

A new approach for smart electric meter based on Zigbee

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Article Info

Article history:

Received Sep 10, 2021

Revised Jan 6, 2022

Accepted Feb 24, 2022

Keywords:

Clustering
Routing protocol
Smart meter
TDMA
Zigbee

ABSTRACT

A smart meter is an electronic device that accurately tracks your energy consumption and transmits that data to your energy provider so that you can be billed. The smart meters allow the central system and the meter to communicate in both directions. This two-way communication feature distinguishes the advanced metering infrastructure (AMI) in this case from automatic meter reading (AMR). This paper employs a hybrid system based on the Zigbee protocol, the Zigbee used to send messages between the smart meter and the utility company. To successfully complete tasks in this scenario, a cooperative communication system utilizing TDMA is used. The outcomes of Zigbee performance are measured using well-known metrics, also known as performance metrics. Many performance indicators have been chosen for performance evaluation: throughput, average end-to-end delivery ratio, and (PDR). The following conclusions were reached: End-to-end latency was 5.01 milliseconds, throughput was 42.63 kbps, and PDR was 97.19 percent. The network simulator successfully reads and wirelessly transmits voltage or power consumption using the Zigbee protocol and a cooperative communication system.

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1. INTRODUCTION

There is a growing interest to upgrade the control systems in today's power grid. The power production, transmission, retail, and the customers build the power supply chain. Electric power utilities made significant investments in additional facilities at times of increasing consumption to avoid blackouts and brownouts [1]. There is a shortage of knowledge sharing between network elements of traditional power grids and customers required to know about combined usage. Power grids are currently facing a redesign to improve reliability and the task of data sharing. One of the methods is the installation of smart meters such that electricity can be preserved as well as rendered more convenient [2].

A smart grid (SG) is an energy system that can be managed and protected by automated reporting and monitoring. Except for inter-grid or intelli-grid for other system applications, this grid will be the most reliant on wireless connectivity networks [3]. The future electric grid system allows users to self-generate electricity across various tiers. Fixed capacity generators will handle peak load demand better than fixed capacity peakers. Many operation centers and substations handle this component. Transmission lines transport electricity generated by various power plants to their distribution architecture. A network of delivery servers distributes electricity to areas, towns, and neighborhoods. Aside from supply-demand models, SG's advancement often aided high-level ICT operations such as calculating, tracking, and metering.

SG acts as a subsystem and is related to calculation systems. This device requires some security and control functions. A distribution system operator of the distribution system may be defined as a distribution management system (DMS) is required by this control mechanism for the reporting, calculation, and measurement functions to conduct the several minor estimations, simplifications, and adjustments. The current and voltage calculations need to be considered by DMS in order to have nominal current and voltage properties that are delivered to the consumer [4].

In order to maximize information sharing between the S&M and the operation centers, new protocols are being developed using dual means including wireless and wireline transmission. In addition to transmission lines, PLC, or sometimes known as “wireline communication,” is also done via the use of wires. It involves using the power lines to act as a communication medium; this will deal with any additional communication channels that may be needed. Even if the process loses old electrical wires, the strategy also lowers system needs and the overall cost of installing an electrical system by sending the transmission channel instead of increasing the overall installation costs [5].

Most of the negative comments about smart meters have not been corrected. electromagnetic hypersensitivity (EHS) is attributed to radiations data servicing, administration, administration, and storage pose a problem. We cannot compromise the security problems faced by mobile phone transmissions in providing energy usage information to the public. Several major factors influence the collection of connectivity networks, reports KPMG. Adding equipment for demodulation, and/monitoring, and some additional memory to support data collection will increase the total cost of implementation by 25%. In Milwaukee, the university researchers performed a study.

To come out the problem mentioned, the research objective is simulation smart meter by using the clustering methods based on the Zigbee protocol and artificial intelligence. One of the advantages of smart meters is that they utilize automated meter reading to detect fraud in power use, as well as provide security. However, du this research paper we will be designing an intelligence meter that can collect data and send it to the center point by new communication way. In addition, three protocols will be used to evaluate the work.

