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Integration of MANET and IoT for enhancing smart device communication infrastructure

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Abstract: The proliferation of Smart Devices and the Internet of Things (IoT) has revolutionized the way we interact with our surroundings. However, the seamless communication between these devices remains a significant challenge, particularly in dynamic and decentralized environments. This research proposes the integration of Mobile Ad Hoc Networks (MANETs) with IoT to enhance the communication infrastructure for smart devices. The integration aims to address the limitations of traditional communication protocols in scenarios where fixed infrastructure may be unavailable or impractical. MANETs, characterized by their self-organizing nature, provide a dynamic and adaptable solution for establishing ad-hoc networks on-the-fly. This research explores the synergy between MANETs and IoT to create a robust and flexible communication framework. The study investigates the key aspects of integration, including routing protocols, energy efficiency, security, and scalability. Routing protocols play a vital role in MANETs, and adapting them to suit the requirements of IoT devices is crucial for efficient communication. Energy efficiency is a critical concern for IoT devices with limited power resources, and the integration seeks to optimize energy consumption while maintaining reliable connectivity. The proposed integration offers a versatile solution for various applications, including smart homes, industrial automation, and smart cities. Through simulations and real-world experiments, the research aims to validate the effectiveness of the integrated MANET-IoT communication infrastructure in diverse scenarios. The findings of this study contribute to the development of more resilient and adaptive smart device networks, fostering the evolution of the IoT landscape in dynamic and challenging environments.

Keywords: MANET, IoT, LoRa, AODV, OLSR.

I. INTRODUCTION

The integration of Mobile Ad hoc Networks (MANET) and the Internet of Things (IoT) represents a cutting-edge approach to enhancing smart device communication infrastructure. MANET and IoT are two dynamic and rapidly evolving technologies that, when combined, have the potential to revolutionize the way smart devices communicate and collaborate in various environments.

Mobile Ad hoc Networks (MANET) are decentralized wireless networks where nodes communicate with each other without relying on a fixed infrastructure or centralized control. These networks are particularly well-suited for dynamic and ad-hoc environments, making them ideal for scenarios where smart devices need to establish communication quickly and efficiently, such as in emergency response situations, military operations, or large-scale events.

On the other hand, the Internet of Things (IoT) refers to the interconnected network of physical devices, vehicles, buildings, and other objects embedded with sensors, software, and network connectivity, enabling them to collect and exchange data. IoT has gained widespread adoption in various industries, including healthcare, agriculture, transportation, and smart cities, to improve efficiency, automation, and decision-making processes.

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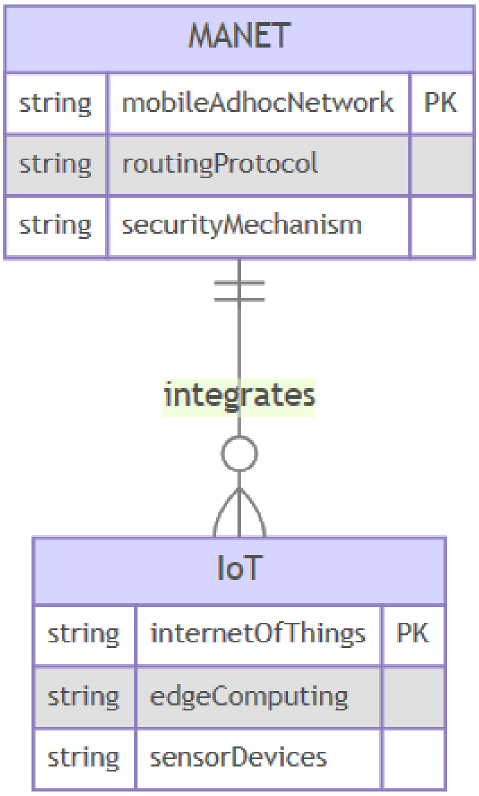

Fig.1.1. Class representation various attributes involved of integrating MANET with IoT

The integration of MANET and IoT aims to leverage the strengths of both technologies to create a robust and flexible communication infrastructure for smart devices. This integration [1] can enhance the scalability, reliability, and responsiveness of IoT devices by leveraging the self-organizing and adaptive nature of MANETs. In scenarios where traditional communication infrastructure may be unavailable or impractical, the combination of MANET and IoT can provide a resilient and adaptable solution.

