Efficient Data Delivery Model for Wireless Sensor Network

Akanksha Gupta
Assistant Professor, Department of Information Technology, Guru Ghasidas Vishwavidyalaya (Central University), Bilaspur, akanksha.me2011@gmail.com

Santosh Soni
Assistant Professor, Department of Information Technology, Guru Ghasidas Vishwavidyalaya (Central University), Bilaspur, santoshsoni.77@gmail.com

Pankaj Chandra
Assistant Professor, Department of Information Technology, Guru Ghasidas Vishwavidyalaya (Central University), Bilaspur, pankaj2684@gmail.com

Abstract

Wireless Sensor Networks (WSNs) and Internet of Things (IoT), both are often made up of a broad range of devices like sensor nodes, routers, microcontroller, GPS and communication devices etc. some of are configured by their resources (such as energy, storage and processing) and some of are subject to extremely varied demands so that the data collection is becoming the key application area of the present time. In harsh and emergency situations such as floods, fires, or earthquakes where human participation in monitoring and collecting environmental data is too risky so the wireless sensor networks are typically deployed. Wireless Sensor Networks (WSNs) offer advantages like real-time data collection, low cost, easy deployment, and robustness in harsh environments. For these scenarios, we need to have certain devices which consume low energy to enhance network life time along with data collection models that can provide improvement in all parameters/aspects of WSN. Presently, there are various types of data delivery models, some of are Query-Driven Model, Time-Driven/Periodic Model, Hybrid Model and Event-Driven Model.

In this research paper, we are proposing a new data delivery model (PDDM). This Proposed Data Delivery Model (PDDM) is evaluated with different parameters like throughput, PDR and End to End Delay by using real time implementation of WSN kit. Our proposed model has shown that Periodic model has 50.24% improvement in Throughput, 89.9% improvement in PDR when compared to Event-Driven data delivery model. Event-Driven model showed 74.67% improvement in End-to-End delay when compared to Periodic data delivery model.

Keywords: *WSN, Zigbee Technology, Data Delivery Models, Network Life Time.*

1. INTRODUCTION

In WSNs, there are many different data delivery models, including data aggregation, unicast, and broadcast communication, as well as multi-hop and single-hop communication. Data is used to send directly from a sensor node to sink node in single-hop communication. Data is transferred from a sensor node to sink node via intermediary nodes during multi-hop communication. Broadcasting is point-to-multipoint communication, whereas unicasting is point-to-point communication. Before transmission to sink node, data used to gathered

and compressed at intermediate nodes as part of data aggregation. The choice of data delivery type is dependent upon the particular requirements of the application. These approaches have trade-offs in terms of energy usage, dependability, and scalability.

WSNs are considered as major producers of rich data in large quantities. Data-driven models are categories in order to acquire real-time application of particular data. There are four different types of data models available for different applications. They are Query Driven, Periodic/Time Driven, Event-Driven and Hybrid Model.

The process of collecting data is full of challenges. Thus, the main aim of all these data driven models is to conserve operational and processing energy in WSN during data collection for any application. Brief discussion and comparison on data delivery model is as follows-

1.1 - Query-Driven Model: Sensor Nodes continuously sense the environment in this data delivery model, and they store the data in local buffers. The query-driven model begins the procedure by generating queries to obtain data from sensors in accordance with user requirements. The produced query is subsequently sent to the sensor nodes of the WSNs after being generated by the user. The query is allowed if the data coming from the sensor node matches it; if not, it will be refused and discarded. [16]

Advantage and disadvantage: The Query-Based Model enhances network dependability, lowers the amount of data delivered, and sensor node energy consumption when compared to other data delivery models.

Due to the destination having to wait for the sensor nodes to reply, the Query-Based Model is also vulnerable to rising latency.

The network may become more sophisticated as a result of the sensor node's requirement to be able to respond to requests, store data, and transfer data.

The query-based Data Delivery Model is a helpful data delivery model when selective data transfer is required.

1.2 - Event-Driven Model: The Sensor nodes are usually in sensing mode in the event-driven model in this model also. Sensors typically sense data in response to an event, sending the data to the sink node at that precise moment; otherwise, data are sensed continually. [16]

Advantage and disadvantage: Due to the requirement that sensor nodes have the ability to detect events, store data, and transmit data, event-driven models have more complexity.

Event-Driven model may also have increased latency, because the destination may not receive the data immediately after the event occurs.

