

Enhanced IoT Network Longevity using Adaptive Data-Rate Communication and Virtual Energy Balancing

¹ Gulupalli Ysaswi

UG Student

Department of ECE

GMR Institute of Technology

(GMRIT) – Deemed to be

University

Rajam, Andhra Pradesh, India

22341A0463@gmrit.edu.in

² Bonela Mounika

UG Student

Department of ECE

GMR Institute of Technology

(GMRIT) – Deemed to be

University

Rajam, Andhra Pradesh, India

22341A0432@gmrit.edu.in

³ Thota Pavithra

UG Student

Department of ECE

GMR Institute of Technology

(GMRIT) – Deemed to be

University

Rajam, Andhra Pradesh, India

22341A04H6@gmrit.edu.in

⁴ Dunna Praveen

UG Student

Department of ECE

GMR Institute of Technology

(GMRIT) – Deemed to be

University

Rajam, Andhra Pradesh, India

22341A0451@gmrit.edu.in

^{*5} P Kalyan Chakravarthi

Assistant Professor

Department of ECE

GMR Institute of Technology

(GMRIT) – Deemed to be

University

Rajam, Andhra Pradesh, India

Kalyanchakravarthi.p@gmrit.edu.in

Abstract— Adaptive Data Rate Transmission Protocol designed to improve the performance and efficiency of wireless communication systems. In traditional communication methods, fixed transmission protocols often lead to problems such as high energy consumption, increased delay, packet collisions, and reduced network lifetime. To overcome these issues, the proposed system combines three different transmission protocols into a single adaptive framework that can intelligently select the most suitable protocol based on current network conditions. The system continuously monitors important parameters such as energy, bandwidth, latency, data rate, and transmission accuracy to make smart decisions for reliable communication between devices. By adapting to changing conditions, the protocol reduces packet loss, minimizes delay, improves bandwidth utilization, and increases overall transmission efficiency. In addition, efficient energy management helps to extend the network lifetime and maintain stable performance. MATLAB simulation results and graphical analysis demonstrate that the proposed adaptive approach performs better than existing methods, providing more reliable, efficient, and accurate data transmission in a practical and user-friendly manner.

Keywords:

Adaptive Data Rate, Hybrid Transmission Protocol, Network Lifetime Improvement, Energy Efficient Communication, Reliable Data Transmission.

I. INTRODUCTION:

This project is an Adaptive Data Rate Transmission Protocol designed to improve the efficiency, reliability, and lifetime of wireless communication networks operating under limited energy and bandwidth constraints. The rapid growth of internet of Things (IoT) devices has created a strong need for intelligent communication system capable of managing varying data rates, network congestion, and energy consumption effectively. Traditional fixed transmission protocols often fail to adapt to changing network conditions, leading to inefficient bandwidth usage, increased delay, packet collisions, and reduced network lifetime. [1]. Recent advancements in intelligent communication and adaptive networking have enabled systems to dynamically adjust transmission parameters based on real-time network conditions. Similar to how intelligent systems analyse data to make optimized decisions, adaptive communication protocols monitor parameters such as latency, bandwidth, energy availability, and data rate to select the most suitable transmission strategy. This dynamic behaviour helps in improving communication efficiency, reducing packet loss, and maintaining stable network performance.[2]. In modern large-scale IOT and wireless sensor environments, devices operate with limited battery resources and heterogeneous capabilities. Fixed communication approaches often cause uneven energy consumption, network congestion, and early node failures, which ultimately reduce overall network longevity. To address these challenges, adaptive transmission mechanisms are required that can intelligently balance energy usage while maintaining reliable and efficient communication between devices. [3]. The proposed system integrates multiple transmission strategies into a unified adaptive framework capable of dynamically selecting the most appropriate protocol based on network conditions. By continuously monitoring parameters such as energy consumption, bandwidth availability, latency, and data rate, the system ensures efficient data delivery, minimizes collisions, and improves transmission reliability. This adaptive approach not only enhances communication performance but also extends the operational lifetime of the network through balanced energy utilization.[4]. Existing communication systems often suffer from challenges such as inefficient bandwidth utilization, high energy