The potential benefits of this integration include improved communication coverage, reduced latency, increased energy efficiency, and enhanced overall system performance. However, challenges such as security, routing optimization, and protocol interoperability need to be addressed to ensure the seamless integration and operation of MANET and IoT in real-world applications [2].

In summary, the integration of MANET and IoT holds great promise for advancing smart device communication [3] infrastructure, offering a flexible and resilient solution that can adapt to diverse and challenging environments. As these technologies continue to mature, they are likely to play a crucial role in shaping the future of communication systems for smart devices in a wide range of applications.

II. EXISTING SYSTEMS

Mobile Ad hoc Networks (MANET) and the Internet of Things (IoT) are two distinct but interconnected domains in the field of networking. MANETs are self-configuring networks of mobile nodes without a fixed infrastructure, while IoT involves the interconnection of various physical devices and objects through the internet.

A hybrid multipath energy and quality of service (QoS)-aware optimized link state routing protocol (MEQSA-OLSRv2) [4] for IoT networks. The protocol uses a multi criteria node rank metric to reduce complexity and control overhead. It outperforms existing schemes in heavy traffic load and high-mobility scenarios, enhancing QoS, reducing energy consumption, and decreasing energy cost per packet.
Communication architectures and topographies for MANET-connected IoT systems, focusing on standardized Routing Protocol for Low-power and Lossy Networks were investigated [5]. It discusses security threats, vulnerabilities, and proposes security enhanced protocols and trust models. The paper identifies research challenges in emerging MANET-IoT connectivity and suggests a synthesis of current and future proposals. Another research on Quality of Service (QoS)

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provisioning for video streaming in Mobile Ad hoc Networks (MANETs), discussing preliminary concepts, coding methods, challenges, and optimum parameters for video transmission [6]. 6LoWPAN, a combination of IPv6 and LoWPAN [7], enables small devices to transmit information wirelessly. It faces routing issues but incorporates a new routing header using different versions, protocols, and their classification based on memory usage, energy utilization, and application environment.

A parallel routing approach for mobile ad hoc networks was proposed [8], enhancing resource utilization and performance, compared to unicast routing algorithms, demonstrating superior performance. Mobile adhoc networks (MANETs) are dynamic networks with no central control. GloMoSim [9] simulates three MANET protocols: AODV, DSR, and WRP. WRP model outperforms AODV and DSR, making it a better choice for effective routing. An existing solution for future IoT [10] devices involves a multi-protocol architecture for M2M communication, endpoint user interfacing, and edge computation to reduce infrastructure costs and enhance setups. Another solution [11] proposes a communication system based on LoRaWAN and Zigbee protocols for long-distance data transmission in remote locations. The system consists of a sensor cluster, microcontroller, and Xbee module, designed for self-forming networks and energy efficiency. The system is compatible with IoT applications.

A proactive approach-based secure routing protocols for MANET-enabled IoT networks was investigated [12], focusing on resource-constrained networks and identifying security issues, lightweight protocols, and defense against active attacks. Research proposes a wireless-fidelity peer-to-peer communication strategy [13] for IoT devices, reducing capital investment and power infrastructure costs while allowing for lower data rates for further expansion, aiming to align with the technological vision of the future Internet. Ad-hoc networks are popular wireless technology for mobile hosts that introduces [14] a security mechanism for packet encoding and decoding using an arbitrary method selection scheme. The model outperforms existing models, with a 22% cost function and better performance in dissimilar analysis.

MANET is a dynamic wireless communication network with movable nodes, IoT devices, and cloud storage. It uses intrusion detection and secure data transmission through machine learning and genetic algorithms, improving overall system efficiency [15]. A study proposes an energy-saving strategy for Mobile Adhoc Networks (MANETs) [16], focusing on improving energy balance and network lifetime. The proposed method reduces energy usage by 60% and extends the network's lifespan by 73%. A QoS Multicast Routing (QSMR) protocol for IoT-enabled Mobile Ad Hoc Networks [17] in a Reconfigurable Intelligent Surface-aided Cell-Free Massive MIMO environment was performed. It uses cross-layer design, optimization problems, and a Deep Neural Network to establish a QMM route, outperforming other routing protocols.

To improve energy efficiency and security in mobile ad hoc networks (MANETs) a decentralized trust architecture was proposed [18]. Using a tree-block design, similarity metrics, and Deep Optimization Model, the approach enhances network performance in terms of energy efficiency, longevity, security, productivity, and route overhead.