Event-Driven Data Delivery Model has a number of advantages, including a reduction in the amount of data delivered, a decrease in the energy consumption of the sensor node, and improvement in network reliability.

When selective data transmission is needed in response to particular occurrences, the event-driven data delivery model can be helpful.

1.3 - Time-Driven Model/Periodic Model: In a Periodic model, sensors are continually sensing the data. Every sensor nodes receive a timer from the sink node so they can sense the data. Sensor nodes divide their particular time into slots and then further into periods. When a certain amount of time has passed, the sensor

node delivers the data to the sink; otherwise, they continue to collect data constantly. [16]

Advantage and disadvantage: Since nodes continuously transfer data to sink nodes even when no change is visible, energy consumption is high.

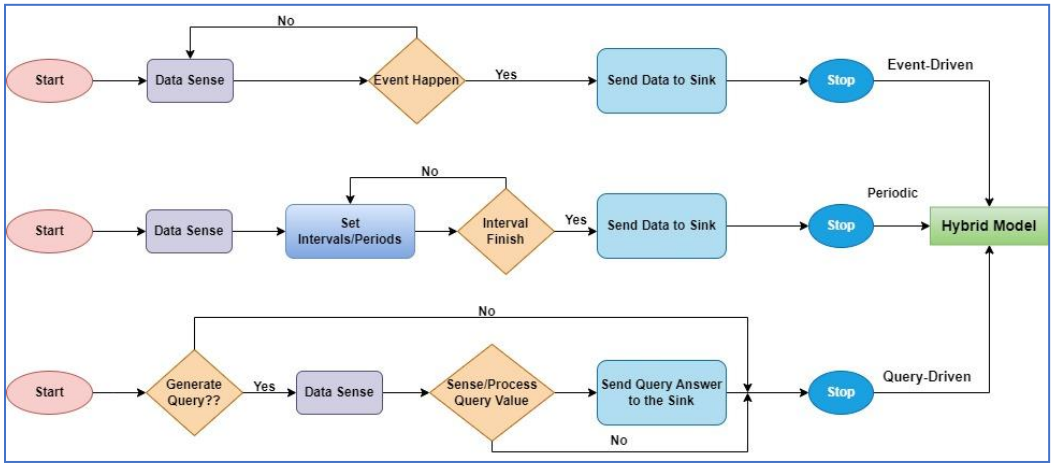
Network Congestion- As sensor nodes transmit data simultaneously, there may also be network congestion due to collisions and retransmissions.

The model may also increase the amount of data delivered because it sends data even if the destination is not interested in it.

The periodic data delivery model is a useful model when WSNs need a steady stream of data and data generation rates are modest.

1.4 - Hybrid Model: Finally, any two models are combined to create the hybrid model. Consider a scenario in which Event-driven and Periodic model are combined for creating a hybrid model. This hybrid model typically processes in relation to the Periodic model to sense and communicate the data on a regular basis. This hybrid model converts from a Periodic model to an event-driven model whenever any event takes place for processing in the WSNs. [16]

Fig.1 All Data Delivery Models



1.5 - Comparison of Different Data Models

In this research paper Periodic and Event-Driven model has been compared with our new Proposed data delivery models for various parameters like Energy Consumption, throughput etc.

Table1. Comparison of Periodic Model and Event-Driven Data Delivery Models

Model/Parameter	Energy Consumption	Throughput	Latency	Packet Loss	Network Lifetime
Periodic	High	High	High	High	Short
Event-Driven	Low	Low	Low	Very Low	Longer

For evaluation of Performance of different models we proposed a new data delivery models (PDDM) through Zigbee sensor kits.

WSNs, or wireless sensor networks, are utilized extensively in a variety of industries, including agriculture, medicine, the military, and others. Zigbee and other similar technologies are

mostly employed for environmental and physical conditions monitoring, including temperature pressure and sound. In WSN fields, there are technologies such as Z-Wave, Wi-Fi, Radio frequency (RF), ZigBee, Bluetooth, and so on. Furthermore, out of these technologies which offers outstanding futures to provide long distances of transmissions as well as more energy-saving when compared to other technologies is "Zigbee" technology, and this had become the first high-quality to use and as a result the most usable technology in WSNs. [13]

The promise and benefits of WSNs in terms of economics, efficiency and data sending speed make them one of the highly researched and advanced topics in the technology areas.

