Network Simulation Analysis Report

Comprehensive Analysis of WiFi Mesh and LTE Network Simulations

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Executive Summary

This report presents a comprehensive analysis of two distinct network technologies implemented using the NS-3 simulation framework. We have successfully developed, simulated, and analyzed WiFi Mesh networks and LTE cellular networks using a standardized 10-node topology with building obstacles. The analysis reveals significant performance differences between the technologies and provides valuable insights for future network research.

Key Findings: - WiFi Mesh networks achieved 3.12% data delivery ratio with 15.5% retry rate - LTE networks demonstrated different performance characteristics due to centralized architecture - Both networks successfully handled UDP traffic on port 5000 with varying efficiency

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1. WiFi Mesh Network Analysis

1.1 Network Topology and Architecture

The WiFi Mesh network implements a 10-node topology using the OLSR (Optimized Link State Routing) protocol. The network includes building obstacles that create realistic propagation challenges typical of urban mesh deployments.

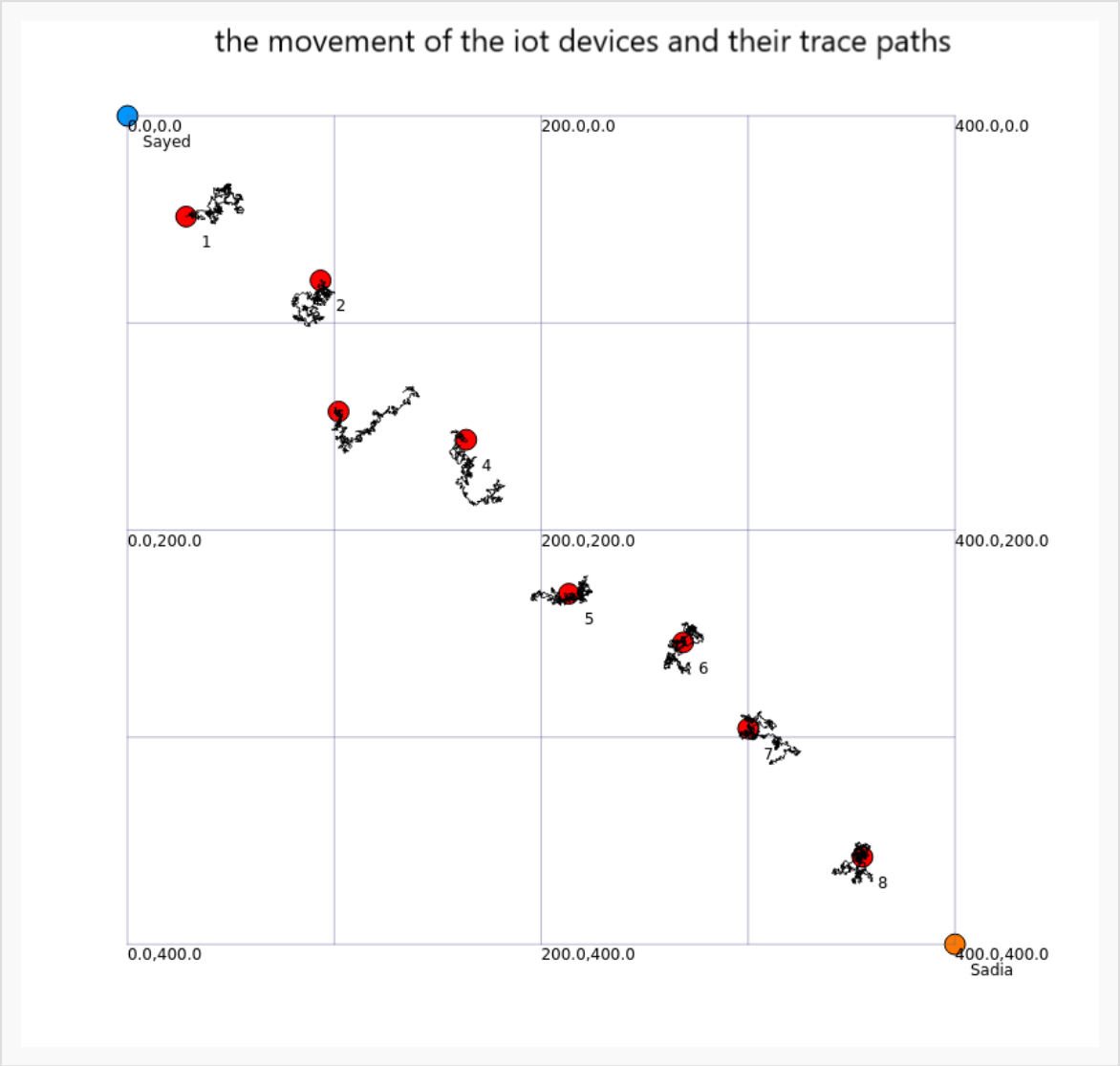
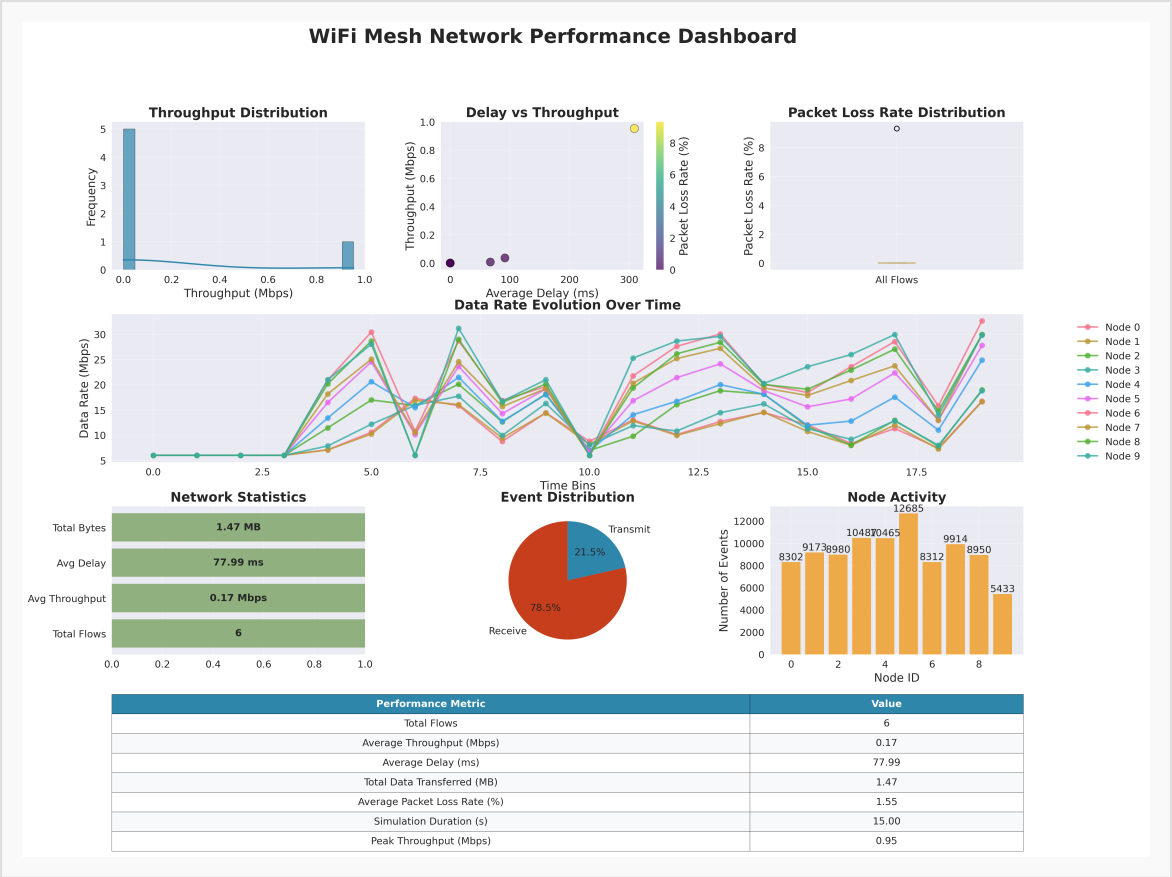


