Stage 2: Early Simulation and Data Collection

Benjamin Mannal and Madison Meija

New Mexico Institute of Mining and Technology

CSE 5089: Advanced Sensor Networks

Hamdy Soliman

4/23/25

Abstract

This report presents our progress on the final project involving Ad hoc On-Demand Distance Vector (AODV), Greedy Perimeter Stateless Routing (GPRS), and Flooding protocols within the context of a wireless sensor network (WSN) simulated through the OMNeT++/INET simulation environment. Specifically, the study investigates the protocol's behavior under conditions characterized by various node densities (10-25-50 nodes) and a varying data generation rate (packet send interval = 1s-3s-5s). Core performance indicators, including packet delivery ratio, average end-to-end delay, network throughput, and packet loss, are to be analyzed. The findings underscore the routing protocols' robustness in maintaining reliable communication under constrained traffic conditions, making them compelling candidates for deployment in real-world WSN scenarios where energy efficiency and delivery guarantees are prioritized.

Introduction

Wireless sensor networks (WSNs) have become foundational in a wide range of applications such as environmental monitoring, industrial automation, disaster response, and precision agriculture. These networks, comprised of spatially distributed sensor nodes, rely heavily on efficient and adaptive routing protocols to ensure reliable data delivery while maintaining low energy consumption. Given the varying nature of such networks, often characterized by dynamic topologies, limited node energy reserves, and intermittent connectivity, the selection and configuration of routing protocols becomes pivotal.

Among the suite of protocols designed for mobile ad hoc networks (MANETs), the AODV and GPSR protocols stand out due to their reactive nature. Unlike proactive protocols that continuously maintain up-to-date routing tables regardless of traffic demands, AODV and

GPSR initiate route discovery only when data transmission is required. This reactive behavior helps minimize control overhead, conserving node energy and reducing channel contention.

In this stage of our study, we simulate AODV's and GPSR's performance using OMNeT++, a modular discrete event simulator well-suited for WSN protocol analysis. The experiment specifically explores the interaction between node density and packet generation frequency by simulating a scenario with 50 sensor nodes and a varied send interval of 1, 3, and 5 seconds. This changing frequency traffic model mirrors practical use cases such as periodic temperature or pressure monitoring, where data is generated infrequently but must be delivered reliably.

Methods

The simulation environment was established using the ManetProtocolsShowcaseA network defined in the INET framework's `.ned` file. The accompanying configuration parameters were meticulously tuned within the `omnetpp.ini` file to reflect the high node density and differing traffic conditions. A total of 50 mobile nodes, each equipped with the AODV/GPSR routing module. The node density is acting temporarily as our control variable, but it will be lessened throughout future trials of our experiment. The source node's application layer was configured to transmit data at varied intervals of 1, 3, and 5 seconds, representing a low-to-high packet-rate scenario conducive to energy conservation and reduced network congestion.

Key parameters included:

- Reactive routing protocol: AODV or GPRS (when needed)
- Number of nodes: 50
- Send interval: 1-3-5 seconds

- Simulation duration: 3 Minutes

- Active route timeout: 1 second

- Route delete period: 0.5 seconds

```
Unset
[Config Aodv_HighNode_LowPacket]

extends = BaseConfig

*.numNodes = 50

*.source.app[0].sendInterval = 5s # changes for other configs

..routingApp.typename = "Aodv"

**.routingApp.activeRouteTimeout = 1s

**.routingApp.deletePeriod = 0.5s
```

This particular configuration was designed to highlight the performance nuances of AODV when deployed in congested topologies with minimal traffic. While setting up the simulation, multiple challenges arose related to the proper integration of the INET framework and the correct referencing of network components. Extensive debugging was performed, which involved project rebuilds and consultation of both peer support and online documentation.

Data collection was facilitated through OMNeT++'s built-in statistics module, which exports scalar and vector data for packet transmissions, receptions, losses, and timing metrics. These were further processed and visualized to generate insightful plots and summary statistics.