Following are the Contributions of the proposed Models:

1. Sensors are placed in different environment conditions (temperature)

2. Sensors are set to send temperature/data in every 1000miliseconds.

3. Proposed Data Delivery Model (PDDM) for collecting data.

4. An evaluation of received data and Proposed Model (PDDM).

The upcoming sections of the paper are organized as follows. An overview of recently published work for data delivery model and Zigbee Technology is provided in Section 2. In section 3 the problem formulation and the proposed data model are presented. In Section 4 we describe the methodology. Section 5 presents findings of Periodic Data Delivery Model. Finally, Section 6 concludes this study.

2. Previous Work

In this research paper, we begun by reviewing the different research papers that explained the significance of Zigbee technology in different field in WSN and further, papers related to Data Delivery Model. Some of the below stated points are the factors that motivated us to start this research.

1. The findings of Alaoui et.al [1] indicated that ZigBee IP may be the best suitable protocol for connecting numerous nodes with quick communication and little power consumption. [1]

2. Pereira et.al [14] showed that when there is inadequate infrastructure present, ZigBee stands out as a viable alternative.

3. Haque et.al [8] stated that Networking factors include transmission lengths, deployment environment, hopping, data encryption, transmission power, and baud rates all affect how well Zigbee performs. Author also stated that Zigbee is an indoor and outdoor application-neutral short-range wireless communication standard.

5. Alshuhail et.al [2] demonstrated that a system that can be utilised to transmit voice data is called Zigbee-Based Low Power Consumption Wearables Device.

6. Liu et.al [12] discovered that the study used Zigbee technology as its foundation, detailed its technical benefits and drawbacks, and discussed its drawbacks.

7. R Hamdy et.al [15] stated that due to its distinct advantages over other wireless networks, ZigBee is a frequently utilised wireless sensor networks (WSNs) in Internet of Things (IoT) applications for remotely automation and sensing. The network has four levels, as defined by the IEEE 802.15.4 ZigBee

classification. The ZigBee topology is represented in second layer.

8. Islam et.al stated that "ZigBee is a communication standard that gurantee low power, reliable and cost-effective data transfer, but it covers a short range of communication".

9. Hasan et.al [11] explained that a network that connects as well as collaborates is known as a wireless sensor network (WSN). Sensors are placed in various environment conditions to collect the best data. "Built on ad-libbed system architectures, WSNs are made up of distant nodes that hold a lot of promise for a variety of organizations". [9]

10. In WSN and IoT, data collection is core application. Networks, which are often made up of a wide range of devices, some of which are limited by the resources (such as energy, processing, and storage), and some of which are confined by extremely varied demands. There are number of challenges span all the conceptual communication layers, from the Physical to the Application. Numerous original solutions developed in the past that do not scale well with the exponential development in the population of the devices and must be changed, altered, or replaced with new innovative methods in order to keep up with this enormous expansion stated by Gurewitz et.al. [7]

11. Sahar et.al [16] explained that four categories of data-driven models— event - driven, query-driven, time-driven (Periodic), and hybrid-driven—correspond to different applications in WSNs.

12. Liu et.al [9] concludes that there are numerous problems and WSNs' IoT-related restrictions.

13. In gathering data for WSN and IoT networks, Gurewitz et.al [7] discovered that there are numerous problems that cut across all conceptual communication layers, from the Physical to the Application.

14. According to the author, the suggested routing technique for WSNs in smart buildings is secure and uses little energy.[17]

15. Engmann, F. et.al [6] concluded that since energy conservation affects the lifespan of wireless sensor networks, it is important in their design. "Reducing the frequency of transmission is one way of reducing the cost, but it must not tamper with the reliability of the data received at the sink". In order to change the prediction approach employed in this paper's work to reduce data transmission, data-driven and duty cycling approaches have been combined.

16. Ichsan et.al [10] explained that in a large number of nodes, a wireless Sensor Network (WSNs) environment is made up of nodes that sense the environment and relay data to other nodes. Continuous or periodic data gathering is one of the WSN ideas, and the data collected can then be analyzed further.

Due to the potential for producing massive amounts of data from this process, transferring and storing data requires a lot of work. The wide variation in data collected from WSN nodes has an impact on data transmission and storing. Hence, research is required to evaluate WSN's capacity for transmitting and storing massive volumes of data. MQTT is utilised because it may reduce communication resource usage, and MongoDB is utilised because it does not have the concept of tables and rows, which is ideal for the variety of data produced by WSN.

