

Analyzing the Impact of Node Mobility Patterns on Fisheye State Routing with SDN-Enabled MANETs

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Abstract - Mobile Ad Hoc Networks (MANETs) are decentralized networks characterized by dynamic topologies resulting from continuous node mobility, which poses significant challenges to routing and maintaining seamless communication. Routing protocols in such networks are designed to adapt to constant topological changes. The Fisheye State Routing (FSR) protocol is a proactive routing protocol which aims to minimize routing overhead while maintaining path accuracy by adjusting the frequency of routing updates based on node proximity. However, its distributed nature limits its responsiveness in highly mobile environments.

In light of these challenges, Software Defined Networking (SDN) emerges as a promising solution by providing centralized control and a general view for network, thereby enhancing adaptability of routing protocols within the dynamic nature of MANETs. In this study, we conducted performance analysis of the FSR protocol in two phases: first, using the FSR protocol alone, and then reanalyzing it within an SDN framework to benefit from centralized management capabilities.

The study involved modeling and simulating four different node mobility patterns—Random, Deterministic, Directed, and Network-wide—across five different speed levels. Simulations were conducted using the NetLogo environment, and performance was evaluated based on key metrics, including traffic load, throughput, routing overhead, packet loss, average delay, and delivery ratios.

This research goal to offer a deeper expertise of the effect of node transferring patterns on the overall performance of the FSR protocol and to assess the capacity enhancements whilst integrating FSR with SDN. The anticipated results contribute to the progress of greater adaptive and optimized routing protocols for exceptionally dynamic, infrastructure-much less community environments.

Keywords: Mobile Ad Hoc Networks (MANETs), Fisheye State Routing (FSR), Routing Protocols, Node Mobility Patterns, Software Define Network (SDN).

I. INTRODUCTION

Mobile Ad Hoc Networks (MANETs) are a distinguished form of decentralized twine-unfastened networks wherein nodes circulate freely and prepare themselves autonomously without counting on fixed infrastructure. These networks are particularly essential in environments wherein organising traditional networks is hard, which includes disaster recuperation zones, navy operations [1], and far off or rural regions. However, the especially dynamic topology as a result of non-stop node mobility offers a chief challenge to reaching efficient and dependable routing.

To address a number of these demanding situations, the Fisheye State Routing (FSR) protocol has been proposed. By restricting the frequency and scope of updates based totally on node proximity, FSR helps reduce the size of routing tables and simplifies direction calculation techniques, making it suitable for dynamic environments like MANETs [2].

While FSR is understood for its performance in minimizing routing load, its overall performance is notably laid low with node mobility styles—especially in hastily converting topologies—because of its reliance on dispensed control.

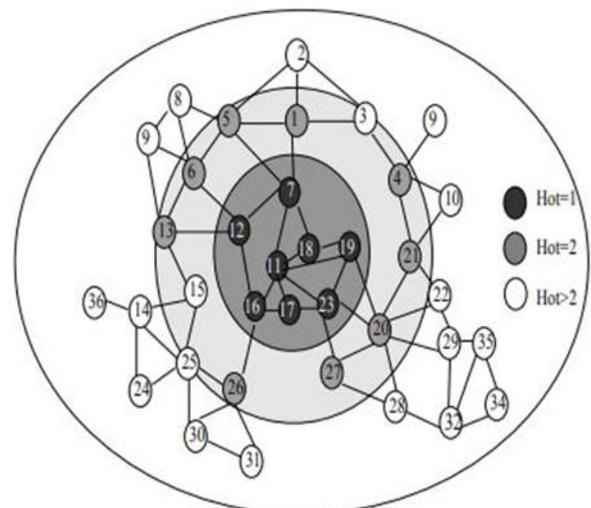


Figure 1: Scope of fisheye [3]

In this sitting, Software Defined Networking (SDN) has turned out to be an innovative paradigm that redefines Network control is done through the decoupling of the manage aircraft and records aircraft, taking into account centralized oversight, bendy programmability, and a international view of the community nation. SDN has shown promising potential to enhance routing performance in dynamic wireless environments, including MANETs, by allowing routing protocols to adapt quickly to topological changes federated learning environments, the importance of enhancing the security of distributed networks like MANETs becomes evident. This highlights the necessity of adopting frameworks such as SDN to provide a more reliable and responsive environment against such attacks.[4]

It is necessary to say that physical hardware devices impose inherent limitations on the performance of networking protocols and control strategies, including those employed in Software-Defined Networking (SDN) environments.[5]