The emergence of smart meters is likely to completely alter how individuals see and handle their energy use. This shows that the government is dealing with excessive energy use via regulation and management. In this paper, it is a smart system for smart meter system introduced. The system is depending on the Zigbee protocol. A contributing to this work is: i) a connection between nodes signifies a customer's account meter; ii) high throughput is provided by the performance hybrid system in smart mete with its packet delivery ratio (PDR). Although it has good routing among nodes, it provides the best values in routing. Data and physical network layers operate together to create a data rate, as the physical and data network layers build a system's high performance; iii) a cooperative system proposed which allows using time division multiple access (TDMA), Zigbee, AI makes from this intelligence system a transformation noticeable in communication; iv) the study helps customers better control their home's energy use by supporting a quick communication system that also allows them to take advantage of savings by using less electricity; v) using less energy, the user will conserve their power and resources, which will help them manage their expenditure; vi) smart meters will digitize the energy sector and will enable suppliers to offer innovative tariffs such as time of use tariffs and far better customer service.

In the rest of this paper, an introduction is included in section 1, section 2 will present the related work of smart meters and their commination ways. Section 3 will include a proposed method with a flowchart for work. Section 4 will present a result that comes out from the simulation. In the end, section 5 will be a conclusion of the work.

2. RELATED WORKS

To look at node deployment in subterranean settings, conducted a simulation study on ZigBee topologies with various numbers of nodes (12, 20, 30, 40, and 50) [6]. PDR, energy consumption, end-to-end delay, packet delivery security, and throughput were some of the metrics utilized for the evaluation of performance. The mesh topology's prioritization in WSNs design was confirmed by the evaluation of the results, which was attributed to PDR, network security, and higher throughput.

Zubairuddin and Thakre [7] presented a simple inexpensive global system for mobile communications (GSM) based automatic energy meter reading system (AEMR). A remote-access approach for the energy provider and consumer was provided by the suggested system. It provided the consumers and suppliers a chance to remotely oversee the energy meters, thus enabling a convenient collection of energy readings. Wilcox *et al.* [8] suggested a new big data analytics architecture that will serve as a fundamental broker-client system. Analytics on smart meters scaled by hadoop (SMASH) was the name of the platform that was run. Work experiences have confirmed the SMASH's ability to run the query, data storage, visualization, and analysis tasks on huge sets of data at a scale of 20 TB.

An experimental study of ZigBee and DigiMesh network designs, two popular and widespread network models, was put forward [9]. Round trip time, throughput, mesh routing recovery time, and received signal strength indication are the performance metrics utilized. DigiMesh was shown by the experiments to have relatively greater throughput than Zigbee networks. Nevertheless, Zigbee networks are still the best with more Received Signal Strength Indication, quicker failure node recovery, and shorter round trip time. Thus, for systems that prioritize rapid information flow, DigiMesh is the better option, whereas, for scenarios in which a low-latency connection is needed, Zigbee performs better. A taxonomy on distinct security protocols targeted at SG environment was built by [10]. This taxonomy made the inclusion of trust computing, authentication, key management, intrusion detection systems, and privacy preservation.

Advanced metering infrastructure (AMI) was analyzed by [11] from the security perspective; possible weaknesses linked with distinct attack surfaces in the smart meter were discussed. Threat implications and security were also given consideration. Finally, better countermeasures and security controls were recommended by them. Ayub *et al.* [12] proposed an electric load forecasting model, which consists of a two-stage process; feature engineering and classification. Feature engineering is made up of feature selection and extraction. A hybrid feature selector was proposed to help minimize feature duplication through a mix of extreme gradient boosting and decision tree (DT) methods (XGBoost). Additionally, the use of recursive feature elimination (RFE) has contributed to increasing feature selection as well as dimension reduction. They used the support vector machine (SVM) system with three primary categories (a penalty fee, incentive loss function, and kernel parameter) to better understand the strength of the load. A 98% load forecasting accuracy is achieved via simulation results.

Wang *et al.* [13] 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. Following data measurement and the smart electricity meter's internal structure, a MATLAB/Simulink model of the meter was developed 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 was run in ANSYS Icepak. Subsequently, the component temperature of the metering circuit is assessed following simulation data in accordance with the approximation model developed by the radial basis function (RBF) neural network. Finally, metering accuracy was 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 had tremendously improved the metering accuracy among the full temperature range.

The wireless sensor home area network (WSHAN) was developed and run by Burunkaya and Pars [14] with Zigbee interfaced smart meter. 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 is able to record usage of energy, display time of use (TOU) values, and log data in real-time. The system is also able to regulate any device that is linked to power outputs. The AC signal's zero-cross is sensed to measure phase shift while powering off and on. The correct power usage is provided by the smart meter, which then relays the data with Zigbee towards the personal computer (PC). The user has the ability to monitor power data and run remote system navigation.