17. El-Sayed et.al [5] suggested that the behavior of WSN is typically impacted by missing information, inaccurate measurements, or noisy values produced by the dissemination

mode. A "Distributed Data Predictive Model" (DDPM) was suggested in this article as a way to increase network lifetime by reducing the energy consumption of sensor nodes. Its foundation was a distributive clustering model for foretelling WSN dispersion errors. The proposed model was created using a "Finite Impulse Response" (FIR) adaptive filter integrated with a "Recursive Least Squares" (RLS) adaptive filter, with the goal of reducing the actual size of transferred data to provide energy efficient performance by removing unusable noise and reflections that accompanied the transferred signals among the sensors.

18. Author said that [18] an essential challenge in data collecting for large-scale and lossy Wireless Sensor Networks(WSNs) is to increase energy economy for a enhanced network lifetime while achieving the adaptive performance requirements under the assurances of transit reliability and latency(WSN). Although many earlier research were committed to reducing network delay, energy consumption, or reliability, they mostly focused on one of the WSN's performance criteria. In order to increase energy economy and decrease delay while maintaining reliability for the lossy WSN, a hybrid transmission system incorporating packet reproduction (PR) and hop-by-hop automatic repeat-request (HBH ARQ) and techniques is proposed in this study.

19. Soni, S et.al [19] proposed "a learning algorithm that selects certain WSN nodes based upon their link quality and higher residual energy to create safe path (green corridor) for emergency situation."

20. Soni, S et.al [20] suggested two new reinforcement learning-based methods to address the hot spot problem in wireless sensor networks.

21. Soni, S et.al [21] proposed "two wireless chargers (fixed and mobile) for sensor nodes. The main difference between fixed and mobile wireless charger is: fixed wireless charger invites mobile sensor nodes for wireless charging at base station whereas mobile wireless charger travels to the position of mobile sensor nodes for wireless charging."

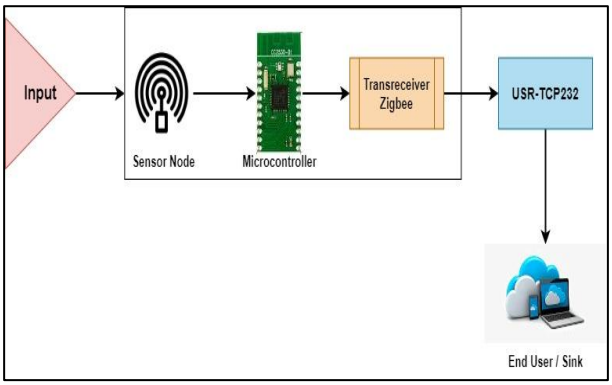
3. DATA MODEL

WSN is a network of tiny and low-power, resource-constrained autonomous devices, which consist of sensors, microcontrollers and wireless communication capabilities. The purpose of this SN is to gather process & transmit data about physical and environmental conditions.

The data delivery model determines how the data is transmitted from the sensor nodes to the sink node, which is responsible for collecting and processing the data.

For efficient data delivery and to minimize energy consumption as well as to enhance Network life time we have proposed our simple data model.

Fig 2. Proposed Data Delivery Model (PDDM)



The central element of a Wireless Sensor Network (WSN) is the wireless sensor nodes. Sensing, processing, and communication are all carried out by nodes. The data-processing techniques and communication protocols are stored and used by these nodes. The node's physical resources have an impact on the type, frequency and quantity of sensed data that can be collected from the sensor network. As a result, creating a wireless sensor node is an important first step. [4]

3.1. The sensing subsystem

One or more than one physical sensors are integrated into the sensing subsystem, which also offers one or more than one analog to digital converters and a multiplexing method to share them. The sensors connect the physical world to the virtual one. [4]

3.1.1 Analog to Digital Converter

A continuous analog signal from a sensor's output is transformed into a digital signal via an analog to digital converter (ADC). This process requires two steps:

1. Firstly the analog signal needs to be quantized (i.e., converted from a continuous signal into a discrete signal; discrete both in magnitude and time).

