Implementing the Internet of Things via High-Speed Dynamic Networks and the LEACH Protocol: Data Transfer

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Abstract- the Internet of Things, or IoT, has been widely used in smart cities, industrial settings, healthcare, and other fields recently, and it is now an essential component of these industries. Because of its self-organizational characteristics, wireless sensor networks (WSNs) have become an essential technique for gathering auxiliary environmental data in various industries when it comes to Internet of Things systems. However, IoT-enabled WSNs have numerous issues due to the massive amount of heterogeneous data from multiple sensing devices, including high transmission delay times (TD) and excessive battery energy consumption (EC). Efficiency must be given top priority in order to maximise energy use and address these issues.

***Keywords** – Transmission Delay Times, Wireless Sensor Networks, Internet of Things, Excessive Battery Energy Consumption, Maximise Energy*.

INTRODUCTION

The advent of Industry 5.0 underscores the urgency of expediting modernization as conventional industries are currently undergoing a digital transition. This reform process is intensifying due to the Industrial Internet of Things' (IIoT) rapid growth. IIoT has significantly altered industry operations in recent years by increasing product safety, decreasing downtime due to malfunctions, and increasing production efficiency. By establishing effective smart factories, the IIoT system may increase production efficiency. The Industrial Internet of Things (IIoT) has the potential to gather diverse data from across the factory, boost efficiency via sophisticated automation procedures, improve worker location awareness to improve production safety, lower the frequency of equipment failures through accident detection, employ wireless sensors to monitor equipment status, create predictive maintenance software, and ultimately lower maintenance expenses. The wireless sensor nodes, which gather and transfer data from diverse machines and devices, are the fundamental components of IIoT technology. Because they enable resource optimisation, predictive maintenance, and real-time physical environment monitoring, these nodes are an essential part of the IIoT system. The effectiveness of these wireless sensor nodes' energy use, however, is a crucial concern. It is difficult and expensive to replace batteries when a large number of wireless sensor nodes are deployed inside a plant due to the hostile environment in which they function. Thus, increasing the wireless sensor nodes' energy consumption efficiency in the Internet of Things has emerged as one of the main study objectives for numerous academics. IoT sensors and devices have been used in many different industries (such as manufacturing, energy, and power), producing a lot of data to help practitioners with data analysis. The latency between data creation, processing, and transmission, or TD, is another crucial problem when deploying industrial IoT. The volume of data generated by sensors and devices in industrial contexts makes it difficult to ensure correct and timely transmission of all of that data. The speed, accuracy, and dependability of mechanical equipment operation can all be negatively impacted by any delay or inaccuracy in data transfer. Serious repercussions, such production stoppage or safety hazards, may result. Enhancing the IIoT system's efficiency, dependability, and security can be achieved by resolving the TD issue. The industry can gain from these actions in a number of ways, including higher safety, lower costs, and increased production. For example, management staff can identify safety hazards before they become safety incidents by using real-time equipment and production process monitoring. The effectiveness of energy use and the transmission density (TD) of sensor nodes are important variables in IIoT that impact system performance as a whole. At the moment, a large number of specialists and academics have studied these topics in great detail.

RELATED WORK

The overall performance and efficiency of the system are greatly impacted by the EC and TD in IIoT. These variables have an impact on crucial elements including battery life, network scalability, and data accuracy. When data is transported from a sensor node to a central server or the cloud for additional processing and analysis, this is referred to as transmission dynamics (TD). Excessive delays in the data transmission process might cause decision-making to be delayed, which can degrade the system's overall performance and efficiency. In addition, the energy that sensors use for communication duties is referred to as their EC. The EC of wireless sensors can have a substantial impact on the system's longevity and maintenance expenses since they are usually used in large quantities and are battery-powered. The three-layer architecture of IIOT is shown in Fig. 1. To tackle these challenges, several methods have been suggested in related research.