Preethi and Harish [15] presented a smart energy meter for an automatic metering and billing system. Within this meter, any energy that is utilized and its corresponding amount will be continuously shown on the LCD and relayed to the control base station. Regulation of power theft is possible as user feedback in terms of identifying usage between unauthorized and authorized users is possible. Zigbee allows communication between households/users 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 post-paid or prepaid meter.

A newly-developed method for authentication, suggested by [16] delivers security and speed compared to certain existing systems. Lastly but most significantly, our suggested scheme's security has received validation via the recognized ProVerif tool and the cryptographic elements have been carried out on appropriate hardware for smart meters. Results suggest that the suggested scheme is well suited for real-world applications.

3. PROPOSED SYSTEM AND COMPONENT

In developing the proposed system for high performance in sending and receiving data with reliable communication (or routing), the following two (2) steps must be performed in a sequential manner: i) the first step is to analyze, design, and establish a model of the high-performance link between any two communicating nodes MANET, once a stable link is established, and then a message can be transmitted reliably between them; ii) the second step is to develop an intelligence system for the ability to have quick

reliable and efficient data rate dissemination, i.e. routing, along a complete route/path in an area connecting any two end nodes, which ultimately allows systems to be implemented successfully with acceptable service quality.

Figure 1 depicts a typical scenario failure of nodes in communication where they are moving in the direction of each other, thus the chance of communication is available for only a short duration, and this chance must be optimized considering various constraints of the network resources. At this link-level communication, a strong and quick link must be first established by a hybrid technology to create a system that is able to establish a connection between any two communicating nodes with a high data rate, throughput, and a small end-to-end delay. This is a design need to combine more than one technique. In this research, a hybrid method is suggested to use inside the meters to become a smart meter. A Zigbee with clustering is proposed in order to achieve wireless communication between nodes. An AODV is used to the reliable routing protocol to efficiently deliver the message. The intelligent system needs to combine more than one layer 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.

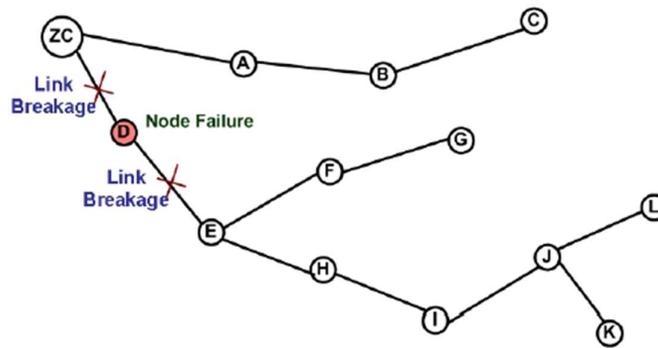


Figure 1. Communication between nodes and node failure

In this study, the usage of TDMA with Zigbee is suggested to discuss. The restricted capacity channels are used to send the varied transmissions. Assuming a fading channel with a link SNR equal to $\gamma_{ij}=g_{ij}$ SNR between nodes i and j , we calculate the following: The channel gain is indicated by the variable g_{ij} . A slot has a constant channel gain for T_s , its length. We have a distinct SNR for each time slot. The transmit time is equal to the slot length, and it applies to each transmitter. Next in line to broadcast is the person after the present transmission. That's why time slots are now assigned to the channel to accommodate each guest as shown in Figure 2.

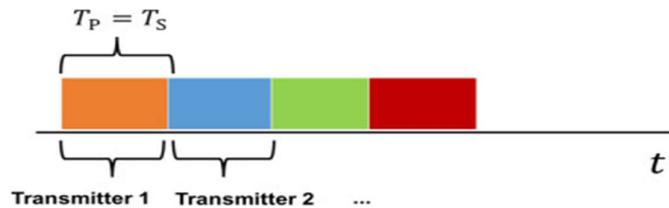


Figure 2. TDMA transmission

The transmitter may access the bandwidth B in each slot. the max possible transmission rate in this slot is defined in (1):

$$R_{i j}(k) = B \cdot \log_2(1 + SNR \cdot |g_{i j}(k)|^2) \text{ bit/s} \tag{1}$$