consumption, limited adaptability, and poor performance under varying network conditions. To overcome these limitations, the proposed model introduces an intelligent adaptive transmission mechanism that supports dynamic protocols selection and efficient resource management. The system is implemented and evaluated using MATLAB simulation, where performance is analysed in terms of latency, bandwidth, data rate, energy consumption, accuracy, and network lifetime.[5]. This section presents the performance evolution and analysis of the proposed adaptive Data Rate Transmission Protocol. The system demonstrates efficient communication between devices, improved energy utilization, and enhanced network lifetime. Simulation results and graphical analysis illustrate the effectiveness of the proposed approach in providing reliable, efficient, and adaptive wireless communication. The evaluation focuses on communication delay, bandwidth efficiency, transmission accuracy, protocol adaptability, and overall network longevity. [6]. As IoT ecosystem continue to expand, networks are expected to support devices with different communication needs, ranging from low-power environmental sensors to high-data industrial monitoring systems. This diversity makes it difficult for a single fixed transmission protocol to efficiently handle all scenarios. An adaptive data rate mechanism becomes essential to intelligently manage these varying requirements without compromising performance. [7]. One of the major challenges in wireless communication is managing the trade-off between energy efficiency and data transmission speed. High data rates often consume more power, while low-energy transmission may increase delay. The proposed adaptive protocol carefully balances these factors by dynamically selecting the most suitable transmission strategy based on current network conditions.[8]. Network congestion and packet collisions are common issues in dense IoT deployments. When multiple devices attempt to transmit data Simultaneously, communication interference may occur, leading to retransmission and unnecessary energy consumption. By continuously monitoring bandwidth and traffic conditions, the adaptive protocol reduces collision probability and improves overall communication stability [9]. Energy conservation is particularly critical in battery-

powered wireless sensor networks where replacing or recharging devices may not be practical. Uneven energy depletion across nodes can result in network partitioning and early failure. The proposed system addresses this by distributing communication load intelligently, thereby extending network operational lifetime [10]. The adaptive framework also improves scalability, allowing the network to handle an increasing number of connected devices without significant degradation in performance. As more nodes join the network, the protocol dynamically adjusts transmission behaviour to maintain consistent efficiency and reliability [11]. Another important aspect of the proposed system is its ability to improve Quality of Service (QoS). By considering parameters such as latency, bandwidth utilization, and data rate requirements, the adaptive protocol ensures that time-sensitive applications receive priority while still maintaining energy efficiency for less critical transmissions [12]. The MATLAB-based simulation environment provides a controlled platform to evaluate the performance of the adaptive transmission mechanism. Through graphical analysis and performance metrics, the system's effectiveness can be clearly observed in terms of reduced delay, improved bandwidth utilization, balanced energy consumption, and enhanced network lifetime [13]. Ultimately, this project contributes toward building smarter and more sustainable wireless communication systems. By integrating adaptive decision-making into transmission protocols, the network becomes more responsive, efficient, and capable of handling dynamic real-world conditions. This approach supports the future development of intelligent IoT infrastructures that require reliability, flexibility, and long-term operational stability [14].

II. Methodology:

The proposed system offers a protocol selection framework for IoT mesh networks based on client needs. It assesses several communication protocols under simulated network conditions and chooses the most appropriate one based on the user's communication requirements.

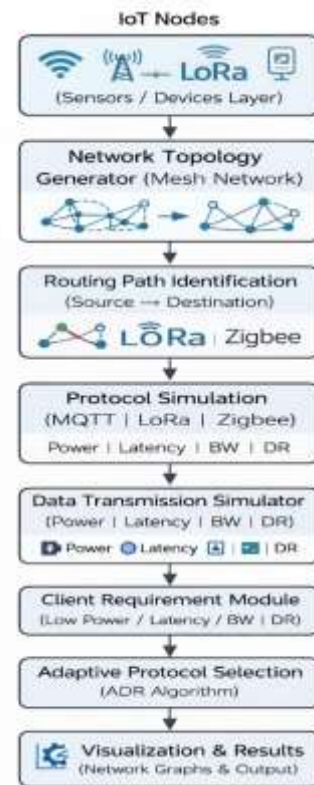


Fig 1: Adaptive protocol selection framework for IOT networks

A. Network Initialization

The simulation starts by forming an IoT mesh network with multiple nodes. Each node represents an IoT device that can communicate with its neighbouring nodes. Connectivity between nodes is shown using an adjacency matrix, where a value of 1 indicates a connection and 0 indicates no connection. The nodes are randomly arranged in a two-dimensional space to reflect realistic device placement. A source node and a destination node are chosen to simulate data transmission across the network.

