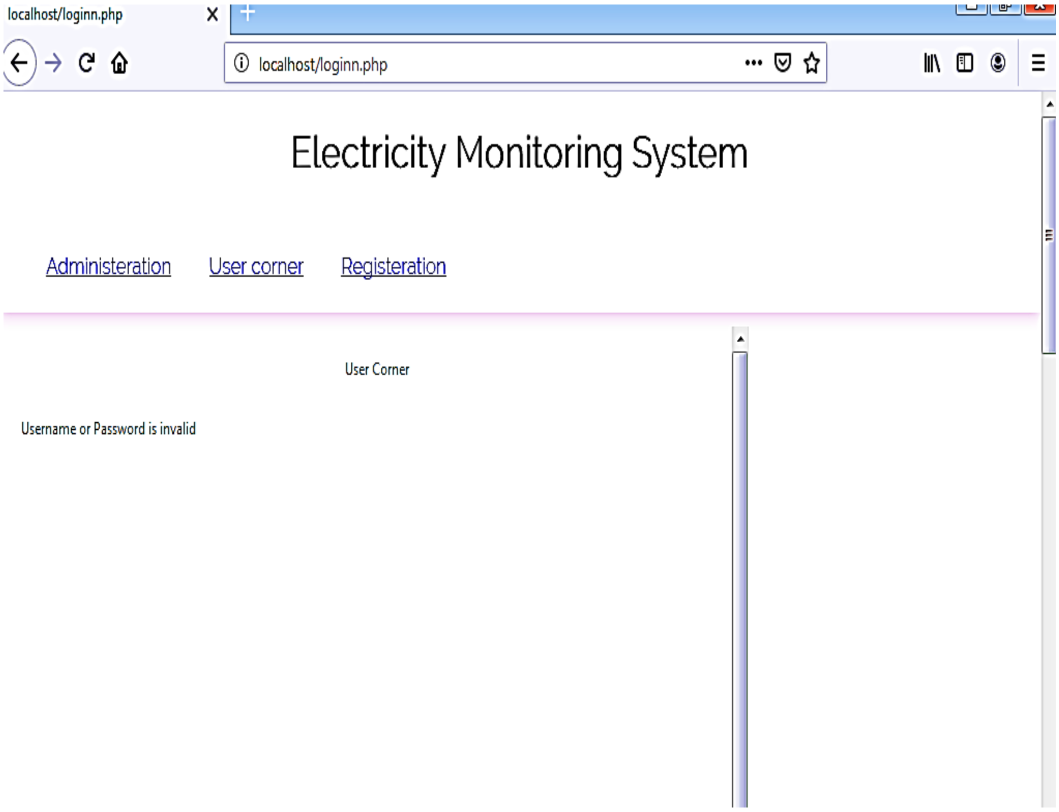
Appendix B

Figure showed web application for new user register.