A Zigbee protocol is proposed to communicate between nodes in areas that include meters. However, Zigbee is a low-powered communication protocol that operates based on a standard of IEEE

802.15.4 [17]. The data rate on this device is 20–250 Kbps, and it reaches up to 100 m [18]. The device uses frequencies of 868 MHz, 915 MHz, and 2.4 GHz [19]. Zigbee's best feature is its power efficiency (up to 100 mW). It is estimated that two batteries may be used up for up to two years, based on that fact [18]. In order to create a network, it used a self-organization method [20]. Advanced encryption standard (AES-128 bit) was used for powerful security by ZigBee [18]. In non-beacon mode and beacon mode, two-way data transmission is used. Since it is in beacon mode, the router and coordinator will constantly monitor incoming data and thus they will consume more power. This is because routers and coordinators do not sleep when in this mode; if any node becomes active, it may immediately interact as shown in Figure 3 [21].

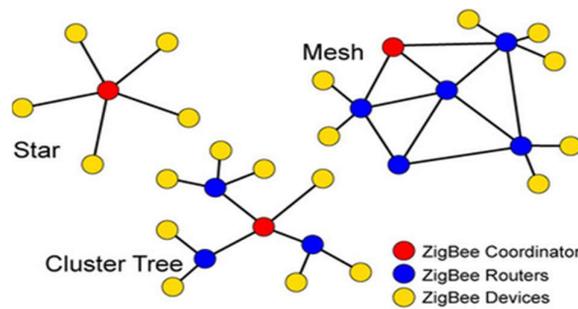


Figure 3. Zigbee topologies [22]

The design of an intelligent system needs the best routing protocols that are able to have a high performance of throughput, PDR, and E2E delay. As proposed in this research, a hybrid system are depended on Zigbee for wireless with a TDMA for share frequency, then a final system will have a reliable and fast communication by recording a high data rate, this point gives a system strong connection because the hybrid system combines between two layers of TCP/IP models. The intelligent system needs one more step to become perfect as possible. This step is a routing protocol, so for this design, a reactive routing protocol is used in our design.

3.1. Cooperative communication for intelligence system proposed

The system proposed is dependent on the companied of data link layer that has TDMA assess method, IEEE 802.15.4 and network layer that have Zigbee and AODV routing protocol. The expanding field of study focusing on cooperative communication will be an essential instrument for more effective use of the spectrum in the future. Sharing resources across network nodes is at the heart of the user-cooperation approach. We can save network resources if users are willing to share their computational power and network access. This readiness may be achieved by investigating the collaboration of network participants. A lot of areas is available to utilize collaboration software on mesh networks [23].

One way of improving communication between parties in a network is to let each terminal in the network be a possible source of information. This kind of information sharing is possible due to the broadcast nature of wireless communications. This may be useful for making networks more connected, improving communication's dependability, and increasing the power and spectrum efficiency. An additional advantage is the ability to do cooperative communication with respect to hardware and deployment requirements. This means that the technique is viable because of the advantages provided by this kind of communication (MIMO). Co-operative communication is certain to thrive as a viable communication strategy due to its gratifying advantages [24]. The physical layer has traditionally been only for transferring information from one node to another. The channel is not just one connection but the network itself; this is a paradigm shift that occurs when the user participates in the exchange [23].

3.2. Flowchart of steps applied in this work

In this research, the flowchart below is describing the workflow of our work in detail Figure 4. The work is focused on choosing the best routing protocol with the Zigbee protocol. The simulation parameters play an important issue in preference for better protocols.