B. Protocol Simulation

The system considers three commonly used IoT communication protocols:

- MQTT (Message Queuing Telemetry Transport)
- LoRa (Long Range Communication Protocol)
- Zigbee

Each protocol is assessed based on key communication performance factors such as:

- Power Consumption
- Communication Latency
- Bandwidth
- Data Rate

These factors are essential for the performance of IoT communication systems.

C. Data Transmission Simulation

To evaluate protocol performance, data transmission is simulated along a specific routing path between the source and destination nodes. This routing path represents the way data packets are sent throughout the mesh network.

During the simulation, the following factors are calculated for each communication link on the path:

- Power Consumption: The energy needed to transmit data through the network.
- Latency: The time delay experienced during packet transmission.
- Bandwidth: The maximum capacity of the communication channel.
- Data Rate: The speed of data transmission across the network.

Small random changes are added to these values to mimic real-world network conditions like interference, congestion, and signal loss.

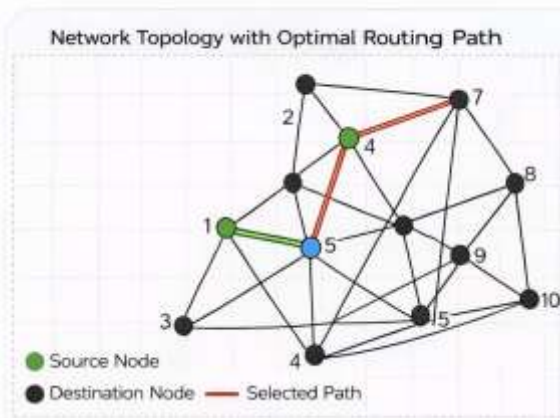


Fig 2: Network topology

D. Parameter Aggregation

After data transmission simulation, the link parameters are combined to get the final path performance values. Total power consumption and latency are calculated by summing the values along the path, while bandwidth and data rate are determined by taking the minimum values of the links to show the bottleneck condition.

These combined values help estimate the expected performance of the protocols under the simulated network conditions.

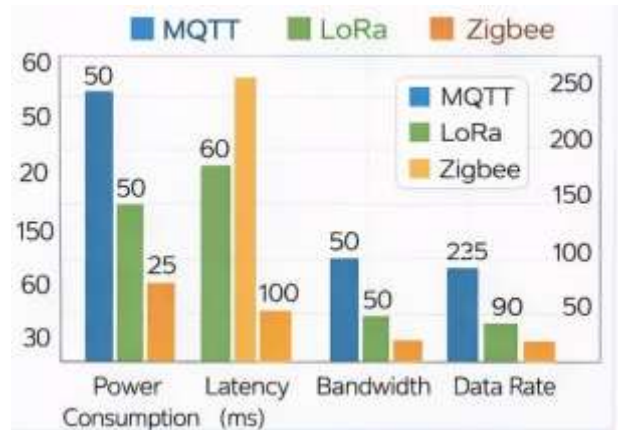


Fig 3: Performance Graph

E. Client Requirement-Based Protocol Selection

The system lets the user specify communication needs based on the application. The user can choose one or more of these requirements:

- Low Power Consumption
- Low Latency
- High Bandwidth
- High Data Rate

To assess the protocols based on these needs, a normalization and scoring method is applied for factors where lower values are better (power consumption and latency), inverse normalization is used. For factors where higher values are better (bandwidth and data rate), direct normalization is used.

The normalized scores of all chosen requirements are combined to create a final performance score for each protocol. The protocol with the highest score is selected as the best communication method for the specific network scenario.