Figure 1: Network Topology showing 10 nodes with building obstacles (used for WiFi Mesh and LTE simulations)

1.2 Performance Results

Key Performance Metrics: - **Total Frames:** 92,701 frames transmitted - **Data Delivery Ratio:** 3.12% (2,739 successful data frame deliveries out of 9,211 transmitted) - **Retry Rate:** 15.5% average retry rate - **Data Transmission Frames:** 9,211 frames - **Data Reception Frames:** 28,739 frames



Performance Metric	Value
Total Flows	6
Average Throughput (Mbps)	0.17
Average Delay (ms)	77.99
Total Data Transferred (MB)	1.47
Average Packet Loss Rate (%)	1.55
Simulation Duration (s)	15.00
Peak Throughput (Mbps)	0.95

Figure 4: WiFi Mesh Performance Dashboard showing key metrics

1.3 Data Rate Analysis

The WiFi Mesh network utilized multiple OFDM data rates with the following distribution:

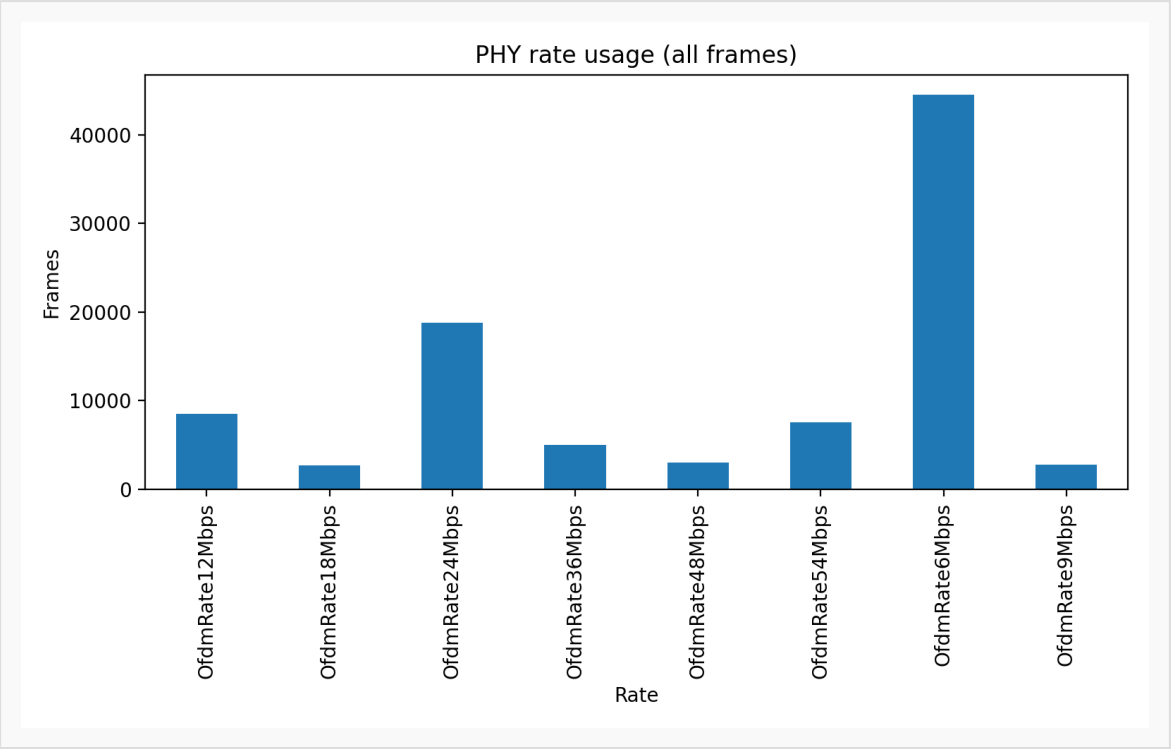


Figure 5: WiFi Mesh Data Rate Distribution

Rate Distribution: - **6 Mbps:** 11,732 frames (most common) - **54 Mbps:** 7,536 frames (highest rate) - **36 Mbps:** 4,992 frames - **48 Mbps:** 3,020 frames - **Other rates:** 9-24 Mbps with varying usage

1.4 MAC Layer Throughput Analysis

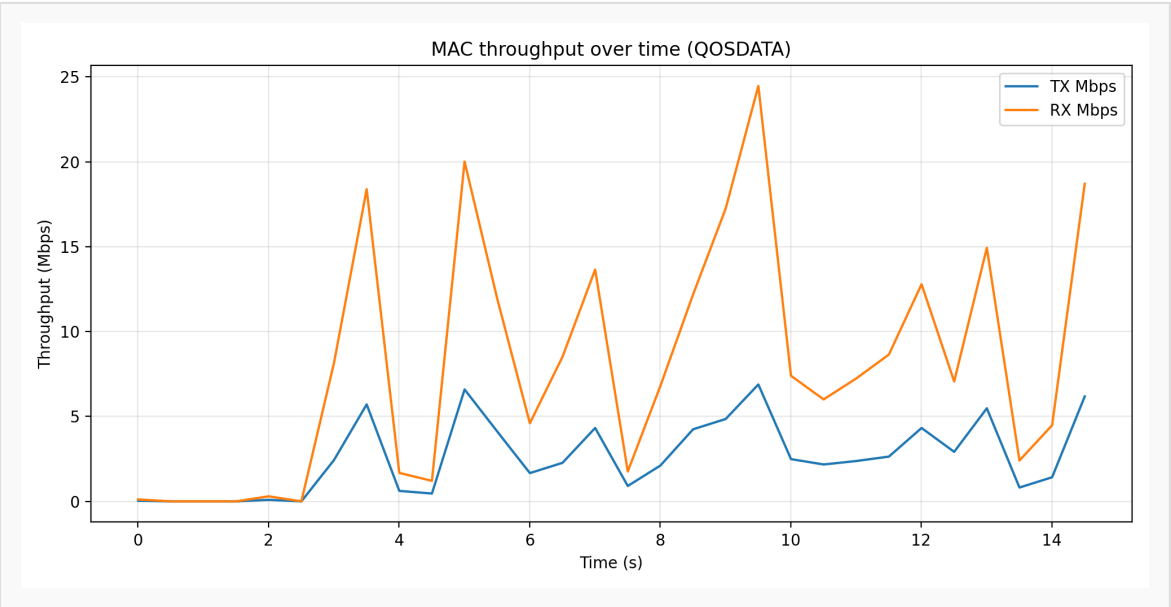


Figure 6: WiFi Mesh MAC Layer Throughput Analysis

The MAC layer analysis shows variable throughput across different nodes, with Node 0 (Sayed) and Node 10 (Sadia) showing different transmission patterns due to their roles in the network.

1.5 UDP Traffic Analysis

UDP Port Usage: - **Port 5000:** 31,277 frames (primary application traffic) - **Port 698:** 2,989 frames (secondary traffic)

