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Data Transmission Reduction Schemes In WSNS For Efficient IOT Systems

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ABSTRACT

Wireless Sensor Networks (WSNs) play a crucial role in collecting the data from the nodes in the Internet of Things (IoT) systems. However, as transmission consumes dominant factor of energy consumption, the number of data transmissions need to be reduced. To address this issue, this project evaluates a two-tier data reduction framework by utilizing data compression and prediction schemes. The data prediction (DP) scheme is implemented by using neural networks and Long Short-Term Memory (LSTM) to minimize the data transmission between sensor nodes and cluster nodes by predicting the data locally and transmitting only when the deviation exceeds the threshold. The data compression (DC) scheme employs Principal Component Analysis (PCA) to reduce data volume between cluster heads (CH) and gateway nodes. The performance of the two-tier scheme is evaluated in terms of percentage reduction in data transmissions.

Introduction

The primary aim of this project is to develop and implement efficient data transmission reduction schemes for Wireless Sensor Networks (WSNs) in IoT systems to optimize energy consumption, minimize bandwidth usage, and extend network lifetime. This is achieved through a two-tier data reduction framework that integrates Dual Prediction (DP) and Data Compression (DC) techniques. The Dual Prediction (DP) scheme aims to eliminate redundant data transmissions by utilizing machine learning models such as Neural Networks (NNs) and Long Short- Term Memory (LSTMs) to predict sensor readings. If the predicted value is within an acceptable error margin, actual data transmission is suppressed, reducing energy consumption at the sensor level. The Data Compression (DC) scheme is designed to minimize the size of transmitted data by applying advanced compression techniques such as Principal Component Analysis (PCA), Non-Negative Matrix Factorization (NMF), Truncated Singular Value Decomposition (T- SVD), and Discrete Wavelet Transform (DWT). These methods leverage the spatio-temporal correlation in sensor data to reduce data redundancy and optimize network performance.

Overall, the project aims to enhance the efficiency, scalability, and sustainability of IoT-based WSNs by reducing data transmission overhead while maintaining data accuracy making it suitable for various real-time applications .

Wireless Sensor Networks (WSNs) play a crucial role in collecting the data from the nodes in the Internet of Things (IoT) systems. However, as transmission consumes dominant factor of energy consumption, the number of data transmissions need to be reduced. To address this issue, this project evaluates a two-tier data reduction framework by utilizing data compression and prediction schemes. The data prediction (DP) scheme is implemented by using neural networks and Long Short-Term Memory (LSTM) to minimize the data transmission between sensor nodes and cluster nodes by predicting the data locally and transmitting only when the deviation exceeds the threshold. The data compression (DC) scheme employs Principal Component Analysis (PCA) to reduce data volume between cluster heads (CH) and gateway nodes. The performance of the two-tier scheme is evaluated in terms of percentage reduction in data transmissions.

Literature Review

The vision of the Internet of Things (IoT) presents exciting opportunities across nearly every aspect of daily life, revolutionizing how we interact with the world. However, several challenges must be addressed to fully realize its potential. IoT is built upon a dynamic global network architecture, where every device, sensor, and "thing" is interconnected, providing real-time accessibility and intelligent decision-making based on environmental data. The pervasive presence of heterogeneous smart devices, each equipped with sensing and communication capabilities, allows for seamless identification, monitoring, and collaboration to achieve a common goal. One of the foundational technologies in IoT is Radio Frequency Identification (RFID), which enables the unique identification, tracking, and monitoring of objects through electronic tags. However, Wireless Sensor Networks (WSNs) play an even more critical role in IoT due to their ability to sense, collect, and transmit real-time physical data from the surrounding environment. WSNs consist of distributed sensor nodes that monitor parameters such as temperature, humidity, motion, and pressure, making them essential for applications such as smart cities, industrial automation, environmental monitoring, and healthcare systems. In addition to WSNs, smartphones, tablets, cloud computing, and edge technologies further enhance IoT's capabilities, enabling large-scale data processing, remote accessibility, and real-time decision-making. Among these technologies, WSNs have the most significant impact on IoT, providing the backbone for intelligent sensing and automated responses. WSNs not only enable real-time data collection but also incorporate actuators for autonomous interactions with monitored objects, bridging the gap between the physical and digital worlds. Their integration with machine learning, artificial intelligence, and advanced data processing techniques further enhances their ability to optimize energy consumption, improve communication efficiency, and ensure reliable data transmission. As IoT continues to evolve, WSNs will remain at the forefront of intelligent automation, enabling a smarter, more connected The pervasive presence of heterogeneous smart devices, each equipped with sensing and communication capabilities, allows for seamless identification, monitoring, and collaboration to achieve a BRECW, Hyderabad Page 3 of 59 Major Project Report Data Transmission Reduction Schemes in WSNS for Efficient IOT Systems common goal.