2. The sampling frequency.

3.1.2 The Processor Subsystem

All other subsystems, along with some more peripherals, are brought together by the processor subsystem. Its primary function is to carry out commands related to self-organization, sensing and communication. It includes a an internal clock ,CPU chip, a nonvolatile memory (often an internal flash memory) for storing programme instructions, and an active memory for temporarily storage of sensory data and other components. [4]

We use temperature sensor for collecting and analyzing the performance for different sensors in periodic manner. These devices sense the temperature from surrounding environment and then send it to the base station in fixed interval. Here are the snap-shot of data collections through new proposed model at some instance-

Fig. 3 Data Collection Through new Proposed Model

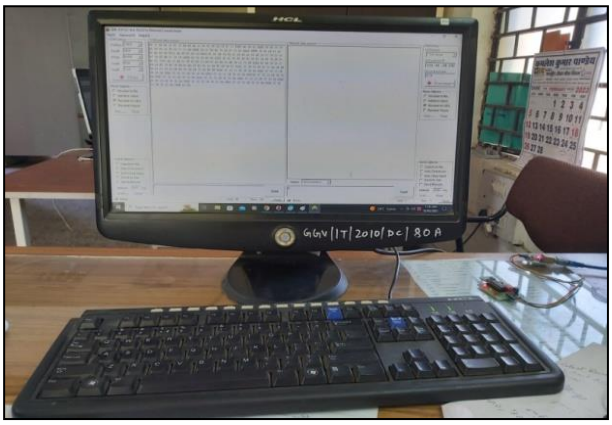
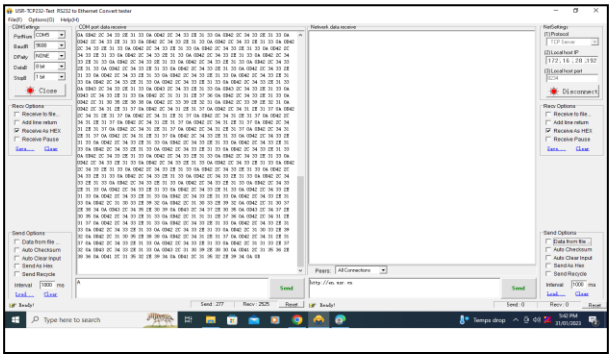


Fig.4 Screen Shot of Data Collection for Periodic Model



4. Methodology

We have used 3 Sensor kits (Zigbee Transreceiver) in different environmental condition and evaluated different parameters. We use 9V HLW batteries for transreceivers. We use BoudRate as 9600 and USR-TCP232-Test RS232 to Ethernet Converter tester.

Compared to competing standards, ZigBee technology has several benefits. It offers

excellent security for its users, is easy to install, has a high capacity for energy conservation in the battery, supports a large number of network nodes, has the ability to expand networks, and does not provide us with many opportunities to connect with wires.

Technologies including Z-Wave, Radio Frequency (RF), Wi-Fi, ZigBee, Bluetooth and others are used in WSN domains. Zigbee technology, which has been the first high-quality to use and as a result the mostly used in WSNs, is another technology that provides more exceptional possibilities to give more energy saving and great distances of transmissions compared to other technologies. [13].We have collected the data through our new proposed model (PDDM) for both the model (Periodic and Event-Driven Model)

Fig. 5 Zigbee Devices (Sensor Kits) with 9V battery

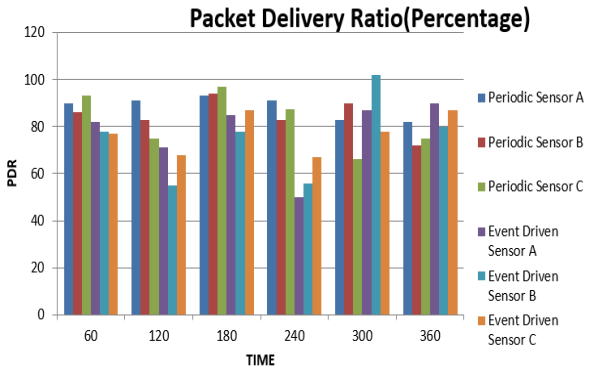
5. Results

We have used following Performance metrics to evaluate the performance of Periodic Model through New Proposed Data Delivery Model.