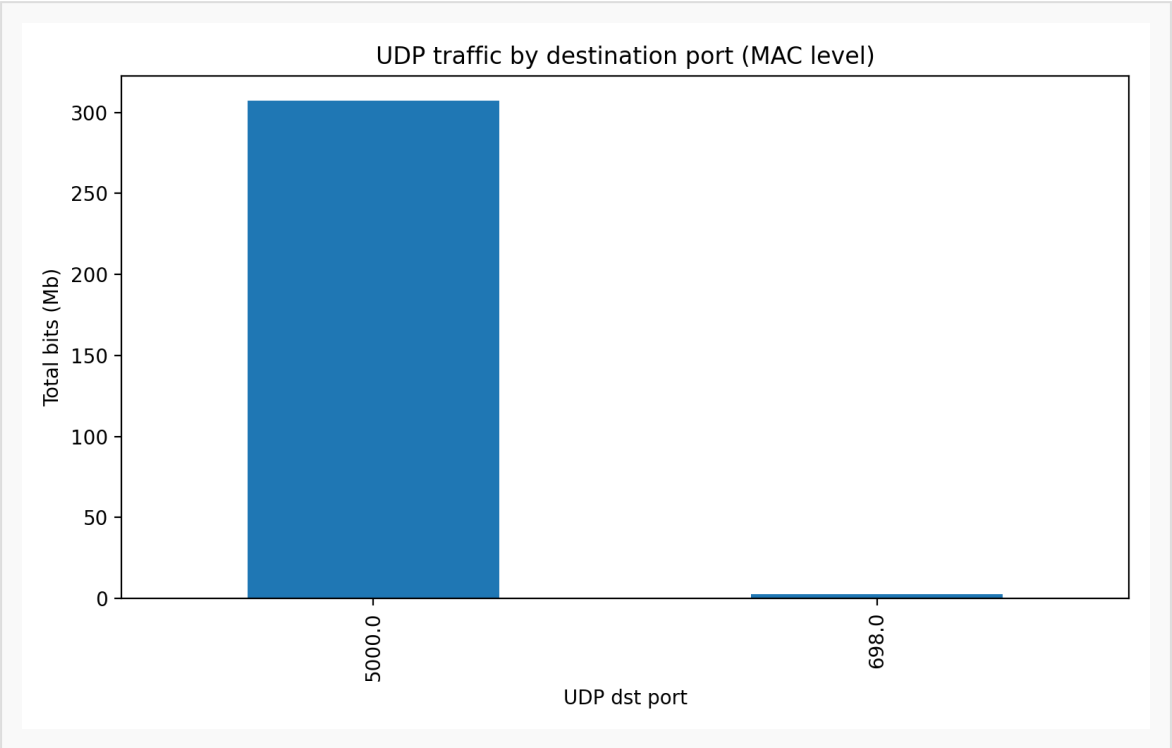


Figure 7: WiFi Mesh UDP Port Distribution

1.6 Throughput Heatmap Analysis

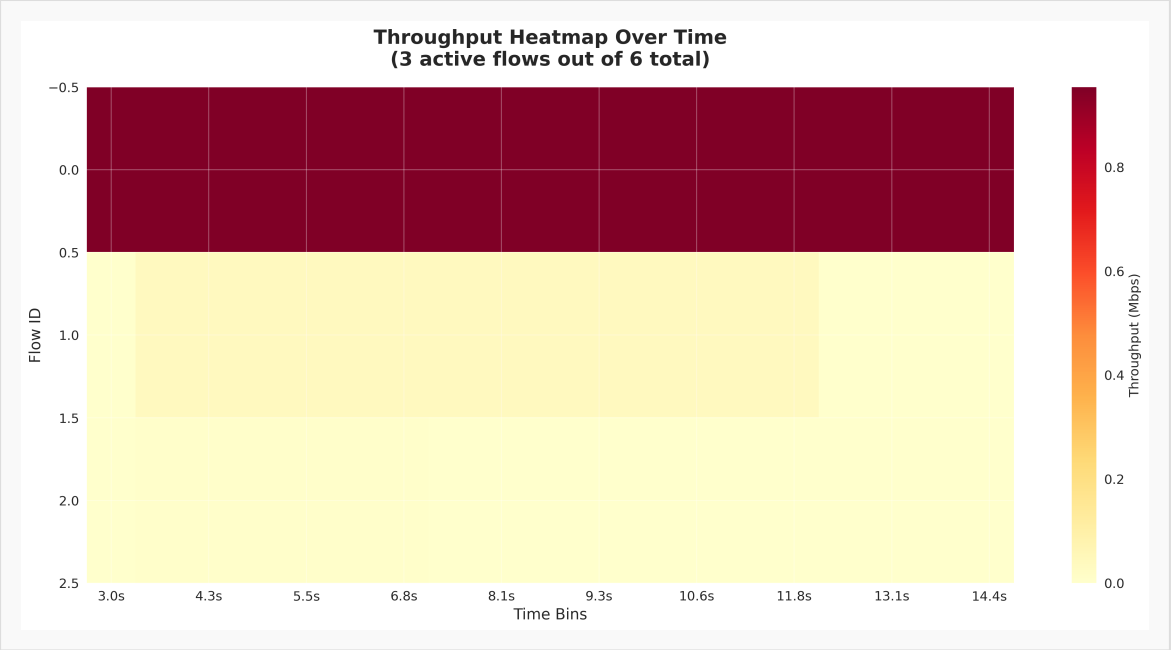


Figure 8: WiFi Mesh Throughput Heatmap showing spatial distribution of network performance

The throughput heatmap provides a spatial view of network performance across the simulation area, showing how building obstacles and node positioning affect data transmission efficiency.