Data Reduction in Wireless Sensors Networks

This project focuses on analyzing the performance of data transmission reduction techniques in Wireless Sensor Networks (WSNs) by implementing optimized data handling mechanisms. The primary objective of this phase is to enhance energy efficiency, extend network lifetime, and improve data accuracy while reducing redundant transmissions. To evaluate the effectiveness of the implemented methods, three key performance metrics were considered:

1. EER-RL (Energy Efficiency Ratio vs. Residual Lifetime)
2. Energy Consumed per Round 3.Operating Nodes per Round

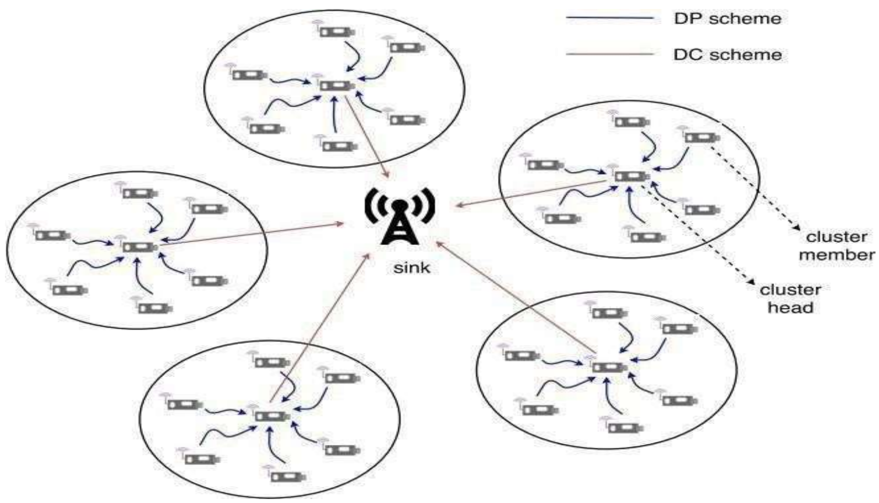

Figure 3.1 DP and DC shemens in a clustered WSN

Network Models

Efficient communication and data management in Wireless Sensor Networks (WSNs) depend heavily on the underlying network architecture. The network model influences data transmission paths, energy consumption, scalability, and fault tolerance—all of which are critical to IoT applications. Several network models are adopted in WSNs based on the deployment environment, application type, and performance requirements.

1. Flat Network Model

- All sensor nodes are treated equally with no hierarchy.
- Each node performs sensing and routing tasks.
- Data is transmitted through multi-hop routing directly to the base station.
- Drawback: High energy consumption due to redundant transmissions and no role specialization.
- Use Case: Small-scale environments with uniform data distribution.

2. Hierarchical (Cluster-Based) Network Model

- Nodes are organized into clusters, with each cluster managed by a Cluster Head (CH).
- Member nodes send data to the CH, which performs data aggregation/compression and forwards it to the base station.
- Reduces communication overhead and prolongs network life.

- Example Protocols: LEACH, TEEN, HEED.
- Relevance to Project: Your dual-scheme (DP + DC) approach is implemented over a clustered network where:
- DP (Dual Prediction) is applied between nodes and CHs.
- DC (Data Compression) is applied between CHs and the base station.

WSN Overall Architecture

WSN comprises the "Global Network (GN)" and a number of "Regional Networks (RN)" . The GN is an overlay network of Biobots as proposed in , and the proposed refinement that satisfies all mentioned WSN challenges is designed in the RN. The RN of *WSN Platforms* is to facilitate a platform that hosts primitive sensors and enables their effective communication to the rest of the regional layer. *WSN Nodes* facilitate the connectivity of all *WSN Platforms* in the regional layer and interfaces this layer to the global layer when required. Connectivity with the GN is not required, and the RN can work autonomously. The global layer is a realization of a research prototype network that achieves several self properties using a bio-inspired solution named EDBO. Thus, the global layer is composed of biobots (logical nodes) that are realized in a biospace (middleware).

Biobots can communicate with *WSN Nodes* if in range; hence a connection between two layers is created.