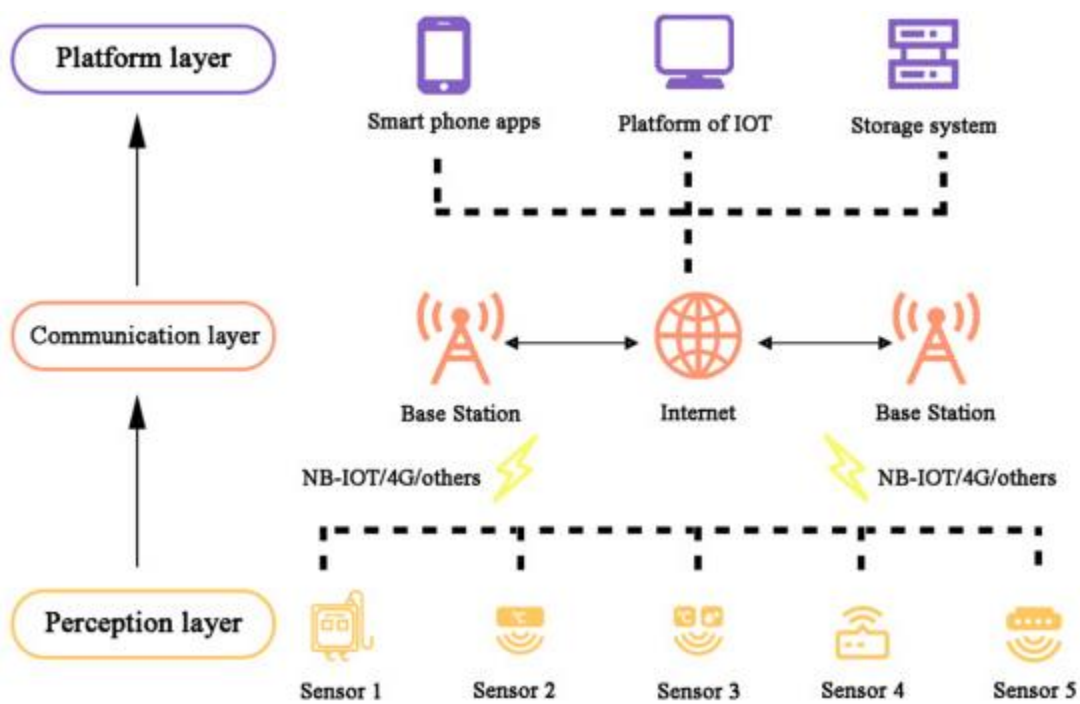

Figure 1- the architecture of IIOT

DATA TRANSMISSION DELAY

Technologies that can process data locally at the edge, such as edge computing, fog computing, and reinforcement learning, minimise the need to send data to the cloud and meet the objective of lowering transmission latency. Hassan et al. covered the application of edge computing in Internet of Things data transmission in their work. Their suggestion is to analyse and analyse data at the edge of the network rather than sending it to a central server. The writers talked on the benefits of edge computing, such as TD reduction and enhanced data security. But putting this strategy into practice necessitates creating custom hardware and software based on real requirements. In the paper, Patil et al. proposed a delay-aware data transmission system for IoT networks that optimises transmission parameters using reinforcement learning (RL) based on previous data. This technique uses reinforcement learning (RL) to modulate node transmission power while accounting for both short- and long-distance transmission delays. This scheme's flexibility in responding to ever-changing network conditions is one of its advantages. But in order to create the model, this technique requires a lot of historical data and has a significant computing cost. In order to enhance the performance of data transmission, Jamil et al. presented a fog computing method that processes and analyses data closer to the source. This technique can lower the EC of fog nodes while improving the system's real-time performance. But putting this method into practice necessitates setting up extra hardware and software, which could make a realistic deployment more complicated and expensive.