It is worth noting that research and development in the area of integrating MANET with IoT are ongoing, and new systems and technologies continue to emerge as the fields of MANETs and IoT evolve.

III. PROPOSED SYSTEM

Integrating Mobile Ad-hoc Networks (MANET) with the Internet of Things (IoT) involves connecting and coordinating devices in a dynamic and self-configuring network environment. This integration can be challenging due to the unique characteristics of both MANET and IoT. Following are the steps undergone for the research process:-

1. Understand MANET and IoT Characteristics:

- MANET Characteristics: Self-organizing, dynamic topology, infrastructure-less, and decentralized.
- IoT Characteristics: Heterogeneous devices, low-power, massive scale, and diverse communication technologies.

2. Define Use Case and Requirements:

- Identify the specific scenario or use case for integrating MANET and IoT. Understand the requirements such as data rate, latency, scalability, and reliability.

3. Choose Communication Protocols:

- Select appropriate communication protocols that suit both MANET and IoT. Common MANET protocols include AODV (Ad-hoc On-Demand Distance Vector), DSR (Dynamic Source Routing), and OLSR (Optimized Link State Routing). For IoT, protocols like MQTT, CoAP, or AMQP may be suitable.

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4. Security Considerations:

- MANET and IoT are vulnerable to various security threats. Implement security measures such as authentication, encryption, and intrusion detection systems to secure communication.

5. Device Compatibility:

- Ensure that IoT devices and MANET nodes can communicate effectively. Address issues related to device heterogeneity, power constraints, and communication technologies.