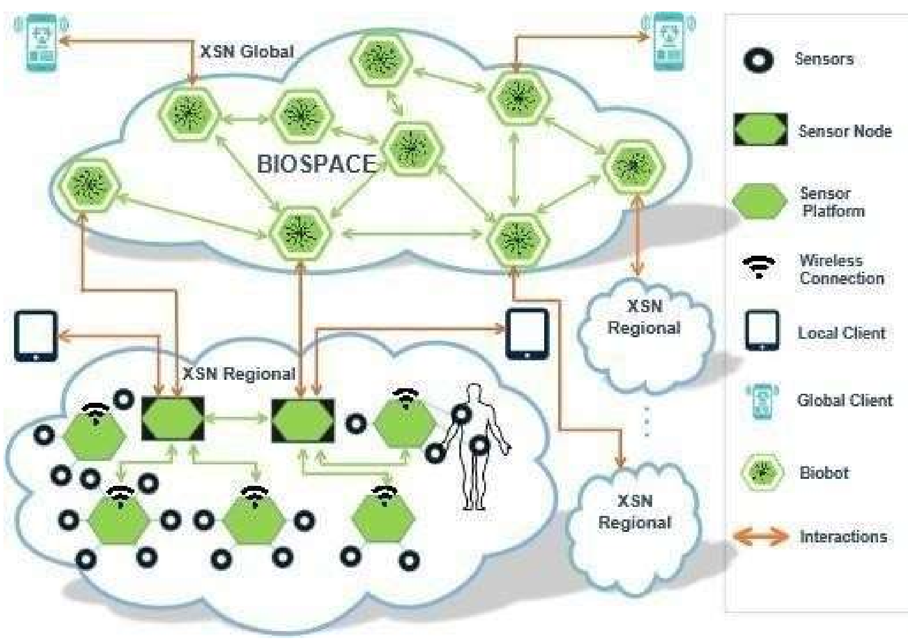

Figure 3.2: Overall system (WSN) architecture

Results and Discussion

MATLAB (Matrix Laboratory) is a powerful environment for technical computing, focusing on matrix operations. It integrates computation, visualization, and programming, enabling matrix manipulation, data plotting, algorithm implementation, and interface development. Its applications include math, modeling, simulation, data analysis, and graphical user interface (GUI) development.

Experimental results:

In this section, the output of Phase 1 focuses on visualizing and analysing the initial performance of the Data Transmission Reduction Schemes in Wireless Sensor Networks (WSNs) for Efficient IoT Systems are presented. It focuses on visualizing and analyzing the network performance under varying simulation conditions. The results highlight the interaction between the sensor nodes, cluster heads (CHs), and the base station (BS).

The 2D and 3D graphs demonstrate the node deployment, cluster formation, and data transmission patterns, providing insights into the system's efficiency. The experiments showcase how the proposed scheme optimizes energy consumption, prolongs network lifespan, and reduces redundant data transmissions. This phase primarily concentrates on:

Evaluating the system's ability to reduce data overhead while maintaining efficient and reliable transmission.

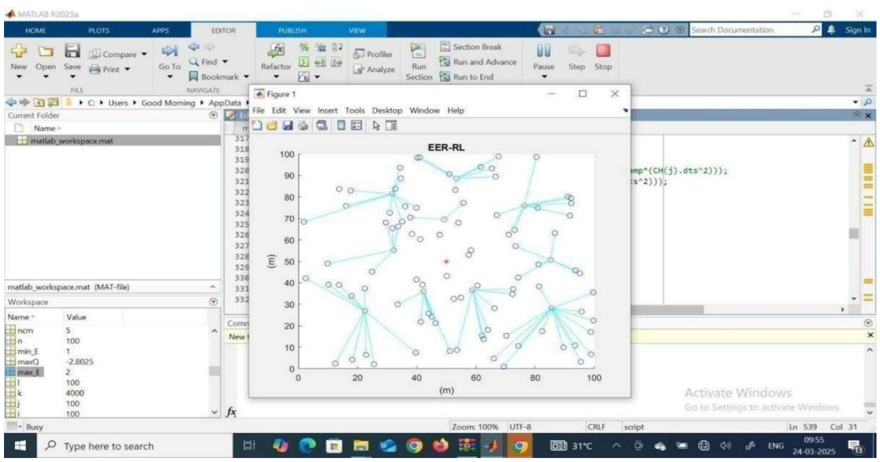

Fig 4.2.1 EER-RL

This graph shows the deployment of nodes in a WSN, where the sink node (red star) is located at the center. The blue circles represent sensor nodes, while the red circles indicate cluster heads. The light blue lines depict the communication links, forming clusters that transmit data to the sink node. This clustering approach reduces redundant transmissions, improving the energy efficiency of the network.