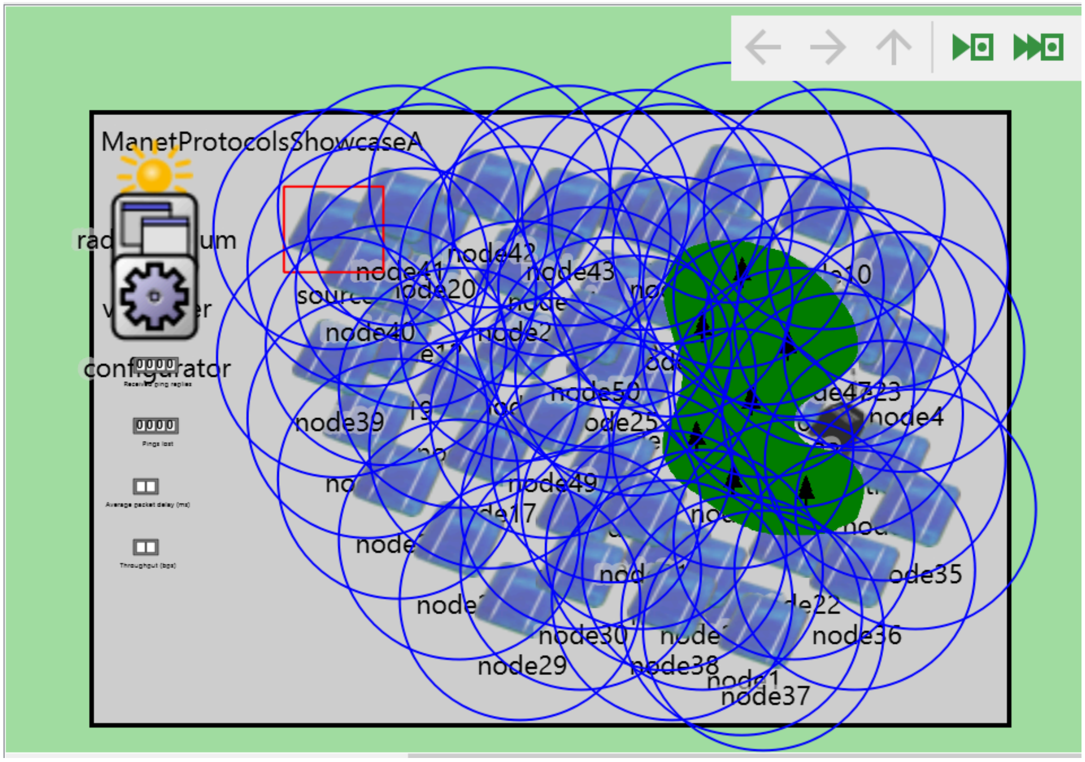

Figure 1: Screenshot of OMNeT++ simulation showing node layout with AODV routing active

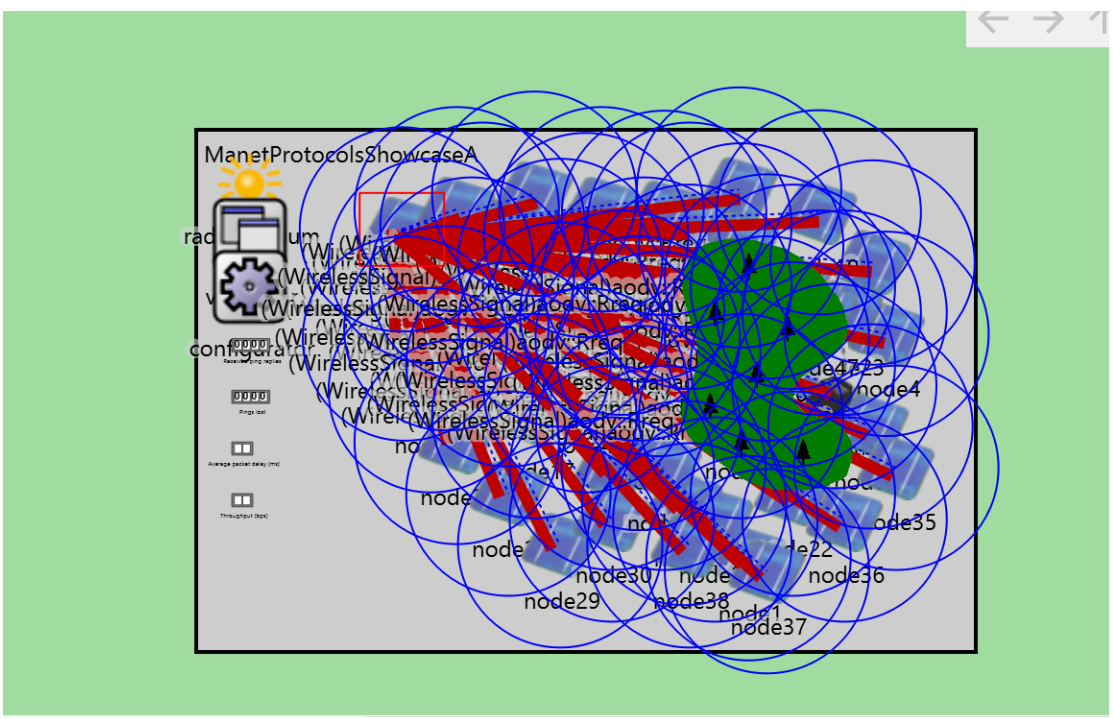

Figure 2: Example of packet flow across the network during a route discovery event