WIRELESS SENSORS’ ENERGY CONSUMPTION

Using an energy-saving communication protocol is essential to lowering sensor node energy consumption and maintenance costs. Heinzelman et al., the authors of paper, introduced LEACH, an extremely efficient clustering approach for WSNs. This technique makes use of the "clustering" notion to speed up the transfer of data. However, the randomness of the CH election could lead to an excessive number of CHs during the LEACH algorithm's implementation. Consequently, this causes the BS's burden to expand dramatically, which lowers network performance overall. In the publication, Mao L et al. introduced the EE-LEACH method as a solution to the LEACH algorithm's aforementioned drawbacks. To increase the probability of choosing a node with more residual energy than the network average as a CH, the algorithm takes into account both the average energy level for the entire network as well as the individual energy level of each sensor node. The CH's lifespan may be increased by this choice. The algorithm also considers the location of the node, reducing the possibility that a CH far from the BS will send data directly to the BS. However, this approach might not have an impact of balanced energy consumption because it ignores the network's overall load. A self-configuring and self-optimizing protocol, termed MRL-SCSO, that utilizes Multi-Agent Reinforcement Learning to evaluate the residual energy of sensors and buffer length for efficient data The protocol's goal is to make it less likely that nodes with less energy available will be chosen to become CHs. In terms of delivery time, the protocol has serious shortcomings despite its advantages. Relay forwarding nodes are chosen by W. Guo et al. using a reinforcement learning-based routing protocol that takes into account the nodes' count of relay points, distance, and available energy. Nevertheless, there are a number of serious issues with the protocol, such as high latency and energy imbalance. Achieving effective and long-lasting IIoT systems requires lowering sensor node consumption and data transfer latency. To lower TD in IoT systems, previous research has mostly leveraged techniques like blockchain, edge computing, fog computing, deep learning, and reinforcement learning. All approaches, however, have drawbacks, including expensive hardware, high computational complexity, and communication overheads. To solve these problems and provide more dependable and effective data transmission techniques for the Internet of Things, more research is required. This research provides a method, called LEACH-D, which improves the LEACH algorithm to balance the energy burden of the entire network in light of the shortcomings of the previously described techniques. Through "secondary clustering" on the chosen CHs, the algorithm maintains a balance in the EC of nodes throughout the network. Deployer nodes use their communication distance and remaining energy to choose the best data transmission channel. As a result, this approach lowers delay times, prevents network energy imbalance and network area segmentation issues, and offers higher quality of service.

ENERGY CONSUMPTION MODEL AND DELAY MODEL

Through data collection and exchange, the IIoT system a network made up of sensors, communication devices, and system applications primarily enhances industrial processes and operations. IIoT's operating efficiency is severely impacted by issues like energy consumption and delay times, though. In the context of IIoT, a model that precisely measures both consumption and delay must be created in order to support research on remedies for the aforementioned issues.

(i) Construction of wireless energy consumption model for industrial IoT- The energy consumption associated with wireless sensors is one of the main challenges in the field of IIoT. With an increasing number of devices and sensors being employed, the EC of the system will rise sharply. Ineffective management of node energy can raise maintenance expenses and cause device outages, which may cause large financial losses. High-efficiency devices and sensors must be installed, device configurations must be optimised to use less energy, or sophisticated energy management techniques must be utilised to monitor and control EC. To make it easier to adopt energy management strategies, wireless energy consumption models are used to assess the EC of various transmission systems.

(ii) Construction of delay model for IioT- The latency in data processing and transmission is another prevalent IIoT problem. Network congestion, data overload, or inadequate data processing and transmission could be the root cause of these problems. Network architecture should be optimised to minimise congestion, edge computing technologies should be used, the amount of data transmitted through the network should be reduced, or more sophisticated data transmission schemes should be used to reduce latency in order to decrease transmission delay times. By resolving these problems, the IIoT system's efficacy and efficiency can be increased, improving industrial operations and processes. To make it easier to assess the latency performance of various data transmission techniques, a latency model has been suggested.

SIMULATION RESULTS AND ANALYSIS OF A STUDY OF THE LEACH-D ALGORITHM BASED ON CLUSTERING

(i) The idea of clustering- In 2000, Heinzelman et al. initially introduced the idea of clustering as an algorithmic approach to enhance WSN performance and lower sensor EC. The suggested approach calls for grouping sensor nodes into clusters, each of which has a CH assigned to act as a gateway connecting the sensor nodes and the BS. Data from the sensor nodes in its group is combined by the CH node and sent to the BS. By using this method, there are fewer nodes that provide data straight to the base station (BS), which lowers the EC of sensor nodes and transmission latency. Numerous algorithms that make use of the clustering notion have been suggested in relevant earlier works. As an illustration, consider LEACH, GAF, HEED, EE-LEACH, I-AREOR, FAJIT, and further LEACH variations.