F. Visualization of Results

Finally, the system displays the simulation results using graphical representations. The network topology diagram illustrates the connectivity between IoT nodes and highlights the routing path from the source to the destination. Additionally, waveform graphs compare the performance scores of the protocols. These visualizations demonstrate how the selected protocol delivers the best performance based on the client’s requirements. To support ongoing health monitoring, the system includes a data persistence layer using a MySQL relational database.

G. Algorithm

Adaptive Data Rate-Based Protocol Selection Algorithm

Input:

IoT mesh network nodes, communication protocols (MQTT, LoRa, Zigbee), client communication requirements

Output:

Optimal protocol selection based on adaptive network parameters

Algorithm:

Step 1: Initialize an IoT mesh network with N nodes.

Step 2: Generate an adjacency matrix to show connectivity between nodes.

Step 3: Assign random coordinates to nodes to mimic real-world network deployment.

Step 4: Choose a source node and a destination node within the network.

Step 5: Find the routing path for data transmission between the source and destination.

Step 6: Simulate data transmission along the chosen routing path.

Step 7: Calculate communication parameters for the path:

- Power Consumption
- Communication Latency
- Bandwidth
- Data Rate

Step 8: Generate protocol-specific parameter values for MQTT, LoRa, and Zigbee based on the calculated path metrics.

Step 9: Display the protocol parameter values in a comparison table.

Step 10: Accept client communication requirements, such as:

- Low Power Consumption
- Low Latency
- High Bandwidth
- High Data Rate

Step 11: Apply normalization to the parameter values:

Use inverse normalization for parameters where lower values are better (power and latency). Use direct normalization for parameters where higher values are better (bandwidth and data rate).

Step 12: Compute a combined performance score for each protocol based on the selected requirements.

Step 13: Rank the protocols based on their computed scores.

Step 14: Choose the protocol with the highest score as the best option for adaptive data transmission.

Step 15: Visualize the network topology and protocol comparison graphs to review communication performance.

H. System Architecture:

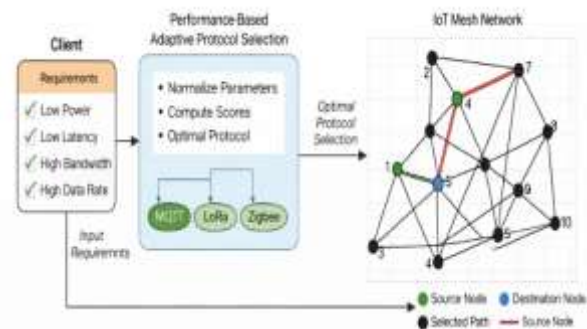


Fig 4 : Architecture of Adaptive communication protocol

The proposed system architecture aims to simulate an adaptable IoT communication framework that selects the best protocol based on network conditions and client needs. The architecture has several functional modules that work together to replicate network communication, assess protocol performance, and choose the optimal protocol.

The overall architecture includes the following key components:

i. IoT Node Layer

The first layer includes multiple IoT nodes set up in a mesh network. Each node is a device that can send and receive data. These nodes communicate wirelessly with each other.

The connection between nodes is defined using an adjacency matrix. A value of 1 shows a connection between two nodes, while 0 means no connection. This setup allows the system to simulate realistic network conditions.

The nodes are randomly placed in a two-dimensional space to mimic real IoT deployment scenarios.

ii. Network Topology Generator

The network topology generator creates the mesh network structure used in the simulation. It generates:

- Node positions
- Connectivity matrix
- Communication links between nodes

This module ensures the network behaves like a real IoT mesh network, where multiple nodes are linked and data can travel through different paths.

iii. Routing Path Identification Module

Once the network topology is created, the system picks a source node and a destination node. A routing path is then defined between these nodes to simulate data transmission.

This module identifies the communication path through which packets travel. Each link along the path affects the overall communication performance.

iv. Protocol Simulation Module

This module simulates the behaviour of various IoT communication protocols. The system evaluates three commonly used protocols are MQTT, LoRa, Zigbee. Each protocol is assessed using key communication parameters such as:

- Power Consumption
- Latency
- Bandwidth
- Data Rate

These parameters are important performance metrics for IoT communication systems.

v. Data Transmission Simulation

The system simulates the transmission of data packets between the source and destination nodes along the chosen routing path. During transmission, communication parameters are generated for each link.