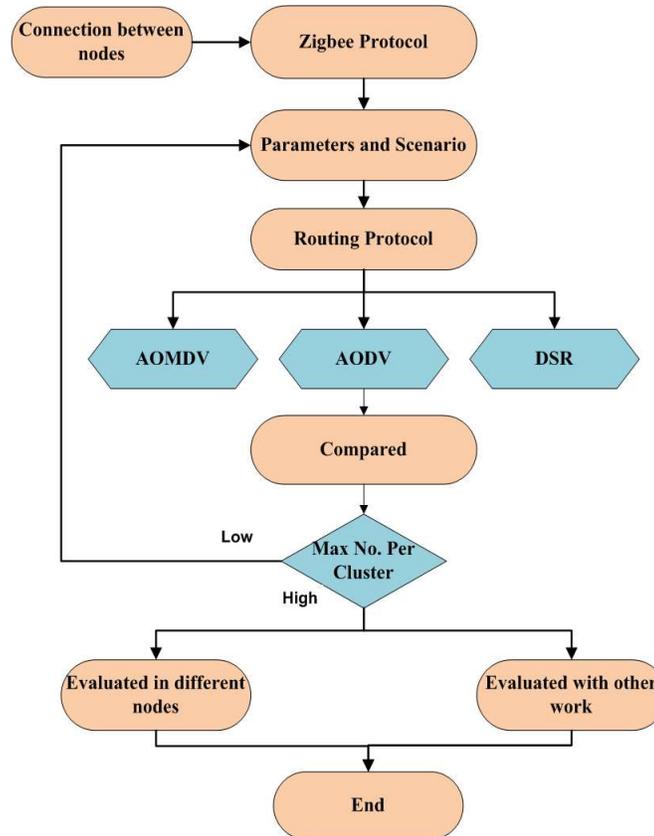


Figure 4. Steps by steps describe the workflow

4. RESULTS

A simulation of their modulation methods via NS-2 was run. The selection of this method was based on the fact that the simulation is specifically useful in system design at times when real-life hardware is unavailable for measurement, and in scenarios requiring reasonable accuracy. Information is being exchanged among the meters by using Zigbee technology as a network backbone. Hence, data has arrived the server node is being shared over the internet on the specific portal where owners can access the same and get the readings. We developed the Zigbee part as well as the meters portal. That portal is made using a local web server which dispenses the use of embedded devices due to resource shortage.

In the design's details, the intelligence system was used for data transfer while the smart meter nodes were synchronized through that data transmission. The design has design elements that keep low-power and low-cost issues in mind. The asynchronous measurement scheduling technique was developed to use less network bandwidth since this would need less power because fewer network connections would be required for synchronization. The hybrid system uses Zigbee with MAC 802.15.4, cooperative communication, and TDMA to do cooperative communication and access methods. Where 10 to 60 nodes were used, two of them representing the electricity centers and the rest representing the meters. The simulation time was the 50s, transport protocol was UDP, routing protocol was AODV, the time interval between packets was 0.01 and energy was 100.

4.1. Performance analysis

Standard units called performance metrics are used to measure the outcomes of simulations. Performance was evaluated by choosing performance metrics: Throughput, Average End-to-End 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 comparison for evaluating the performance are shown in Table 1. The compaction between protocols with a system proposed is come out after simulation; the three Figures 5 to 7 are showing the results for throughput, PDR, and E2E delay. Figure 5 is showing the throughput of the intelligence system based on AODV with DSR and AOMDV protocols.

Figure 5 shows the throughput after comparing a system based on AODV, DSR, and AOMDV. The run was evaluated in different numbers of nodes from 10 to 60 nodes. The results show the DSR is better than

others in throughput in many nodes from 10 to 40 nodes, but the proposed system is better than DSR in numbers of nodes 50 and 60. That means the system proposed which is dependent on many layers works together for the Zigbee protocol make routing in a high number of nodes with AODV protocol better than others when evaluate. On the other ways, the throughput is the record-high value when the number of nodes increases.

Table 1. Simulation parameters for compaction 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
Time interval	0.01
Bandwidth of links	2M
MAC layer type	IEEE 802.15.4
Routing protocols	AODV, DSR, AOMDV

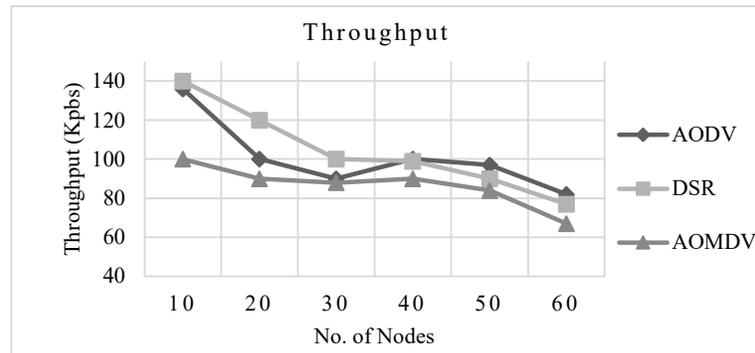


Figure 5. Throughput of the proposed system based on AODV with DSR and AOMDV

The result in Figure 6 shows the proposed system based on AODV protocols is superior in all terms of the test. It's the best in different numbers of nodes that are proposed to test the protocols with the system (Zigbee). The PDR was more than 98, it can work in a different number of nodes with high PDR. The results that come out from the run simulation was present in Figure 7. The E2E delay shows the DSR protocol is the best in all tests, and the hybrid system is recording values from 29 to 34 (ms) in different numbers of nodes. This is due to the weakness of AODV which is used in the system.