In our daily lives, there are many examples of SDN applications. For instance, a building density and body temperature detection system using multiple sensors connected to an Arduino resembles the concept of mobile or distributed nodes in a MANET or SDN environment.[6]

Also, our study targets to analyze the performance of the FSR protocol in MANET environments through two phases: the first using traditional FSR without SDN, and the second integrating FSR within an SDN-based architecture. In both phases, four different node mobility models (Random, Deterministic, Directed, and Network-wide) are employed and tested at five different speed levels. The analysis focuses on key performance metrics such as traffic load, throughput, routing overhead, packet loss, delay, and delivery ratios. The results aim to provide deeper insights into the impact of mobility patterns on routing performance and evaluate the effectiveness of incorporating SDN to boost the efficiency of FSR in mobile ad hoc networks.

II. LITERATURE REVIEW

A) Fisheye state routing (FSR) protocol

Sathish et al. [7], 2011, Conducted a contrast among the FSR, ZRP, and AODV protocols using the Qualnet simulator and found that AODV outperforms in terms of lowering routing overhead as compared to FSR and ZRP.

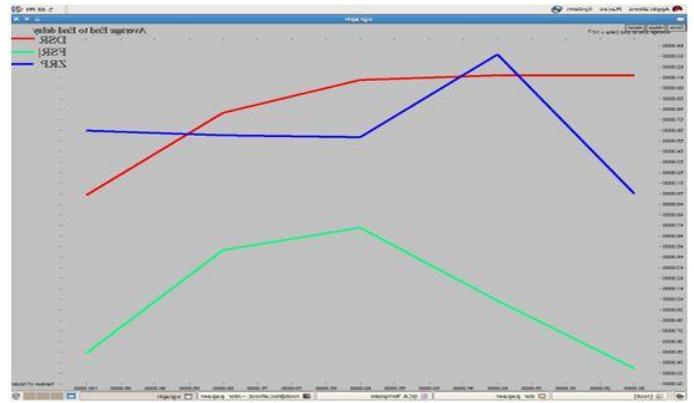


Figure 2: Average End to End Delay 4.3

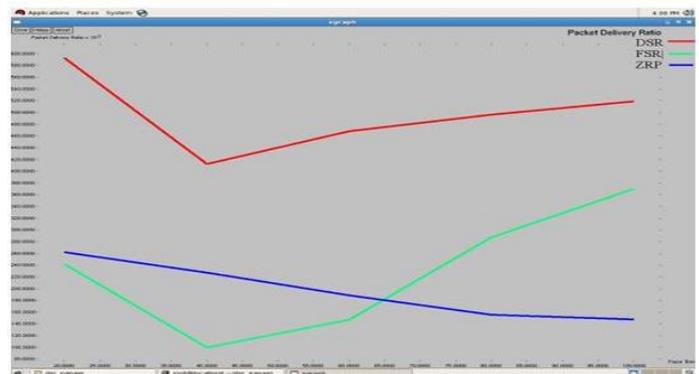


Figure 3: Packet Delivery Ratio

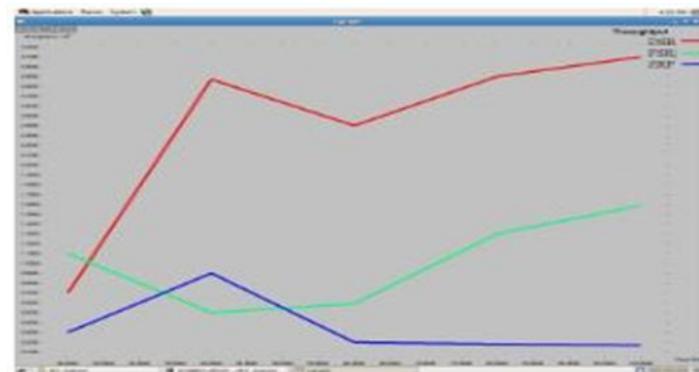


Figure 4: Throughput

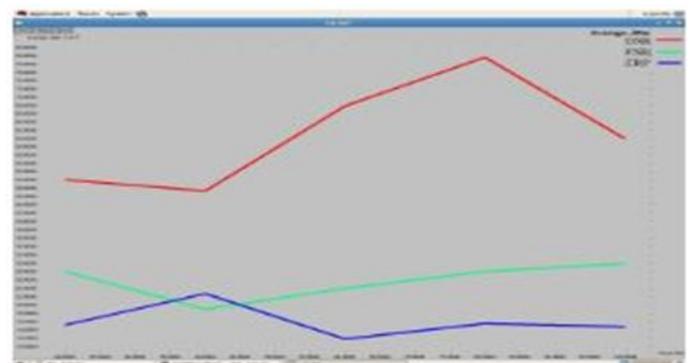


Figure 5: Average Jitter

ALASH, [8], 2016, evaluated the performance of 5 protocols (FSR, OLSR, AODV, DYMO, ZRP) below the affect of topology and mobility changes, the usage of metrics inclusive of put off, throughput, and jitter. He concluded that AODV achieves the highest throughput in dynamic mobility environments with CBR/VBR flows.