5.1Packet Delivery Ratio (PDR): PDR can be calculated by ratio of the number of packets successfully received to the Total number of packets Transmitted [3]. Formula for PDR calculation is as follows-

$$\text{Packet Delivery Ratio(PDR)} = \frac{\text{Numberof Pkts Received}}{\text{Total Number of Pkts Transmitted}}$$

Fig. 6 Comparison of PDR for Periodic Data Delivery Model and Event-Driven Model

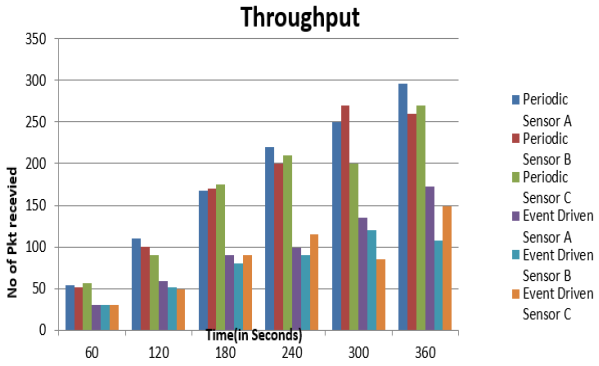


5.2Throughput: Throughput can be calculated by the No. of packets received per unit time.

Formula for Throughput calculation formula is as follows-

$$\text{Throughput} = \frac{\text{No. of Packets Received}}{\text{Per Unit Time}}$$

Fig. 7 Comparison of Throughput for Periodic Data Delivery Model and Event-Driven Model



5.3End-to-End Delay: End-to-end delay can be calculated by difference of time delay for transmit data packet from the source node to destination node. [3] Formula for End-to-end calculation is as follows-

End-to-End Delay =Receiving Time of Pkt-Sending Time of Pkt

Fig. 8 Comparison of End-to-End Delay for Periodic Data Delivery Model and Event-Driven Model

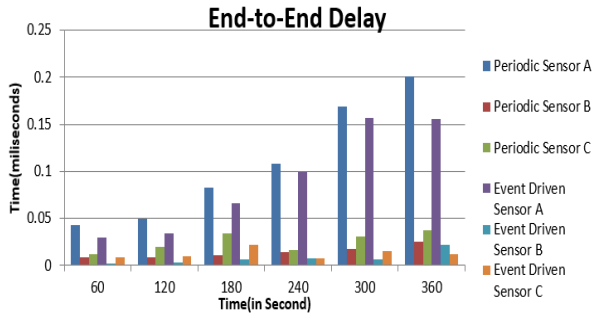
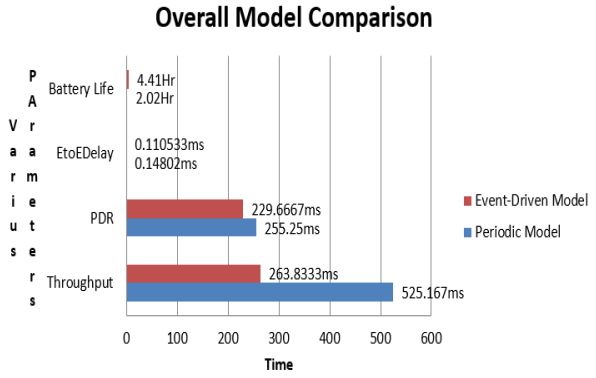


Fig. 9 Overall Comparison of Periodic and Event-Driven data delivery Model



6. Conclusion

To compare different data delivery models like Periodic, Event-Driven we use our proposed PDDM with 3 sensor kit (Zigbee transreceiver) and shown the comparison table in earlier section. We have evaluated the Periodic data delivery model and Event-Driven data Delivery model in different parameters like End-to-End Delay, PDR and Throughput and shown the results. As per the other paper and our work we can say that Periodic data delivery model with our PDDM provides very good results with respect to metric of Throughput and PDR where as prolonged network life time and improved End-to-End delay in Event-Driven Model. So we can conclude that Periodic data delivery model is very helpful in different scenario especially in medical fields to continue monitoring of patient's health condition as well as many other areas like military and environmental conditions, because this model provides continuous data in fixed time interval that can be analyze as per requirement, where as Event-Driven model can be useful in Intrusion Detection, Traffic management and Industrial Automation.

REFERENCES

[1] Alaoui, I., Azyat, A., Raissouni, N., Achhab, N. B., Chahboun, A., & Lahraoua, M. (2019). Comparative study of ZigBee and 6LowPAN protocols: review. In Third Internacional Conference on Computing and Wireless Communication Systems.