(ii) LEACH algorithm- This approach can save a lot of energy because within-cluster nodes only turn on the transmission circuit for data transmission during the allotted time and fall into sleep mode for the remainder of the period. The technique uses clustering as the main method of determining a CH among several sensor nodes. After that, the CH collects data from cluster member nodes and sends it to the BS. To lower transmission costs, the CH also fuses data prior to data transfer. On the other hand, problems such an unequal distribution of CHs, large differences in cluster sizes, and an excessive or insufficient number of CHs could arise during LEACH operation. During data transfer, EC and delay will grow exponentially with transmission distance. It takes more time and energy for nodes that are far from the base station (BS) to send data to the BS. Prolonged data transmission times and early node failure can be caused by increased EC and delay times.

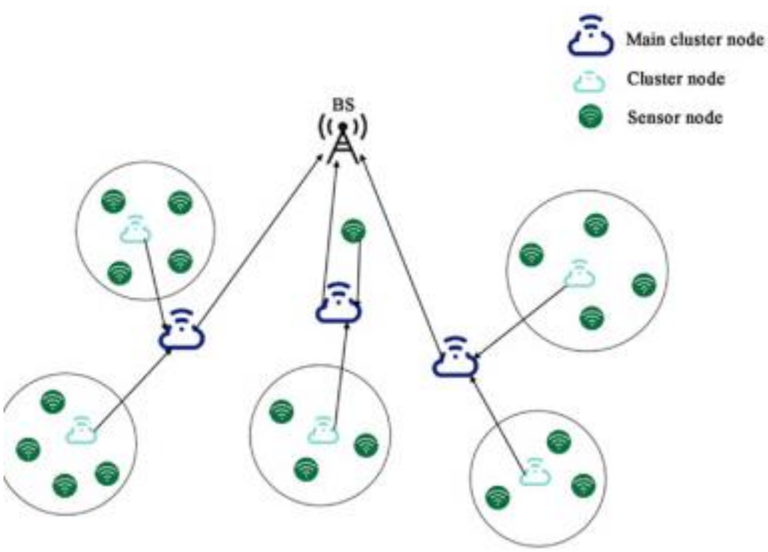

Figure 2- Data transmission diagram of LEACH-D algorithm

LEACH-D

Algorithm 1 LEACH-D

Input: Sensor nodes set S: $S_1, S_2, \ldots, S_n$
BS: Base station
function: Node clustering and data transmission
Initialization
BS broadcasts its location coordinates (x, y) to the nodes in set S
The nodes in set S calculate their distance to BS:

$$d_i = \sqrt{(x_i - x)^2 + (y_i - y)^2}$$

for S_i **do**
Assigning a random number, R, to each node
if $R_i < T(n)$ **then**
S_i becomes a CH
end if
end for
The CHs broadcast a "request to form a cluster" message to nearby nodes. The selection process for which cluster to join is determined by other CHs, who evaluate the strength of the received signal and the distance to each CH. Once they decide, a "consent" message is transmitted to the appropriate CH.
for S_i **do**
Re-assigning a random number R to each CH
if $R_i < T(n)$ **then**
S_i becomes a MCH
end if
end for
The MCHs broadcast a "request to form a cluster" message to nearby nodes. Upon receiving signals from multiple CHs, other CHs use the strength of the signal and distance as criteria to decide which cluster to join. They then communicate their decision by sending a "consent" message to the corresponding MCH.
end function

CONCLUSION

Since IIoT connects everything in the smart factory, implementing network energy consumption that is balanced and has low transmission delay is an exciting and challenging research area. The IIoT's smart sensor-enabled gadgets transmit a lot of data, which raises energy usage. In order to address the aforementioned issues, this paper suggests the LEACH-D algorithm for wireless data transmission in the IIoT. We have examined elements impacting TD and EC, such as communication protocols, power management strategies, etc. In addition, we highlighted several approaches for optimizing the EC of sensor nodes, such as lowering the data size of transmission packets and the load on BS, adopting low-power sensors, and using energy equalization algorithms.

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