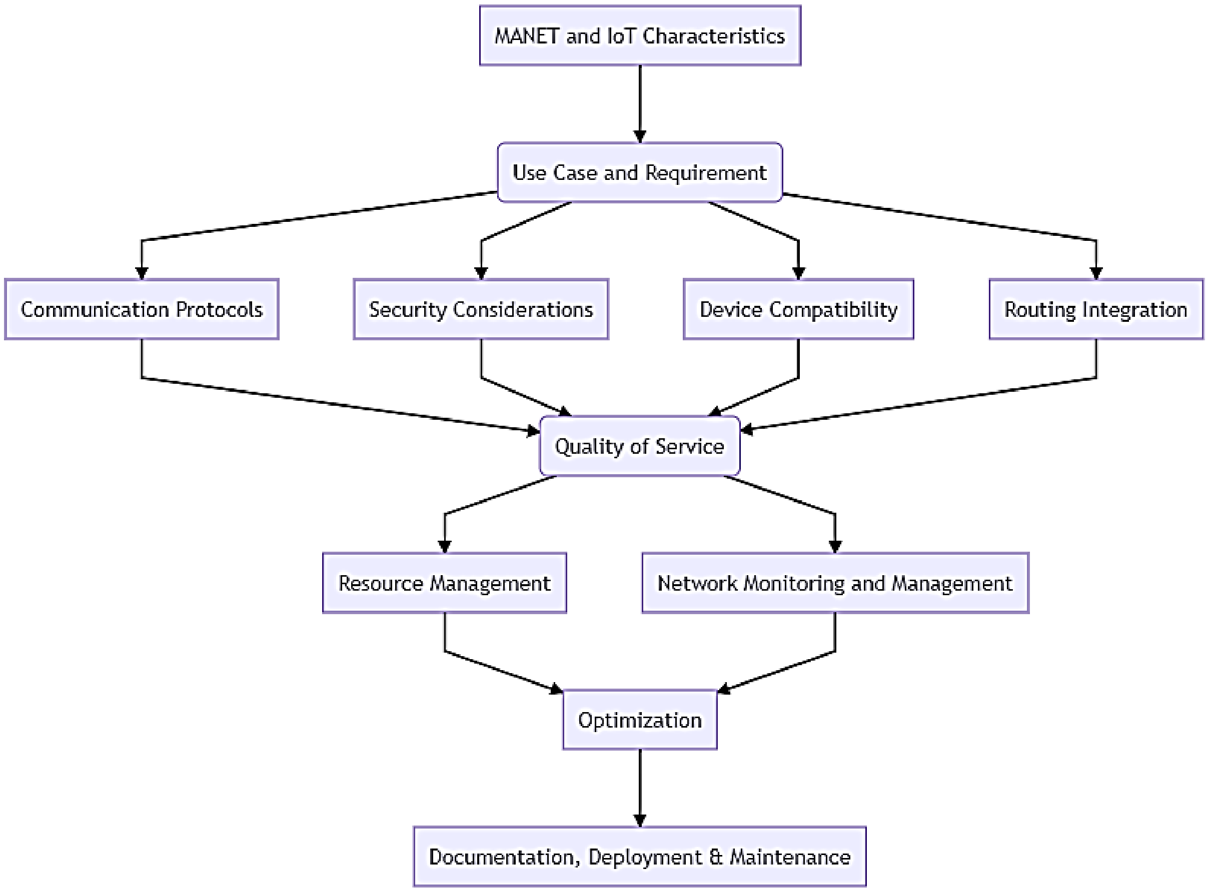

Fig.3.1. Block representation of the sequential flow of development for the proposed system

6. Routing Integration:

- Integrate MANET routing protocols with IoT devices. This may involve adapting existing MANET routing algorithms to work with IoT requirements, considering factors like energy efficiency and variable network conditions.

7. Quality of Service (QoS):

- Establish QoS parameters based on the requirements of the integrated system. This includes addressing latency, reliability, and data rate considerations.

8. Resource Management:

- Implement resource management strategies to handle the dynamic nature of MANETs and the resource-constrained nature of IoT devices. This involves optimizing energy consumption and bandwidth usage.

9. Network Monitoring and Management:

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- Develop mechanisms for monitoring and managing the integrated network. This includes fault detection, performance monitoring, and dynamic reconfiguration.

10. Test and Simulation:

- Conduct thorough testing and simulations to validate the integrated MANET-IoT system. Evaluate its performance under various conditions and assess its scalability.

11. Optimization:

- Optimize the integrated system based on the test results. Address any identified issues and fine-tune parameters for better performance.

12. Documentation and Maintenance:

- Document the integrated MANET-IoT solution, including configurations, protocols used, and any custom implementations. Establish a maintenance plan to address future updates or changes.

13. Deployment:

- Deploy the integrated MANET-IoT solution in the target environment. Monitor its performance in real-world scenarios and make adjustments as needed.

Following is the pseudo-code of process flow of the proposed system:-

```
A[MANET and IoT Characteristics] --> B
B(Use Case and Requirement) --> C
B --> D
B --> E
B --> F
C[Communication Protocols]--> G
D[Security Considerations] --> G
E[Device Compatibility] --> G
F[Routing Integration] --> G
G(Quality of Service) --> H
G --> I
H[Resource Management] --> J
I[Network Monitoring and Management] --> J
J[Optimization]-->K
K[Documentation, Deployment & Maintenance ]
```

Remember that the integration of MANET and IoT is a complex task that requires a deep understanding of both domains. Depending on the specific use case, additional steps or considerations may be necessary. Additionally, staying informed about the latest developments in MANET and IoT technologies is crucial for successful integration.

IV. RESULTS & DISCUSSION

The system setup guidelines for integrating Manet with the Internet of Things are depicted in Figure 4.1. Using LoRa technology, a sensor node is established and configured with attributes such as network ID and sensor radius. Latitude and longitude are the most often used coordinate systems for describing a location's geographical coordinates. Nodes may be built using network IDs and protocol LoRa assigned to these nodes to build a network.
We allocated 10, 20, 30, and 40 nodes to each cluster for configurations, with one cluster head for each cluster, and illustrated the results for different nodes.

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Figure: 4.1 MANET's capabilities in the Internet of Things to route packets from the source IoT end-device to the target via multiple cluster heads

Figure 4.1 depicts the advanced features and functions of mobile ad hoc networks (MANETs) in the context of the Internet of Things, in which end-devices connect with one another via a MANET infrastructure. This demonstrates the dynamic and self-organizing character of MANETs. Figure 4.1 also works as a visual aid to explain the advantages and complications of employing MANETs for packet routing inside the Internet of Things, highlighting their potential to deliver resilient and flexible communication paths in demanding and dynamic situations.