To enhance realism, slight variations are introduced to represent real-world conditions such as:

- Network interference
- Signal attenuation
- Channel congestion

The link parameters are then combined to determine the overall path performance.

vi. Client Requirement Analysis Module

The client requirement module allows users to specify communication preferences based on application needs. The system supports the following demands:

- Low Power Consumption
- Low Latency
- High Bandwidth
- High Data Rate

These requirements guide the protocol selection process.

vii. Adaptive Protocol Selection Engine

The adaptive protocol selection engine employs the Adaptive Data Rate-Based Protocol Selection Algorithm. It assesses the protocol parameters using normalization techniques and calculates a combined performance score for each protocol.

The protocol with the highest score is chosen as the optimal communication protocol for the specific situation.

viii. Visualization and Output Module

Finally, the results are shown through visual outputs that include:

- Mesh network topology diagram
- Routing path visualization
- Protocol comparison graphs
- Performance waveforms

These visualizations aid in analysing the network's behaviour and confirming the performance of the proposed system.

IV. RESULTS:

To evaluate the performance of various IoT communication protocols in a mesh network, they proposed an adaptive protocol selection system using MATLAB. adaptive protocol selection system into practice so as to assess several IoT communication methods in a mesh network setting. Based on major communication criteria, the simulation evaluates protocol performance and automatically chooses the most appropriate one depending on consumer needs.

A. Network Topology Graphical Representation

The IoT mesh network topology is the first thing the system produces. Ten interrelated IoT nodes make up the network, randomly distributed throughout the simulation area. Using an adjacency matrix—which specifies the communication links between nodes—the connectivity between nodes is built. The mesh communication architecture in which every node may interact with nearby nodes is shown in the visualization. This topology depicts actual IoT installations in which several devices work together to move data throughout the network.

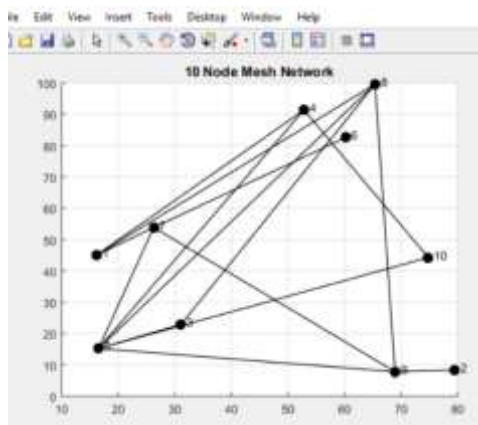


Fig 5: Network topology system

The network diagram shows the destination and source nodes highlighted. The chosen routing path between these nodes is shown using a unique colour to highlight the path taken for data transfer. By illustrating how packets move across middle nodes to get to the ultimate destination, the routing path confirms the communication capacity of the mesh network.

B. Path routing study

The system finds a routing path connecting the source and destination nodes after creating the network topology. An illustration routing path in the simulation might be:

Node -1- 4-8.is chosen for data transmission.

Every communication route along this path helps to improve network performance. Parameters such as power consumption, latency, bandwidth, and data rate are calculated for each link and aggregated to determine the path performance. This routing analysis guarantees that the protocol testing is conducted under normal communication circumstances.

C. Protocol Parameter Evaluation

The system evaluates three widely used IoT communication protocols: MQTT, LoRa, Zigbee. Each protocol is analysed using four major performance metrics: Power Consumption, Latency, Bandwidth, Data Rate. The results generated in the MATLAB command window present a comparison of protocol parameters. An example result is shown below.

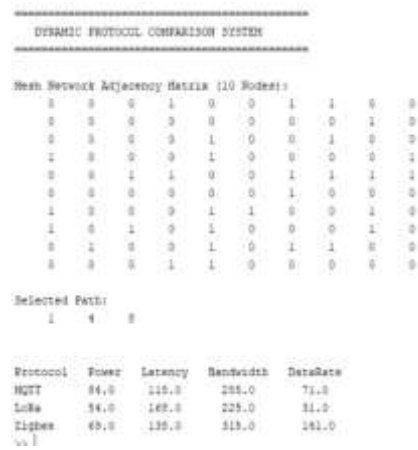


Fig 6: Network matrix with parameters

From the table, it can be observed that each protocol exhibits different strengths and weaknesses. For instance:

LoRa provides lower power consumption

MQTT offers lower latency

Zigbee provides higher bandwidth and data rate

These differences highlight the importance of adaptive protocol selection depending on application requirements.