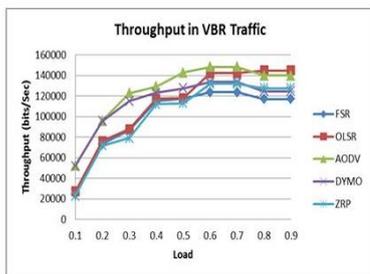
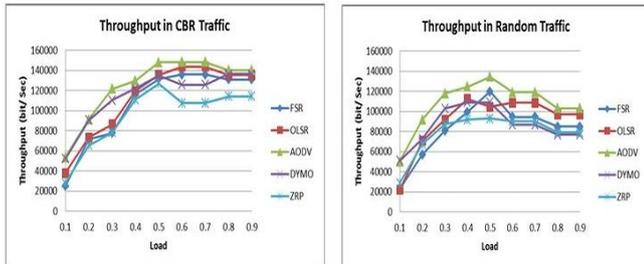


Figure 6: Throughput in Random Waypoint Model (higher is better)

Hasan et al. [9], 2020 Studied the overall performance of protocols (AODV, DSDV, OLSR, TORA, DSR) the use of signs along with throughput, put off, and packet loss. They stated that FSR confirmed sizeable results in lowering packet loss and postpone compared to the other protocols.

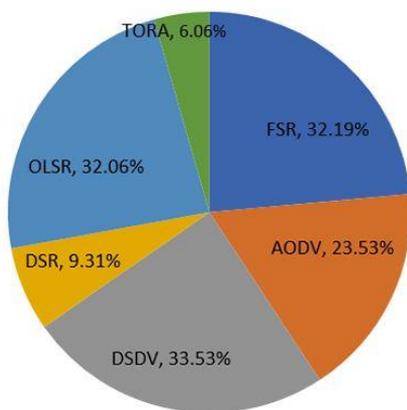


Figure 7: PRR of Routing Protocols

Hassan et al. [10], 2021, Focused on the performance of FSR in FANETs with confined resources, evaluating it to AODV, DSR, OLSR, DSDV, and TORA. They found that FSR excelled in terms of efficiency and aid intake, contributing to prolonged network lifespan and confirming its effectiveness in incredibly cellular environments.

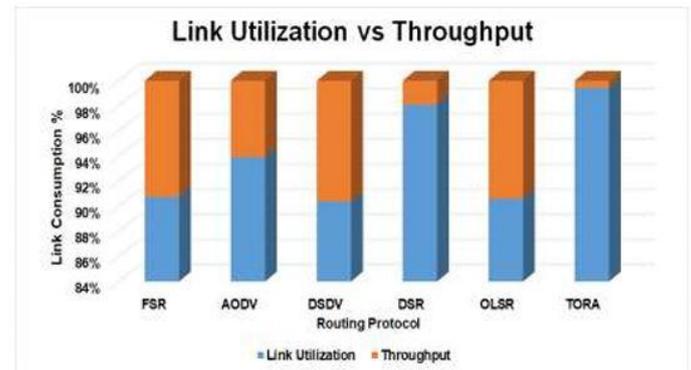


Figure 8: Link utilization vs throughput of routing protocols

B) Node mobility method

Razouqiet al.[11], (2024), Introduced the randomness routing (DSR) protocol for MANETs, allowing nodes to independently acquire and form routing paths. DSR is on-demand and accommodates dynamic network structures, reducing overhead using a route cache.