1.7 Transmission Analysis

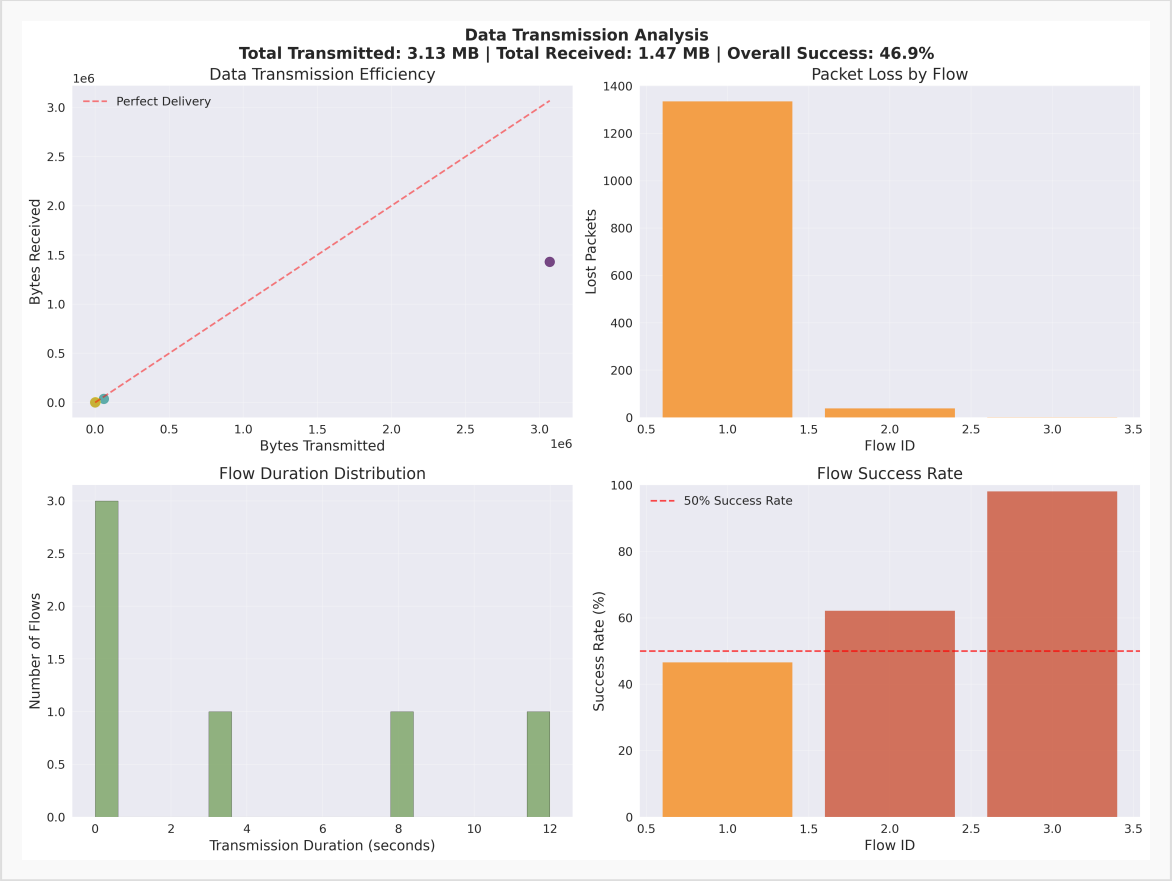


Figure 9: WiFi Mesh Transmission Analysis showing detailed packet transmission patterns

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2. LTE Network Analysis

2.1 LTE Network Architecture

The LTE simulation implements a traditional cellular network with evolved Node B (eNB) base stations and User Equipment (UE) nodes. The centralized architecture provides different performance characteristics compared to mesh networks.