D. Client Requirement–Based Protocol Selection

The proposed system allows users to define communication requirements such as:

Low Power Consumption

Low Latency

High Bandwidth

High Data Rate

Based on the selected requirements, the system applies a normalization-based scoring mechanism to evaluate protocol suitability. Each protocol receives a combined performance score calculated using normalized parameter values. The protocol with the

highest score is selected as the optimal communication protocol.

For example, if the client requirements are:

- i. Low Power + High bandwidth:

```

Selected Path:
  1   4   9

Protocol Power(mW) Latency(ms) Bandwidth(Kbps) DataRate(Kbps)
MQTT      52.0      198.0      170.0      186.0
LoRa      22.0      248.0      143.0      144.0
Zigbee    37.0      219.0      233.0      234.0

Select Requirements :
1. Low Power
2. Low Latency
3. High Bandwidth
4. High Data Rate
Enter choices as vector (example [1 3]): [1 3]

----- FINAL RESULT -----
Selected Requirements: 1 3

MQTT Final Score = 0.333
LoRa Final Score = 1.000
Zigbee Final Score = 1.500

Best Protocol Selected: Zigbee
Reason: Highest combined normalized score.
Network Status: STABLE
Transmission Result: SUCCESS
    
```

Fig 7: Protocol Selection

The scoring process, which involves normalization and aggregation of multiple performance metrics, highlights Zigbee’s ability to satisfy the combined network requirements more effectively than MQTT and LoRa in the given scenario. As a result, Zigbee becomes the most suitable choice for the current network conditions and application needs.

The final scores may appear as:

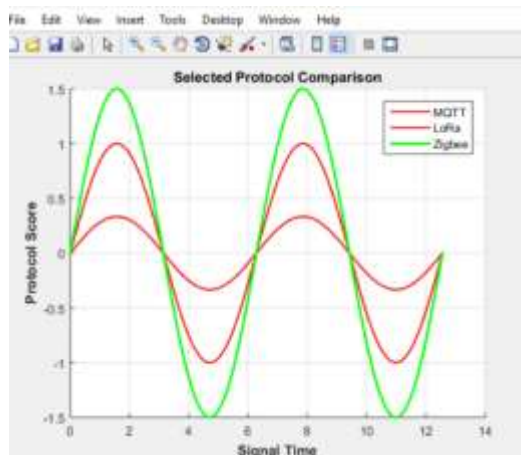


Fig 8: Selected protocol comparison

In this scenario, Zigbee achieves the highest score and is selected as the optimal protocol. This indicates that, based on the selected client requirements and the evaluated communication parameters, Zigbee provides the most balanced and efficient performance among the considered protocols. The protocol demonstrates comparatively lower latency and power consumption while maintaining sufficient bandwidth

and data transmission capability within the simulated IoT mesh network.

- ii. Low latency:

```

Selected Path:
  1   4   9

Protocol Power(mW) Latency(ms) Bandwidth(Kbps) DataRate(Kbps)
MQTT      52.0      198.0      170.0      186.0
LoRa      22.0      248.0      143.0      144.0
Zigbee    37.0      219.0      233.0      234.0

Select Requirements :
1. Low Power
2. Low Latency
3. High Bandwidth
4. High Data Rate
Enter choices as vector (example [1 3]): [2]

----- FINAL RESULT -----
Selected Requirements: 2

MQTT Final Score = 1.000
LoRa Final Score = 3.000
Zigbee Final Score = 0.400

Best Protocol Selected: MQTT
Reason: Highest combined normalized score.
Network Status: STABLE
Transmission Result: SUCCESS
    
```

Fig 9: Protocol selection

The final scores may appear as:

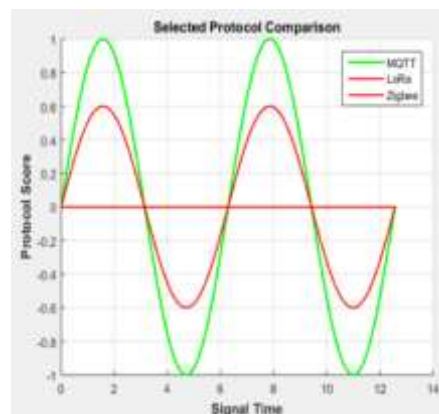


Fig 10: Selected Protocol comparison

In this scenario, MQTT achieves the highest score and is selected as the optimal protocol. Based on the selected requirements, the system applies a normalization-based scoring mechanism to evaluate protocol suitability. Each protocol receives a combined performance score calculated using normalized parameter values. The protocol with the highest score is selected as the optimal communication protocol.

E. Protocol Performance Graph Analysis

The simulation also generates graphical representations to visualize protocol performance. The performance graphs display parameter comparisons between MQTT, LoRa, and Zigbee. These graphs clearly illustrate variations in power consumption, latency, bandwidth, and data rate.

For example:

Power Graph: Shows that LoRa consumes the least power.

Latency Graph: Demonstrates that MQTT provides faster communication.

Bandwidth Graph: Indicates that Zigbee supports higher channel capacity.

Data Rate Graph: Shows the variation in data transmission speed among protocols.

These visual comparisons help in understanding protocol behaviour and validating the adaptive protocol selection process.

F. System Output and Transmission Status:

The MATLAB command window displays the final output of the system including Selected client requirements, parameter values, final protocol scores, best protocol selection.

An example output is shown below:

Selected Requirements: [1 4]

MQTT Final Score = 1.45

LoRa Final Score = 1.72

Zigbee Final Score = 1.60

Best Protocol Selected: LoRa

Reason: Highest combined normalized score

Network Status: STABLE

Transmission Result: SUCCESS

```
Select Requirements :
1. Low Power
2. Low Latency
3. High Bandwidth
4. High Data Rate
Enter choices as vector (example [1 3]): 2

----- FINAL RESULT -----
Selected Requirements:      2

MQTT Final Score = 1.000
LoRa Final Score = 0.000
Zigbee Final Score = 0.600

Best Protocol Selected: MQTT
Reason: Highest combined normalized score.
Network Status: STABLE
Transmission Result: SUCCESS
```

Fig 11: System Status

This output confirms that the proposed adaptive protocol selection algorithm successfully identifies the most suitable communication protocol for the given network conditions and client requirements.

G. Overall System Performance

The simulation results demonstrate that the proposed system can effectively analyse protocol performance and dynamically select the optimal protocol for IoT mesh networks.

By incorporating client requirements and network parameters, the system improves communication efficiency and ensures reliable data transmission. The visualization results and performance graphs further validate the effectiveness of the proposed approach in adaptive IoT protocol selection.

V. CONCLUSION:

This paper focused on fixed data rate transmission protocols, energy-efficient routing techniques, congestion control methods, and hybrid transmission models constitute the foundation of current communication systems. Although these techniques help particular features like traffic management or energy usage, most of them lack dynamic adaptability to shifting network conditions. The fixed data rate protocols sometimes cause more delay under congestion, while energy-efficient routing approaches concentrate mostly on power optimization with restricted bandwidth awareness. Similarly, although they increase network stability, congestion and collision control solutions offer little protocol choice flexibility. Conversely, the suggested project presents an adaptive protocol selection framework that dynamically analyse several communication variables and picks the best protocol, hence enhancing general network performance in IoT mesh settings. The proposed system demonstrates the importance of integrating adaptive decision-making mechanisms in IoT communication networks. By evaluating multiple performance parameters simultaneously, the framework ensures that the selected protocol satisfies both network efficiency and application-specific requirements. The adaptive protocol selection process also helps reduce unnecessary energy consumption, minimize communication delay, and improve overall data transmission reliability within the mesh network environment. In addition, the simulation results

highlight that different communication protocols perform better under different network conditions. Therefore, relying on a single protocol for all scenarios may not always provide optimal performance. The proposed adaptive framework overcomes this limitation by enabling dynamic protocol evaluation and selection, allowing the system to adjust according to changing network conditions.