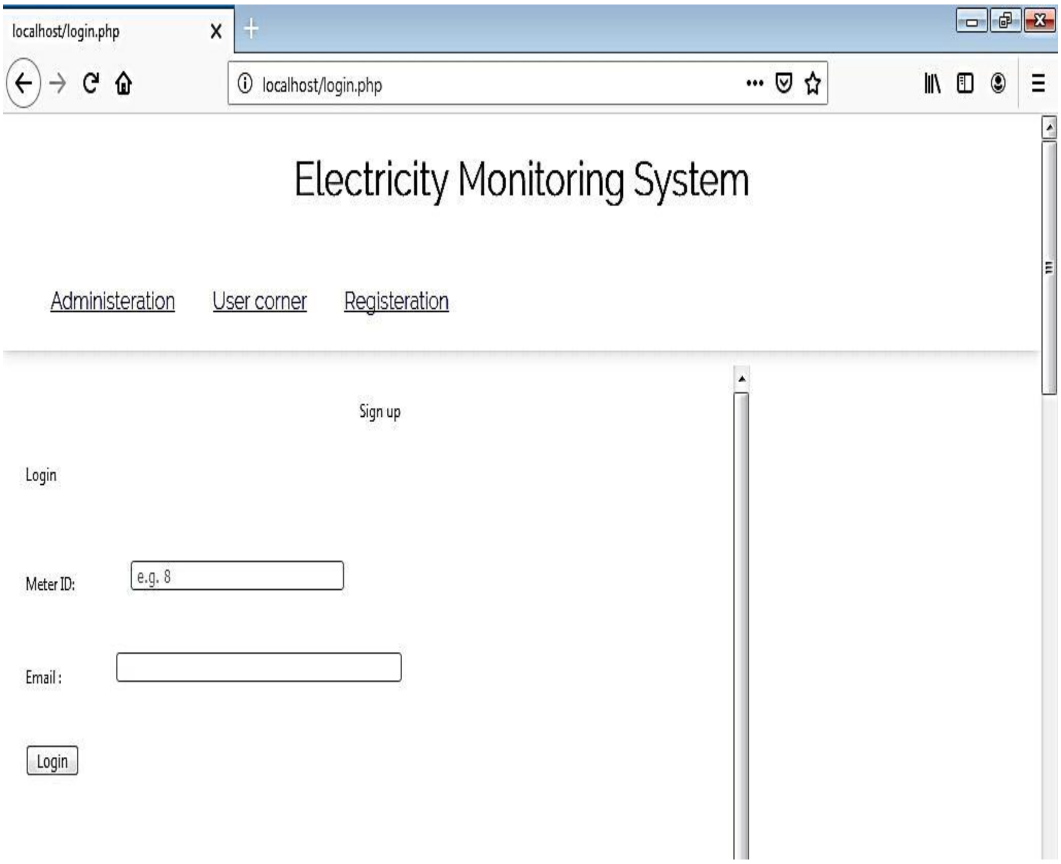
Appendix C

Figure showed web application for the username or password is invalid.



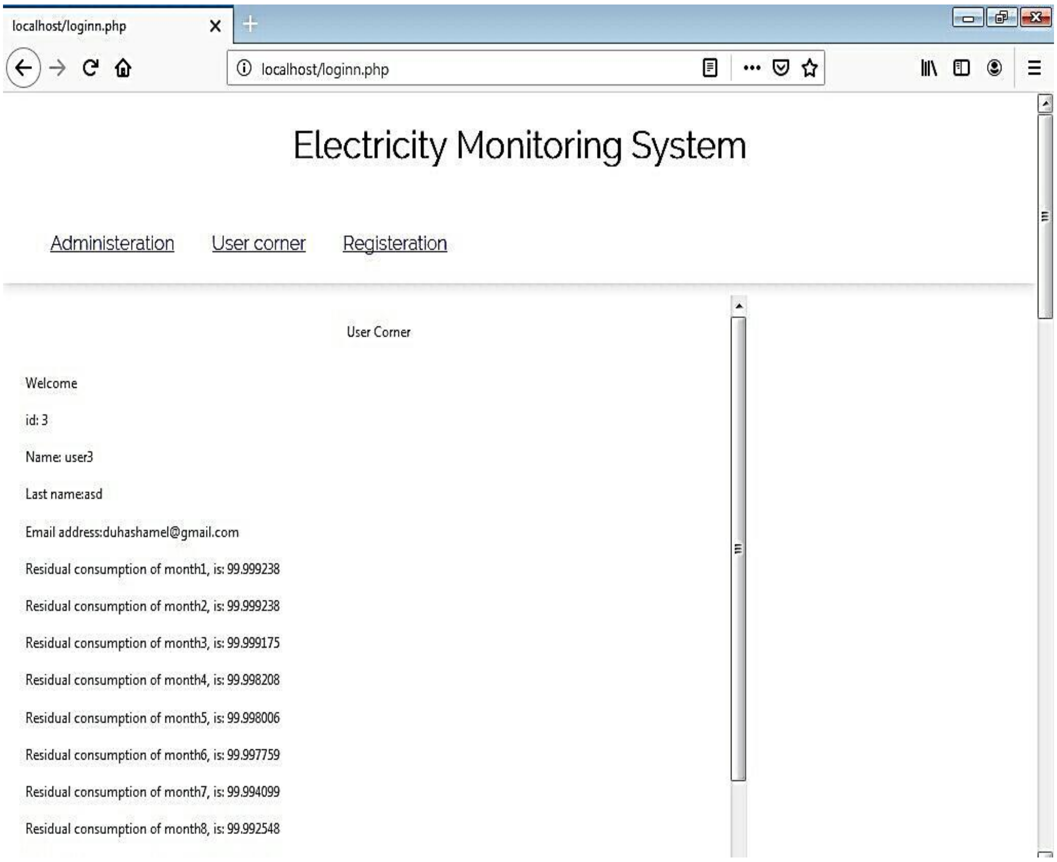
Appendix D

Figure showed web application for entering meter ID and email.