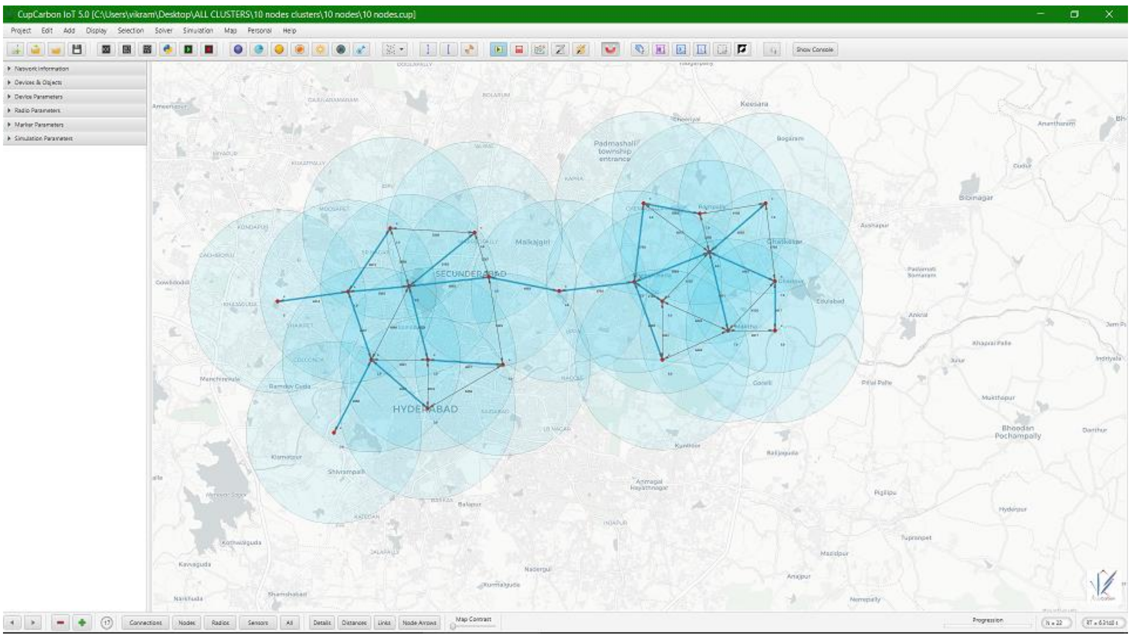

Figure: 4.2 MANET's capabilities in the Internet of Things to route packets from the source IoT end-device to the destination for 10 nodes via multiple cluster heads.

Figure 4.2 depicts MANET's (Mobile Ad-Hoc Network) capabilities in the Internet of Things (IoT) context, specifically the routing of packets from a source IoT end-device to a destination involving 10 nodes and employing multiple cluster

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heads for efficient communications. MANET, which is recognised for its dynamic and self-configuring capabilities, is critical in easing data transfer in this IoT context.