[2] AlShuhail, A. S., Bhatia, S., Kumar, A., & Bhushan, B. (2022). Zigbee-Based Low Power Consumption Wearables Device for Voice Data Transmission. Sustainability, 14(17), 10847.

[3] Chandra, P., & Soni. (2020). [Performance Variations of AODV, DSDV and DSR Protocols in MANET under CBR traffic using NS-2.35. IJCSNS.

[4] Dargie, W., & Poellabauer, C. (2010). Fundamentals of wireless sensor networks: theory and practice. John Wiley & Sons.

[5] El-Sayed, W. M., El-Bakry, H. M., & El-Sayed, S. M. (2023). Integrated data reduction model in wireless sensor networks. Applied Computing and Informatics, 19(1/2), 41-63.

[6] Engmann, F., Katsriku, F. A., Abdulai, J. D., & Adu-Manu, K. S. (2020). Reducing the energy budget in WSN using time series models. Wireless Communications and Mobile Computing, 2020.

[7] Gurewitz, O., Shifrin, M., & Dvir, E.

(2022). Data Gathering Techniques in WSN: A Cross-Layer View. Sensors, 22(7), 2650.

[8] Haque, K. F., Abdelgawad, A., & Yelamarthi, K. (2022). Comprehensive performance analysis of zigbee communication: an experimental approach with XBee S2C module. Sensors, 22(9), 3245.

[9] Hasan, M. Z., & Mohd Hanapi, Z. (2023). Efficient and Secured Mechanisms for Data Link in IoT WSNs: A Literature Review. Electronics, 12(2), 458.

[10] Ichsan, M. H. H., Hanggara, B. T., & Primananda, R. (2021). Data delivery performance on MongoDB generated by WSN over high data load. TELKOMNIKA (Telecommunication Computing Electronics and Control), 19(4), 1169-1176.

[11] Islam, M., Nooruddin, S., Karray, F., & Muhammad, G. (2022). Internet of things device capabilities, architectures, protocols, and smart applications in healthcare domain: a review. arXiv preprint arXiv:2204.05921.

[12] Liu, Z., Wang, Y., Zeng, Q., Yang, Y., & Dai, Z. (2021). Research on optimization measures of Zigbee network connection in an imitated mine fading channel. Electronics, 10(2), 171.

[13] Nguyen, C. V., Coboi, A. E., Bach, N. V., Dang, A. T., Le, T. T., Nguyen, H. P., & Nguyen, M. T. (2021). ZigBee based data collection in wireless sensor networks. Int J Inf & Commun Technol ISSN, 2252(8776), 213.

[14] Pereira, D. S., De Morais, M. R., Nascimento, L. B., Alsina, P. J., Santos, V. G., Fernandes, D. H., & Silva, M. R. (2020). Zigbee protocol-based communication network for multi-unmanned aerial vehicle networks. IEEE Access, 8, 57762-57771.

[15] R Hamdy, Y., & I Alghannam, A. (2020). Evaluation of ZigBee topology effect on throughput and end to end delay due to different transmission bands for IoT applications. Journal of communications software and systems, 16(3), 254-259.

[16] Sahar, G., Bakar, K. A., Rahim, S., Khani, N. A. K. K., & Bibi, T. (2021). Recent advancement of data-driven models in wireless sensor networks: a survey. Technologies, 9(4), 76.

[17] Sivasankararreddy, V., Sundari, G., Rami Reddy, C., Aymen, F., & Bortoni, E. C. (2021). Grid-Based Routing Model for Energy Efficient and Secure Data Transmission in WSN for Smart Building Applications. Applied Sciences, 11(22), 10517.

[18] Zhang, J., Hu, P., & Long, J. (2019). A hybrid transmission based data collection scheme with delay and reliability guaranteed for lossy WSNs. IEEE Access, 7, 70474-70485.

[19] Soni, S., & Shrivastava, M. (2019). Green corridor: A self-learning and educating algorithm for engineers (industry/students) to send data in emergency situations through wireless sensor network. The International Journal of Electrical Engineering & Education, 0020720919879383.

[20] Soni, S., & Shrivastava, M. (2018). Novel learning algorithms for efficient mobile sink data collection using reinforcement learning in wireless sensor network. Wireless Communications and Mobile Computing, 2018, 1-13.

[21] Soni, S., & Shrivastava, M. (2019). Novel wireless charging algorithms to charge mobile wireless sensor network by using reinforcement learning. SN Applied Sciences, 1, 1-18.