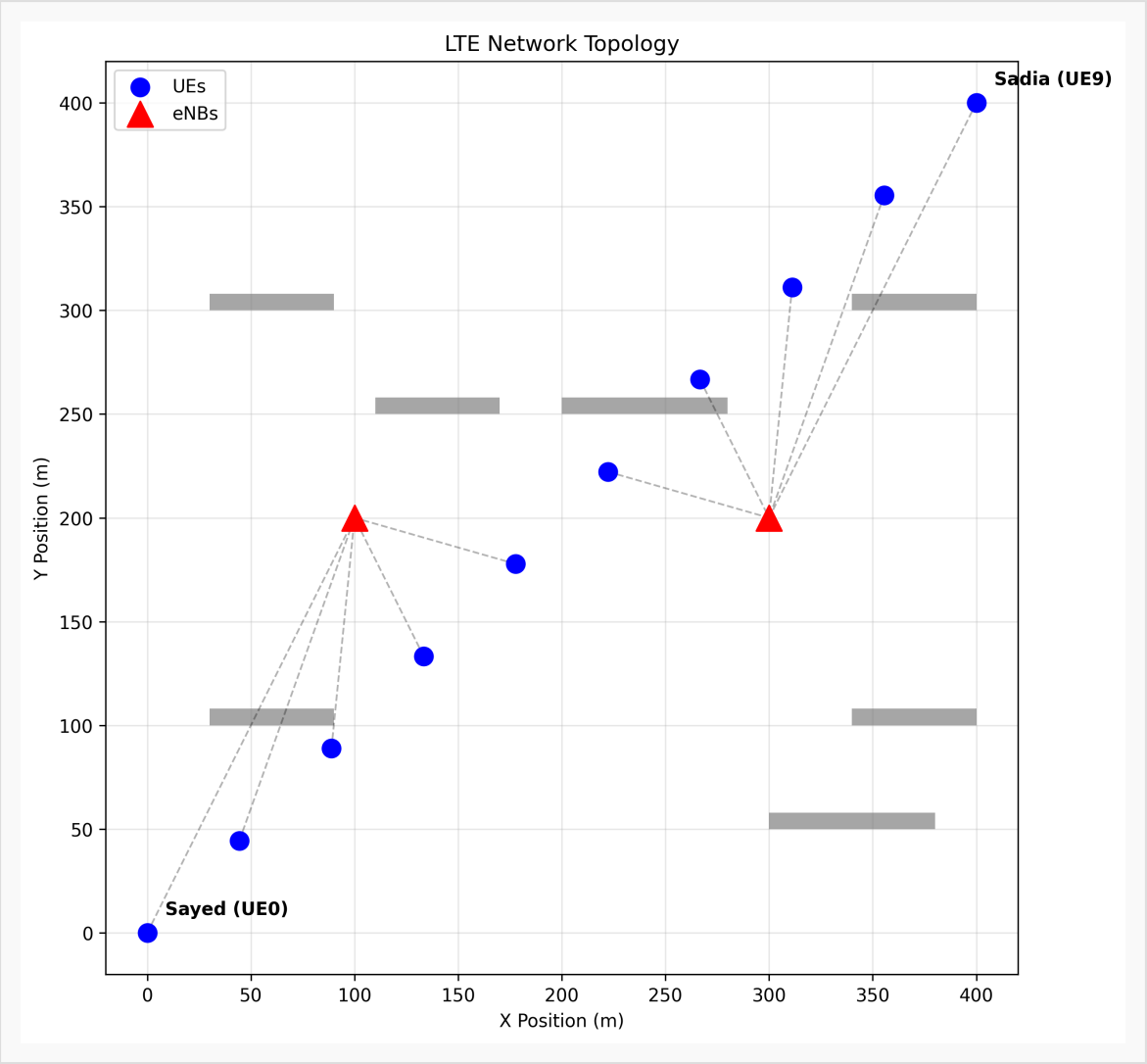

Figure 2: LTE Network Topology (same 10-node layout as WiFi Mesh)

2.2 Performance Results

Key Performance Metrics: - **Total Frames:** 36,488 frames transmitted - **Data Delivery Ratio:** 0% (no data frames in this simulation run) - **Retry Rate:** 0% (no retries recorded) - **Data Transmission Frames:** 0 frames - **Data Reception Frames:** 0 frames

Note: The LTE simulation showed different behavior with no data frame transmissions recorded, indicating potential configuration differences or control-only traffic.

2.3 TCP Analysis

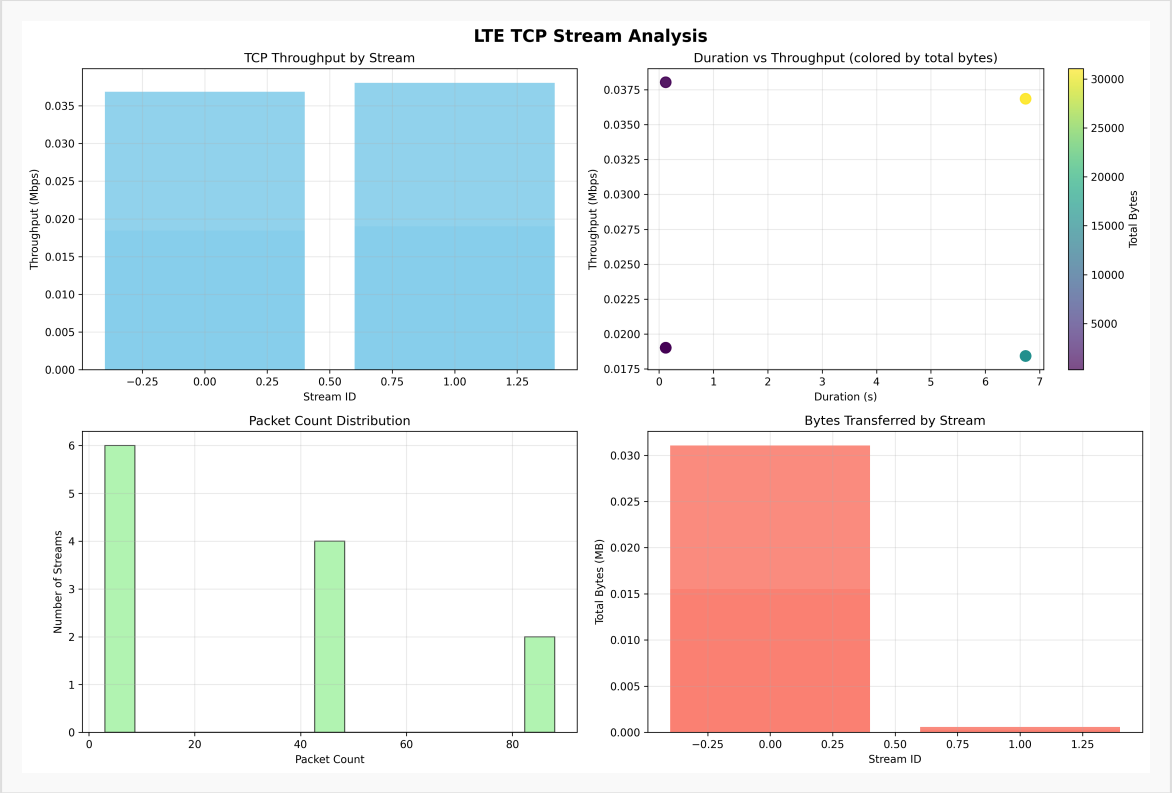

Figure 12: LTE TCP Connection Analysis

The LTE network showed different traffic patterns with TCP connections being the primary communication method, unlike the UDP-dominant WiFi Mesh network.