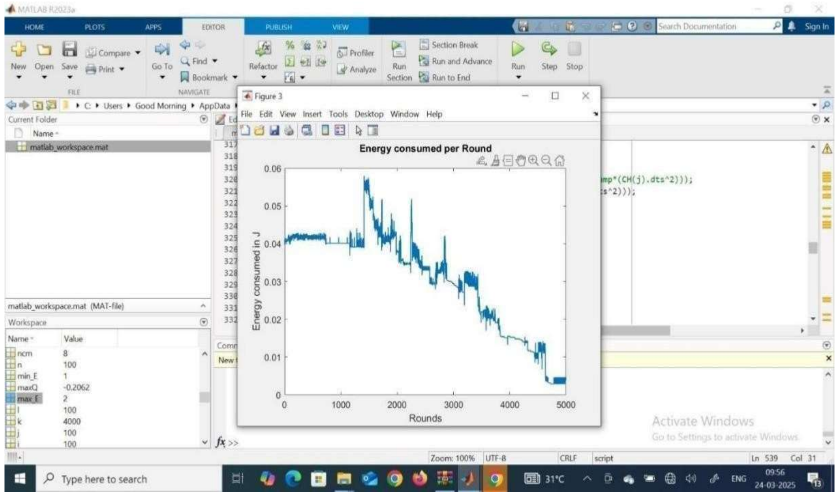

Figure 4.2.2 Energy Consumption per Round

This graph displays the energy consumption pattern in the network. Initially, the energy usage is consistent but fluctuates due to varying node activities. As the network evolves, the energy consumption decreases as more nodes fail. This showcases the effectiveness of energy- efficient data transmission schemes in prolonging the network's lifespan.

4.2.1 Training progress

The training progress graph illustrates the learning behavior of a neural network over 5900 iterations across 50 epochs. In the top graph, the RMSE (Root Mean Square Error) decreases sharply during the initial iterations and gradually stabilizes, indicating that the model is learning effectively and converging.

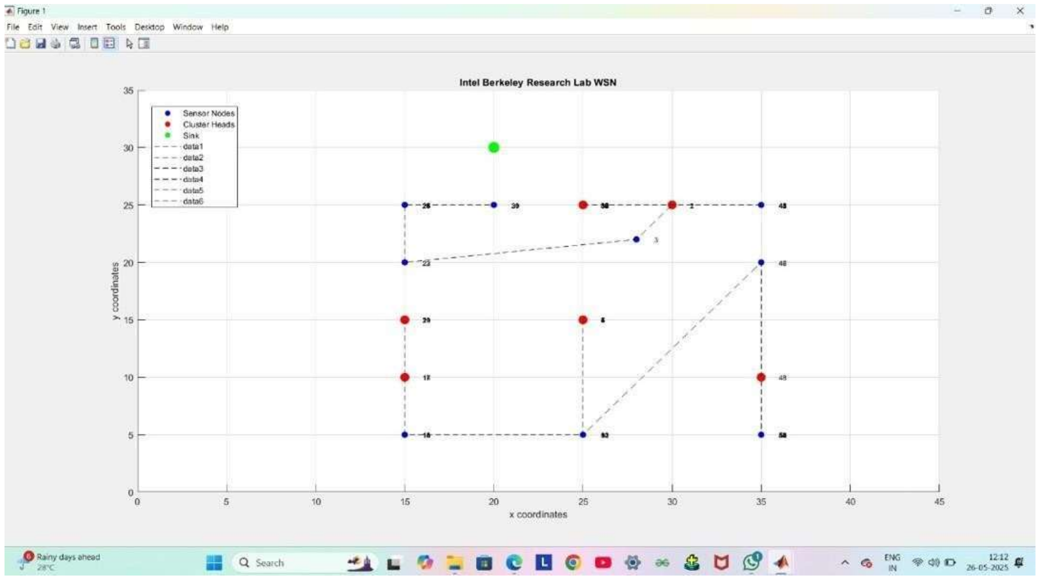

Fig.4.2.5 Intel Barkeley Lab WSN

The above figure represents the simulation of a Wireless Sensor Network (WSN) using node data from the Intel Berkeley Research Lab dataset. It visualizes the placement of sensor nodes, their cluster heads, the sink node, and the data transmission paths within the network