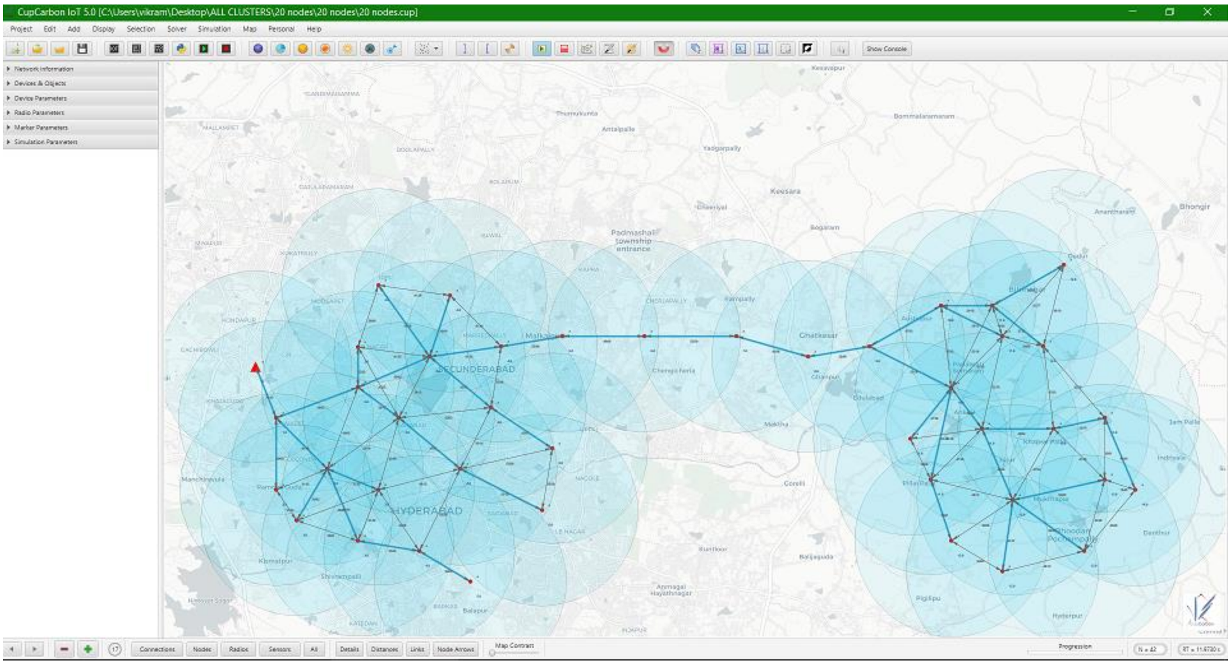

Figure: 4.3 MANET's capabilities in the Internet of Things to route packets from the source IoT end-device to the destination for 20 nodes via multiple cluster heads.

Figure 4.3 illustrates the capabilities of MANET (Mobile Ad-Hoc Network) in the context of the Internet of Things. Specifically, it demonstrates how packets are routed from a source IoT end-device to a destination using 20 nodes and various cluster heads for efficient communication.

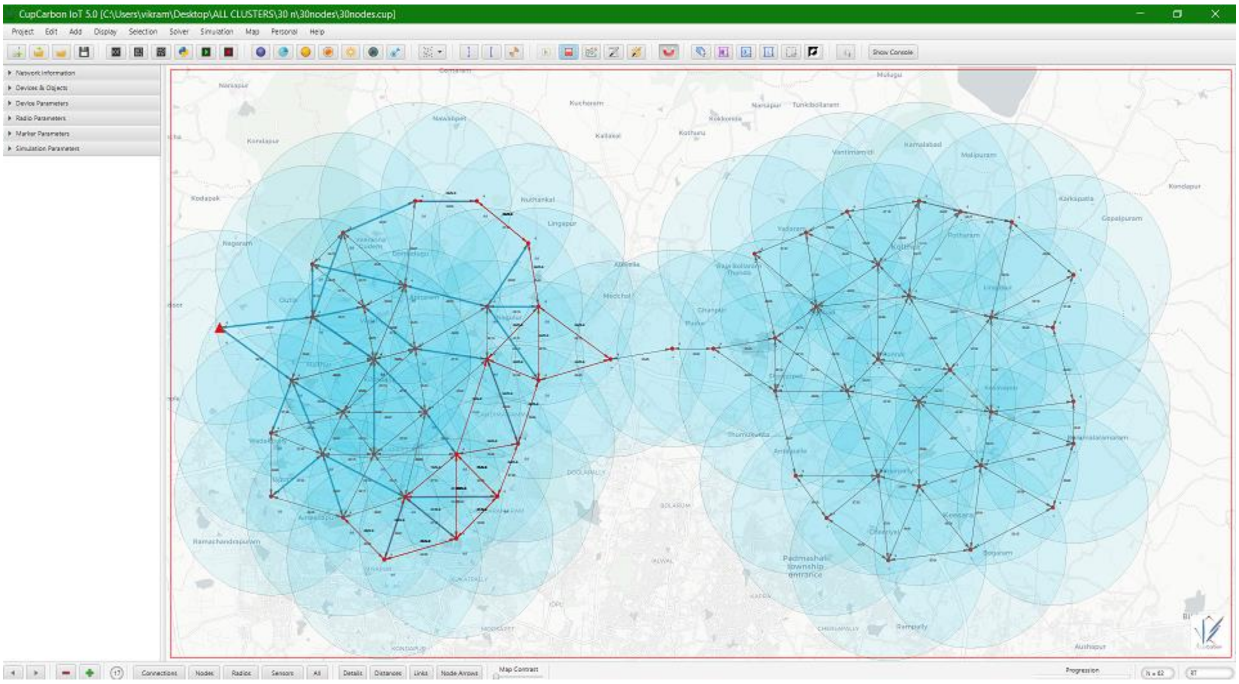

Figure: 4.4 MANET's capabilities in the Internet of Things to route packets from the source IoT end-device to the destination for 30 nodes via various cluster heads.

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Figure 4.4 illustrates the capabilities of MANET (Mobile Ad-Hoc Network) in the context of the Internet of Things. Specifically, it demonstrates how packets are routed from a source IoT end-device to a destination using 30 nodes and various cluster heads for efficient communication.