Appendix F

Figure showed web application for user information.


localhost/loginn.php
localhost/loginn.php
Electricity Monitoring System
Administeration
User corner
Registeration
User Corner
Welcome
id: 3
Name: user3
Last name:asd
Email address:duhashamel@gmail.com
Residual consumption of month1, is: 99.999238
Residual consumption of month2, is: 99.999238
Residual consumption of month3, is: 99.999175
Residual consumption of month4, is: 99.998208
Residual consumption of month5, is: 99.998006
Residual consumption of month6, is: 99.997759
Residual consumption of month7, is: 99.994099
Residual consumption of month8, is: 99.992548

الخلاصة

العداد الذكي هو جهاز إلكتروني يقوم بتسجيل دقيق لاستهلاك الطاقة الكهربائية ، ثم يقوم بنقل هذه البيانات إلى مراكز الكهرباء لأغراض إعداد الفواتير والمراقبة. يتم توفير اتصال ثنائي الاتجاه بين المراكز والعداد بواسطة العدادات الذكية. تعمل وظيفة الاتصال ثنائي الاتجاه بين مراكز الكهرباء والعداد على تحديد بنية القياس المتقدمة (*AMI*) هذه بصرف النظر عن القراءة التلقائية للعداد (*AMR*). نظرًا لأن العدادات التقليدية تعمل من خلال معرفة استهلاك الكهرباء للأسر المعيشية على أساس شهري ، فهناك حاجة إلى المرافق الكهربائية لإيجاد تطورات جديدة لصالح كل من مجهزي خدمات الكهرباء والمستهلكين. في هذه الرسالة ، تمت محاكاة عداد الكهرباء الذكي بواسطة استخدام نظام الهجين المستند الى بروتوكول *Zigbee* ، حيث يستخدم بروتوكول *Zigbee* للتواصل بين العداد الذكي ومركز الكهرباء. في الطريقة المقترحة استخدم نظام اتصال تعاوني مع *TDMA* لتعمل معا في النظام الهجين . يتم قياس نتائج الأداء *Zigbee* باستخدام الوحدات القياسية التي تسمى مقاييس الأداء. تم اختيار العديد من مقاييس الأداء لتقييم الأداء: الإنتاجية ، ومتوسط التأخير ، ونسبة تسليم الحزمة.

يتم تصميم مواقع الويب للسماح للمستخدمين بتسجيل معلوماتهم مثل: رقم العداد والاسم الأول واسم العائلة والبريد الإلكتروني. تتلقى قاعدة البيانات من العقد التي ترتبط بها بواسطة نظام الهجين بعد فصل البيانات التي تخرج من المحاكي. يجب على كل مستخدم نهائي تسجيل الدخول إلى موقع الويب لتسجيل معلوماته. يرسل الموقع الإلكتروني إشعار إلى جميع المستخدمين عن طريق البريد الإلكتروني يخبره عن الاستهلاك.

أظهرت النتائج أن متوسط التأخير يبلغ ٥.٠١ مللي ثانية ، ومتوسط الإنتاجية هو ٤٢.٦٣ كيلو بايت في الثانية ، ونسبة تسليم الحزمة ٩٧.١٩٪. استخدام بروتوكول *Zigbee* مع نظام الاتصالات التعاونية ، من خلال محاكي الشبكات ، لقد نجح في تسهيل قراءة الاستهلاك عن طريق النقل اللاسلكي و تقليل من استهلاك الطاقة للمستخدم. تعد هذه الرسالة قراءه للعداد الذكي باستخدام تقنيه الهجينة وتصميم مواقع الويب لأشعار المستخدمين.

جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة الانبا ر
كلية علوم الحاسبات وتكنولوجيا المعلومات

عداد الكهرباء الذكي بأستخدام نظام مدمج

رسالة مقدمة الى
كلية علوم الحاسبات وتكنلوجيا المعلومات – قسم علوم الحاسبات
- جامعة الانبار وهي جزء من متطلبات نيل درجة الماجستير في علوم
الحاسبات
قدمت من قبل

ضحى شامل مصطفى

بإشراف

ا. م. د. عبد الكريم الالوسي ***ا. م. د. خطاب معجل الهيتي***

٢٠٢٠م **١٤٤١هـ**