Overall, the proposed approach provides a flexible and scalable solution for IoT communication systems, supporting efficient data exchange between devices in distributed environments. The framework can be extended to support larger IoT networks and additional communication protocols, making it a promising solution for future intelligent networking applications.

REFERENCES:

- [1] L. Atzori, A. Iear, and G. Morabito, "The Internet of Things: A Survey," *Computer Networks*, vol. 54, no. 15, pp.2787-2805, Oct.2010.
- [2] D. B. Rawat and C. Bajracharya, "Energy-Efficient Transmission Strategies for IoT Networks," *IEEE Internet of Things Journal*, vol. 6, no.3, pp. 4512-4522, Jun. 2019.
- [3] W. Heintzelman, A. Chandrakasan, and H. Balakrishnan, "Energy-Efficient Communication Protocol for Wireless Microsensor Networks," in *Proc. IEEE Hawaii International Conference on System Sciences (HICSS)*, 2000, pp. 1-10.
- [4] J. N. Al-Karaki and A. E. Kamal, "Routing Techniques in Wireless Sensor Networks: A Survey," *IEEE Wireless Communication*, vol. 11, no. 6, pp. 6-28, Dec. 2004..
- [5] S. K. Singh, M. P. Singh, "Routing Protocols in Wireless Sensor Networks-A Survey," *International Journal of Computer Science & Engineering Survey*, vol. 1, no. 2, pp. 63-83, Nov 2010.
- [6] I. F. Akyildiz, W. Su, Y. Sankara Subramaniam, and E. Cayirci, "Wireless Sensor Networks: A Survey," *Computer Networks*, vol. 38, no. 4, pp. 393-422, Mar. 2002.
- [7] T. Clausen and P. Jacquet, "Optimized Link State Routing Protocol (OLSR)," *IETF RFC 3626*, Oct. 2003.
- [8] A. K. Singh, V. C. Gungor, "Adaptive Data Rate Control for IoT Networks: A Survey," *IEEE Communications Surveys & Tutorials*, vol. 21, no.3, pp. 3506-3533, 3rd Quarter 2019.
- [9] M. Wang and J. Zhang, *Machine-Type Communication for Maritime Internet of Things*. Cham, Switzerland: Springer 2021.
- [10] L. Chettri and R. Bera, "A Comprehensive Survey on Internet of Things (IoT) Toward 5g Wireless Systems," *IEEE Internet Things J.*, vol. 7, no. 1, pp. 16-32, Jan. 2020.
- [11] D. S. Deif and Y. Gadallah, "Classification of Wireless Sensor Networks Deployment Techniques," *IEEE Comm. Surveys Tuts.*, vol. 16, no. 2, pp. 834-855, 2nd Quart., 2014.
- [12] Y. Wang, K. Yang, W. Wan, Y. Zhang, and Q. Liu, "Energy-efficient data and energy integrated management strategy for IoT devices based on RF Energy Harvesting," *IEEE Internet Things J.*, vol. 8, no. 17, pp. 13640-13651, Sep. 2021.
- [13] K. Gulati, R. S. Kumar Boddu, D. Kapila, S. L. Bangare, N. Chandnani, and G. Saravanan, "A Review Paper on Wireless Sensor Network Techniques in Internet of Things (IoT)," *Mater. Today, Proc.*, vol. 51, pp. 161-165, May 2022, doi: 10.1016/j.matpr.2021.05.067.
- [14] L. D. Xu, W. He, and S. Li, "Internet of Things in Industries: A Survey," *IEEE Trans. Ind. Informat.*, vol. 10, no. 4, pp. 2233-2243, Nov. 2014, doi: 10.1109/TII.2014.2300753.

- [15] A. Karaki, A. Nasser, C. A. Jaoude, and H. Harb, “An adaptive sampling technique for massive data collection in distributed sensor networks,” in *Proc. 15th Int. Wireless Commun. Mobile Comput. Conf. (IWCMC)*, Tangier, Morocco, Jun. 2019, pp. 1255-1260, doi: 10.1109/IWCMC.2019.8766469.