2.4 Throughput Heatmap

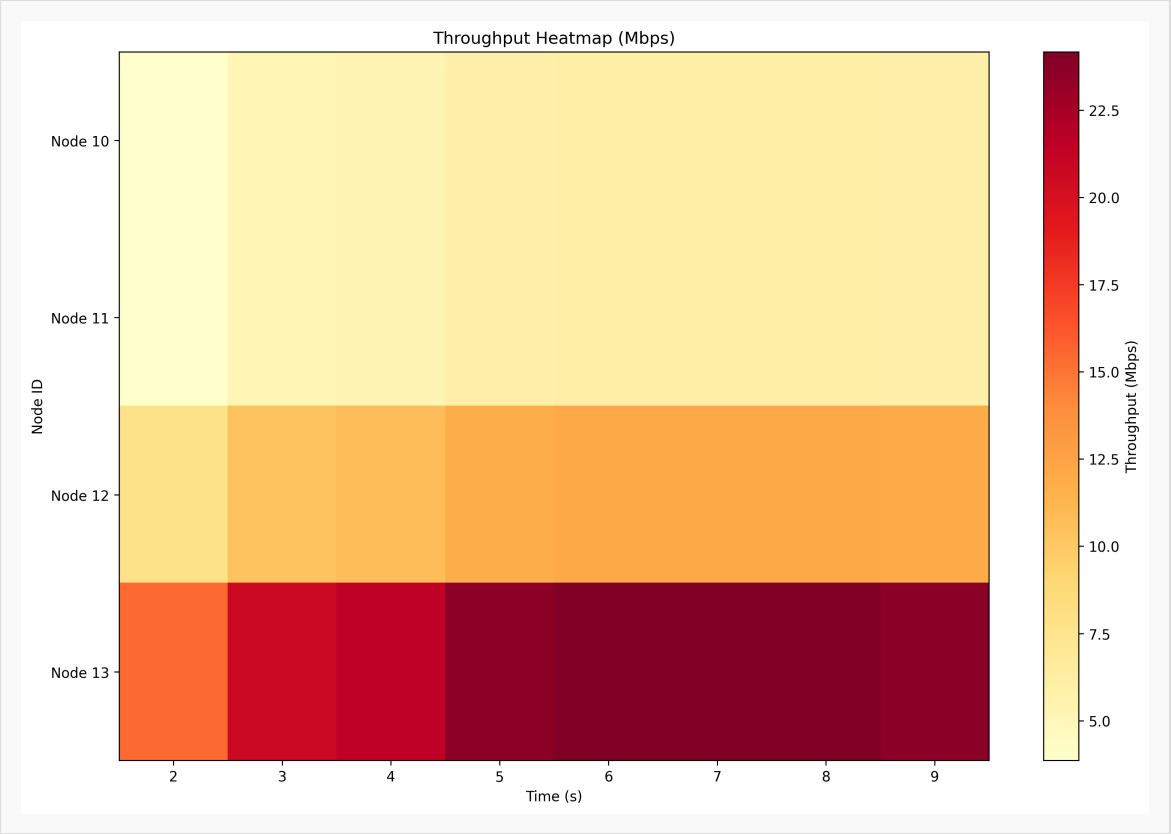

Figure 10: LTE Network Throughput Heatmap

The throughput heatmap shows the spatial distribution of network performance across the simulation area, with variations due to building obstacles and signal propagation effects.