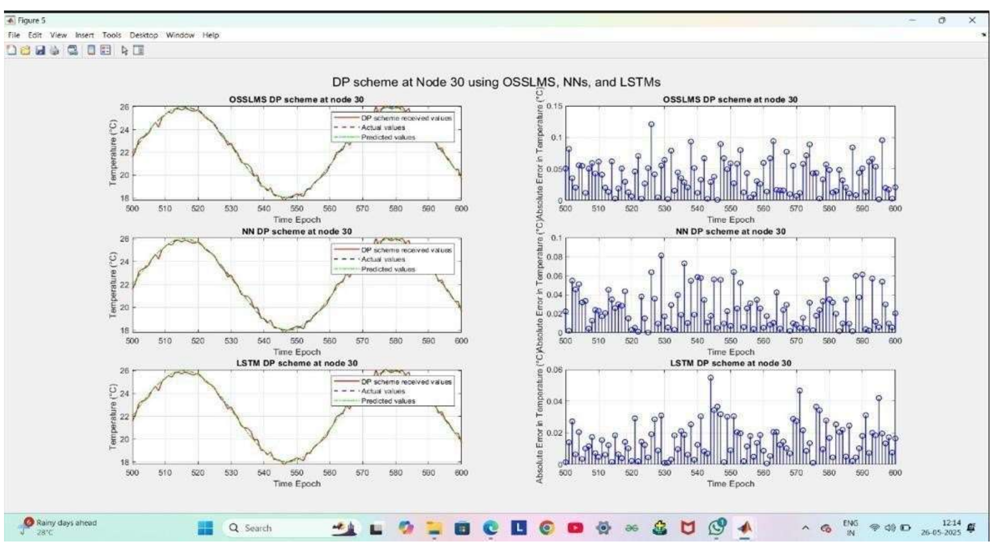

Fig 4.2.6 DP scheme at Node 30 using OSSLMS, NNs, and LSTMs

Conclusion and Future Scope

Conclusion

The conclusion of this study emphasizes the significance of data transmission reduction schemes in Wireless Sensor Networks (WSNs) for enhancing the efficiency of Internet of Things (IoT) systems. WSNs are essential in IoT applications, but their limited energy resources necessitate efficient data management strategies to extend network lifespan and improve performance. The study highlights various techniques such as data aggregation, compression, and filtering, which help minimize redundant transmissions, reducing overall power consumption and improving data accuracy.

Efficient data transmission reduction not only optimizes energy usage but also enhances network scalability and reliability. By implementing advanced algorithms and protocols, WSNs can support real-time data processing with minimal delays. Techniques like machine learning-based data prediction, adaptive sampling, and clustering algorithms further contribute to reducing unnecessary data transmissions, ensuring only relevant and high- quality data is sent to central processing units.

Moreover, the integration of AI-driven optimization methods can further refine data transmission strategies, making IoT systems more autonomous and efficient. These advancements will play a crucial role in enabling smart applications such as industrial automation, environmental monitoring, healthcare systems, and smart cities. Future research can focus on developing hybrid approaches that combine multiple data reduction techniques, improving both network longevity and system accuracy.

In conclusion, the study underscores the importance of optimizing data transmission in WSN- based IoT systems to enhance their sustainability, scalability, and efficiency.

Future Scope

The future scope of data transmission reduction schemes in Wireless Sensor Networks (WSNs) for IoT systems is vast, with numerous advancements expected to enhance efficiency, scalability, and energy conservation. As IoT applications expand in areas such as smart cities, healthcare, industrial automation, and environmental monitoring, optimizing data transmission will become even more crucial. Future research will focus on integrating Artificial Intelligence (AI) and Machine Learning (ML) for intelligent data management, enabling predictive models to analyze sensor data patterns and transmit only relevant information. Additionally, adaptive sampling techniques will dynamically adjust data collection rates based on environmental changes, reducing redundant transmissions. Another promising area is edge computing and fog computing, which process data closer to the source, minimizing latency and bandwidth usage while enhancing system responsiveness. Blockchain-based data transmission can also improve data security and integrity, ensuring reliable communication in distributed networks. Moreover, hybrid data reduction techniques, combining methods like compression, aggregation, and clustering, will optimize performance. Future advancements in energy-harvesting technologies, such as solar-powered sensor nodes, can further extend WSN lifespan by reducing battery dependence. By integrating AI, edge computing, blockchain, and energy-efficient protocols, IoT systems can achieve higher accuracy, lower power consumption, and improved real-time processing, paving the way for more autonomous and sustainable networks.

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