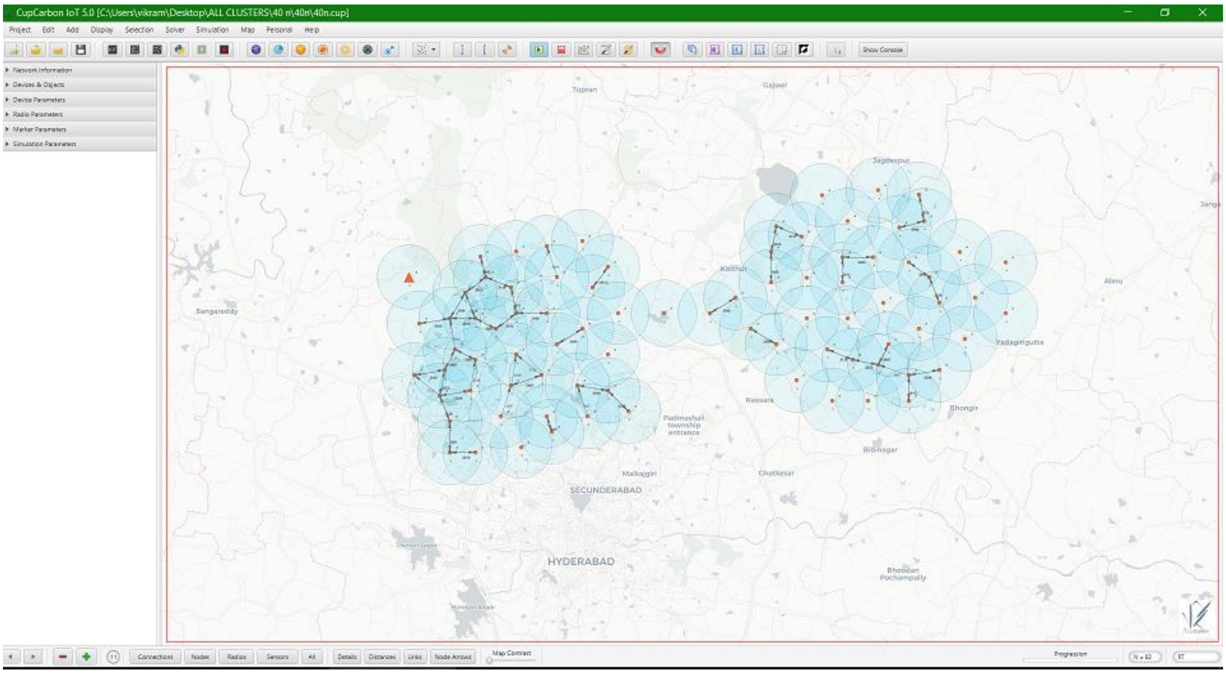

Figure: 4.5 MANET's capabilities in the Internet of Things to route packets from the source IoT end-device to the destination for 40 nodes via multiple cluster heads.

Figure 4.5 illustrates MANET (Mobile Ad-Hoc Network) capabilities in the Internet of Things (IoT) context, specifically the routing of packets from a source IoT end-device to a destination involving 40 nodes and employing multiple cluster heads for efficient communication. The Broadcast Packet Reception Ratio(BPPR) of simulation over various systems was collected for comparison.

Table:4.1 Simulation scenario of MANET and Internet of things using LoRa

No of Nodes	Signal strength	Mean BPPR of existing systems [19]	BPPR of proposed system
5 nodes	5000	48.23%	54.16%
10 nodes	5000	22.80%	28.20%
20 nodes	5000	19.11%	24.41%
30 nodes	5000	16.45%	19.80%
40 nodes	5000	15.87%	19.77%

These conditions differ in terms of distance, signal strength, number of nodes required, messages transmitted, and BPPR from the source, as well as whether the destination receives or loses them.

The BPPR is the fraction of packets transmitted by network nodes that communicate via broadcast. Broadcasting is a typical communication strategy used in MANET and IoT to provide information to several nodes at the same time. Figure 4.6 shows how the BPPR fluctuates under various simulation scenarios, with a particular emphasis on the integration of LoRa technology into MANET and IoT systems using CupCarbon as the simulation platform. The findings shed light on the efficiency and efficacy of communication in such settings, helping to optimize and improve wireless networks in real-world applications. It should be noted that as the number of nodes rises, the BPPR drops owing to packet loss.