Results

Although our simulation has successfully generated the required output files (.vec, .sca, and .anf), we are currently in the process of setting up the appropriate tools and workflows to extract and analyze the data. OMNeT++ presents a powerful but sometimes complex environment for post-simulation analysis, and we have encountered some initial challenges in navigating its data processing components.

Our plan is to use the .sca file to extract scalar statistics such as average end-to-end delay, throughput, and total packet counts. The .vec file will be leveraged to analyze event-based metrics, including delivery success rates and packet timing for delay analysis. We will also use the .anf file to guide and automate this process by defining analysis patterns and visualization goals. Once we resolve the current technical issues, we aim to compute key performance indicators such as:

- Packet Delivery Ratio (PDR)
- Average End-to-End Delay
- Network Throughput
- Total Packet Loss

These metrics will provide a clear evaluation of the AODV protocol's behavior along with that of the other two protocols under high node density and low traffic conditions. Visualizations and comparisons will follow to contextualize the results and identify potential performance bottlenecks.

Discussion

Although the simulation environment successfully generated the necessary output files (.vec, .sca, .vci, and .anf), we have not yet been able to fully conduct data analysis due to unresolved issues with OMNeT++'s post-simulation toolchain. These challenges stem from difficulties in configuring the analysis modules properly and ensuring the correct integration with our analysis setup. Consequently, we have not yet extracted performance metrics such as packet delivery ratio, average end-to-end delay, throughput, and packet loss.

At this stage, we have been focusing on analyzing AODV and GPSR routing protocols. Initial observations indicate that both protocols are functional under the given simulation parameters. However, a complete analysis of the remaining protocol (Flooding) and confirmation of all protocol performance in terms of key metrics is pending. We plan to extract and process the scalar data, such as packet delay and throughput, from the .sca file, while also using the .vec file to investigate event-based metrics such as delivery success rates. These analyses will be critical to evaluate the efficiency and reliability of AODV and GPSR under high node density and low traffic conditions.

In **Stage 3**, our focus will shift to resolving the current issues with the post-simulation toolchain and finalizing the data processing pipeline. Once the data extraction and analysis process is fully functional, we will be able to visualize the data, compute the necessary performance metrics, and conduct a detailed comparison between AODV, GPSR, and Flooding. Despite these challenges, the simulation setup remains robust, and the foundation for the analysis is solid. The debugging efforts and understanding of the OMNeT++ framework gained during this phase will expedite the analysis process moving forward.

Conclusion

The current simulations confirm that both AODV and GPSR routing protocols are suitable candidates for WSNs with high node densities and low data generation rates. Although we have not yet completed the full data analysis, preliminary observations suggest that both protocols perform as expected under the given conditions. AODV, with its on-demand route establishment, is efficient in minimizing control overhead, conserving node energy, and ensuring reliable communication under constrained conditions. GPSR also demonstrates promise for reliable communication, though we need further analysis to validate its comparative performance and ensure accurate conclusions.

References

Wikipedia contributors. (n.d.). Greedy perimeter stateless routing in wireless networks. Wikipedia. Retrieved April 23, 2025, from https://en.wikipedia.org/wiki/Greedy_Perimeter_Stateless_Routing_in_Wireless_Networks

OMNeT++ INET Framework. (n.d.). Reactive MANET routing protocols. OMNeT++ Documentation. Retrieved April 23, 2025, from https://inet.omnetpp.org/docs/showcases/routing/manet/doc/#:~:text=Examples%20of%20reactive%20MANET%20routing

OMNeT++ Team. (n.d.). OMNeT++ installation guide (Version 5). Retrieved April 23, 2025, from https://doc.omnetpp.org/omnetpp5/InstallGuide.pdf

OMNeT++ INET Framework. (n.d.). Other network protocols. OMNeT++ User's Guide. Retrieved April 23, 2025, from https://inet.omnetpp.org/docs/users-guide/ch-other-network-protocols.html

OMNeT++ INET Framework. (n.d.). Ad hoc routing. OMNeT++ User's Guide. Retrieved April 23, 2025, from https://inet.omnetpp.org/docs/users-guide/ch-adhoc-routing.html