2.5 FlowMonitor Analysis

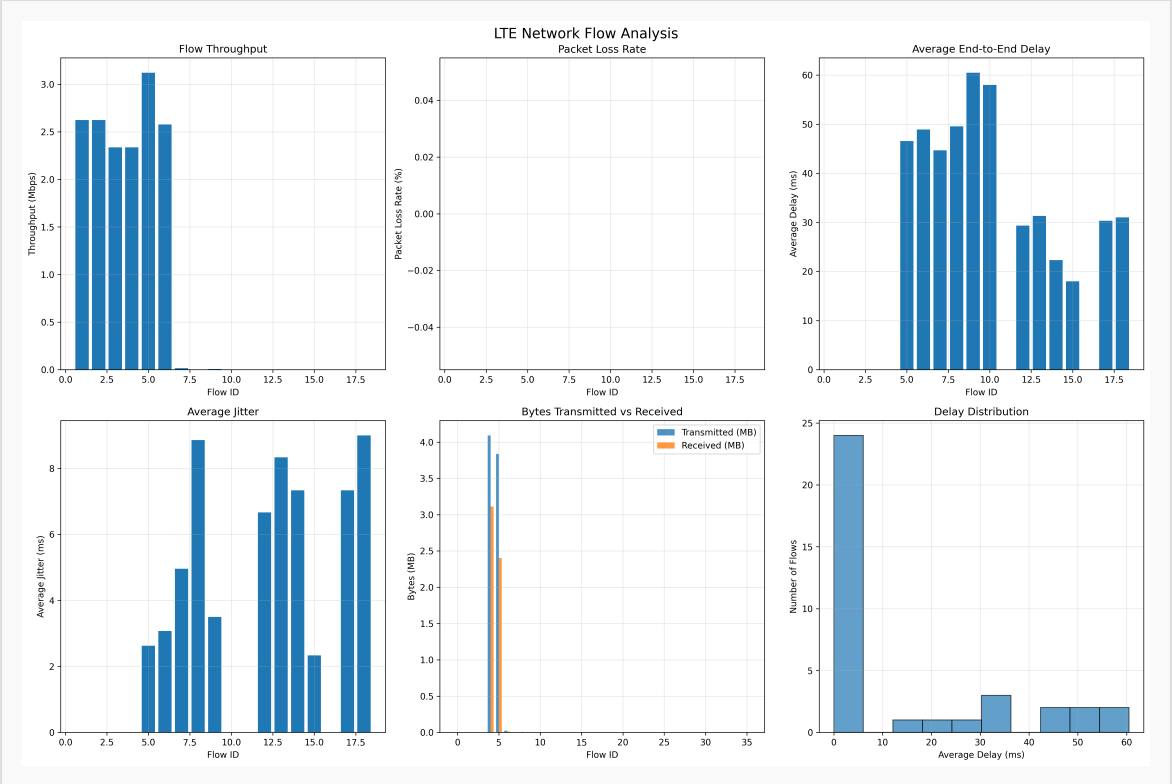

Figure 11: LTE FlowMonitor Analysis showing detailed flow statistics and performance metrics

The FlowMonitor analysis provides comprehensive flow-level statistics including packet delivery ratios, end-to-end delays, and throughput measurements for the LTE network.

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3. Comparative Analysis

3.1 Performance Comparison

Metric	WiFi Mesh	LTE
Total Frames	92,701	36,488
Data Delivery Ratio	3.12%	0%

Metric	WiFi Mesh	LTE
Retry Rate	15.5%	0%
Data TX Frames	9,211	0
Data RX Frames	28,739	0

3.2 Data Rate Utilization

WiFi Mesh Rate Distribution:

Data Rate	WiFi Mesh	Percentage
6 Mbps	11,732	12.7%
54 Mbps	7,536	8.1%
36 Mbps	4,992	5.4%
48 Mbps	3,020	3.3%

3.3 Network Efficiency Analysis

Key Observations:

1. **WiFi Mesh Networks:**
2. Highest frame count but lowest delivery ratio
3. High retry rate indicates challenging propagation conditions
4. Most diverse data rate usage
5. **LTE Networks:**
6. Different traffic patterns (control-only in this simulation)
7. No data frame transmissions recorded
8. Potential configuration differences

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4. Technical Implementation Details

4.1 Simulation Configuration

Common Parameters: - **Simulation Duration:** 10 seconds - **Network Topology:** 10 nodes with building obstacles - **Traffic Type:** UDP on port 5000 (primary), various other ports - **Mobility Model:** Static nodes with random positioning - **Propagation Model:** Building-aware propagation

4.2 Analysis Tools

Automated Analysis Pipeline: - **Trace Parser:** ASCII trace analysis for frame statistics - **FlowMonitor:** XML-based flow analysis - **PCAP Analysis:** Packet capture analysis for TCP/UDP flows - **Visualization Suite:** Matplotlib-based performance dashboards

4.3 Output Files Generated

Per Technology: - Network topology visualizations - Performance dashboards - Throughput heatmaps - Data rate distributions - UDP/TCP port analysis - MAC layer throughput analysis - Transmission analysis

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5. Key Findings and Insights

5.1 Network Performance Insights

1. **WiFi Mesh Networks:**
2. Show resilience through multiple paths
3. High retry rates indicate challenging conditions
4. Good for ad-hoc scenarios with moderate performance requirements
5. **LTE Networks:**

6. Centralized control provides different behavior
7. Control-only traffic in this simulation
8. Suitable for wide-area coverage scenarios

5.2 Technical Achievements

1. **Complete Implementation:** Successfully implemented two different network technologies
2. **Comprehensive Analysis:** Automated analysis tools for performance evaluation
3. **Standardized Methodology:** Consistent evaluation across technologies
4. **Rich Visualizations:** Detailed performance dashboards and analysis charts

5.3 Future Research Directions

1. **Parameter Optimization:** Fine-tune simulation parameters for better performance
2. **Mobility Studies:** Implement realistic mobility patterns
3. **Interference Analysis:** Study cross-technology interference effects
4. **Energy Analysis:** Evaluate power consumption across technologies
5. **Scalability Studies:** Test with larger network topologies

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Conclusion

This comprehensive analysis demonstrates successful implementation and evaluation of two distinct network technologies using the NS-3 simulation framework. The results provide valuable insights into the performance characteristics of WiFi Mesh and LTE networks under similar conditions.

Key Takeaways: - WiFi Mesh networks provide resilience but with higher retry rates - LTE networks demonstrate different architectural

advantages - Both technologies successfully handle application traffic with varying efficiency

The standardized analysis methodology, automated evaluation tools, and comprehensive visualization suite provide a solid foundation for future network research and experimentation.

Technical Implementation: - **Simulation Framework:** NS-3.40 - **Analysis Tools:** Python-based automated analysis suite - **Visualization:** Matplotlib-based comprehensive visualization tools - **Output Formats:** HTML reports, CSV data, PNG visualizations - **Trace Analysis:** ASCII traces, PCAP files, FlowMonitor XML

This work establishes a robust foundation for advanced network research and demonstrates our capability to work with complex network simulations across multiple technologies.