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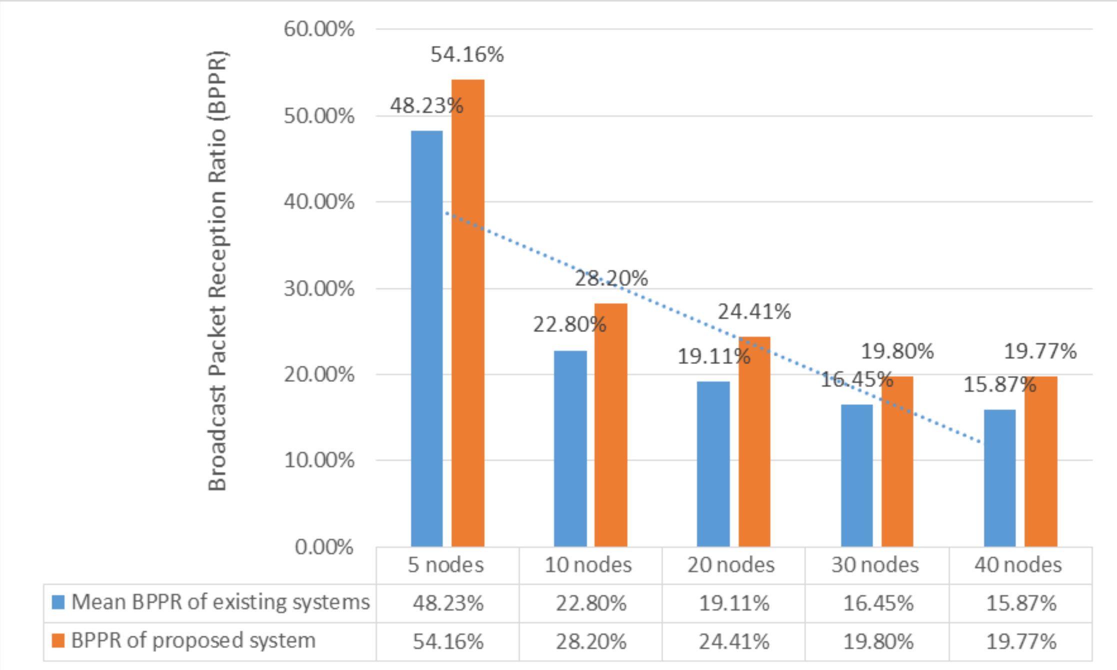

Figure:4.6 BPPR related to the Simulation scenario of MANET and Internet of things using LoRa.

V. CONCLUSION

The integration of Mobile Ad-hoc Networks (MANET) and the Internet of Things (IoT) presents a compelling paradigm for advancing smart device communication infrastructure. This synergy harnesses the strengths of MANET's dynamic, self-organizing nature and the pervasive connectivity of IoT devices, ushering in a new era of efficient and resilient communication networks. One key advantage of this integration lies in the enhanced scalability and flexibility it offers to smart device communication. MANET's ability to dynamically adapt to changing network topologies complements the diverse and often unpredictable nature of IoT deployments. As the number of IoT devices continues to proliferate, the integration with MANET ensures that the communication infrastructure can seamlessly accommodate this exponential growth, providing a robust framework for the expanding ecosystem of interconnected devices.

Furthermore, the collaboration between MANET and IoT contributes to improved reliability and fault tolerance in smart device communication. MANET's self-healing capabilities enable the network to quickly adapt to node failures or changes in the environment. This resilience is crucial for maintaining uninterrupted communication among IoT devices, especially in scenarios where traditional infrastructures may falter. The integration also facilitates energy-efficient communication, a critical consideration in the realm of IoT, where many devices operate on limited power resources. MANET's adaptive routing mechanisms can optimize energy consumption by dynamically adjusting communication paths, thereby prolonging the operational lifespan of IoT devices and reducing the overall environmental impact of smart device networks.

In conclusion, the integration of MANET and IoT holds great promise for revolutionizing smart device communication infrastructure. The collaborative synergy between these technologies not only addresses the challenges of scalability, reliability, and energy efficiency but also paves the way for innovative applications and services in the ever-expanding landscape of the Internet of Things. As we continue to witness the evolution of smart ecosystems, this integrated approach stands as a cornerstone for building resilient, adaptive, and sustainable communication networks for the future.

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