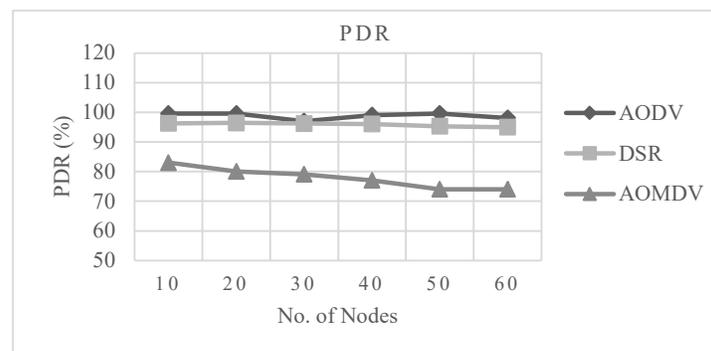


Figure 6. PDR of the hybrid system, DSR, and AOMDV

Due to the results and performance of the hybrid system, DSR, and AOMDV in three performance matrixes; throughput, PDR, and E2E delay, the hybrid system provided better performance in terms of PDR and throughput. The Zigbee with AODV routing protocol and cooperative communication is given results in terms of PDR, throughput, and E2E delay that can use it in smart meters to connect nodes for high performance. On the other hand, the Zigbee with AODV protocol and cooperative system TDMA are proposed in the simulation scenario for testing a smart meter with 58 nodes. This node (58) will be a number

of clusters, each 58 nodes will combine together to send the data once. This way is achieved a new communication. The performance of Zigbee protocols of 58 nodes is shown in Table 2.

Table 2 shows the average end-to-end delay, the average throughput, and PDR. At the same time same Table 2 also shows the compared our result with result that published by [25] in terms of PDR, E2E delay, and throughput then still our results the best, where [25] compared the PDR, E2E delay, and throughput for the conventional and the improved (i.e., intelligent) systems based on Zigbee in the SG.

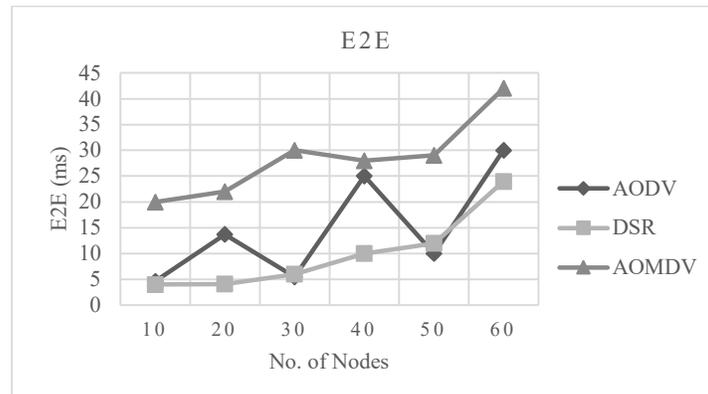


Figure 7. End-to-end delay for a proposed system based on AODV with DSR and AOMDV

Table 2. Results of performance metrics for a proposed system in the case of 58 nodes

No	Performance metrics	Value	Other work
1	End to end delay	5.01 (ms)	9 (ms)
2	Throughput	42.63 (kbps)	23 (kbps)
3	PDR	97.19%	55 %

5. CONCLUSION

The study looked at the SG. A short explanation of SG is included in this study, including details on the wireless communication technologies, smart measurement, and metering. A broad perspective and basic background information are included, with an extensive look at past publications on the subject. Smart metering solutions have advanced the importance of measurement and provide a variety of smart measurement methods that provide measurements in addition to networks. A smart meter, using Zigbee technology, implemented an intelligent system as a connection network via using the software known as NS-2, an established leader in the field. An assessment method based on throughput, average end-to-end latency, and PDR is being designed.

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