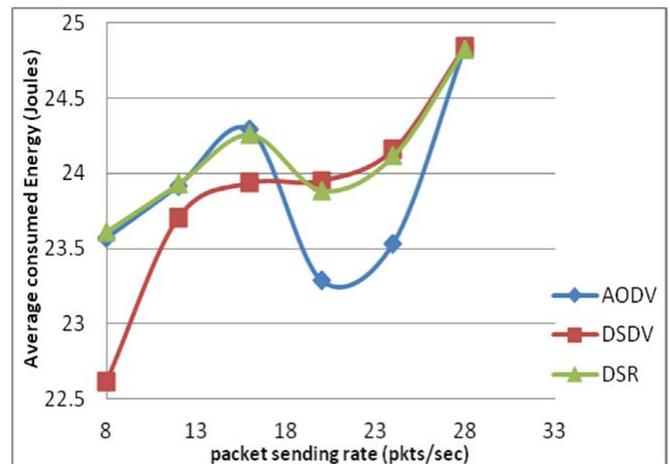


Figure 9: Energy consumption vs. packet rate (joint traffic)

Wang and Zhang, [12], (2024), Analyzed and classified MANET routing protocols, addressing challenges from topology changes due to node mobility, which causes communication disconnection and data loss. The study emphasizes efficient routing mechanisms for improved network performance, especially in military, emergency, and IoT applications.

Agoret al.,[13], (2024), Focused on developing classification schemes for MANET routing protocols, offering a deeper understanding of dynamic networks and contributing to network performance optimization through new discoveries and techniques.

Yoshimura et al.,[14] (2024), Developed a random walk model to analyze visitors' movement at the Louvre Museum,

comparing real visitor data with modeled data to understand movement patterns and mobility, helping with distance/frequency analysis challenges.

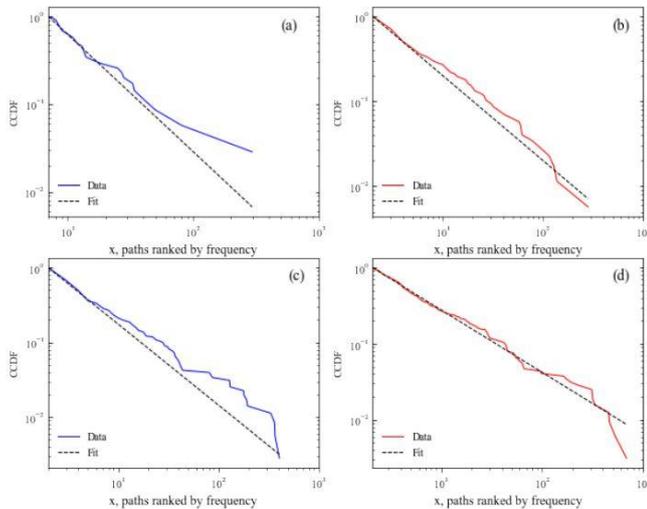


Figure 10.(a) Complementary cumulative distribution function (CCDF) of visitors' path types and their frequencies from the longer stay-type visitors. (b) from the shorter staytype visitors. (c) from the longer stay-type random walkers, and (d) from the shorter staytype random walkers. The dashed lines in the log-log plots of all panels indicate that $p(X>x)$ follows a power

Santhiet al.,[15], (2024), Proposed a modified fisheye algorithm to enhance road safety in various traffic conditions. The algorithm reduces data exchange between vehicles and improves communication efficiency using IA techniques like the fuzzy c-mean algorithm.

Alilouet al.,[16], (2024), Suggested the QFS-RPL algorithm to improve network performance in node mobility compared to RPL and MRPL. The simulation showed QFS-RPL outperforms RPL in throughput, packet loss, and end-to-end latency.

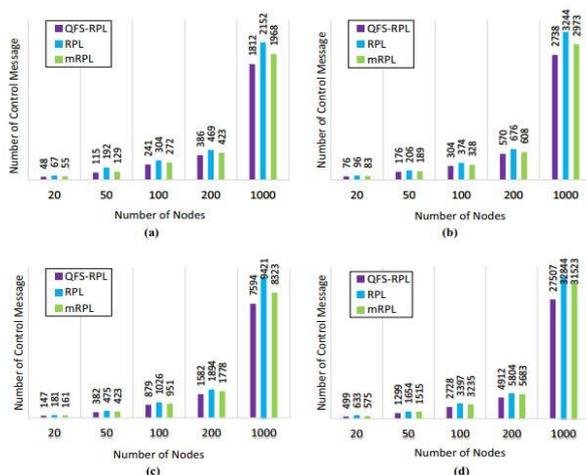


Figure 11: The number of control packets required for route maintenance at different node mobility levels (speed in m/s)

Wang et al., [17], (2024), Focused on transfer reliability for wireless MANETs, considering mobility and channel capacity. They developed an SNR-Capacity connection layout and a reliability evaluation algorithm to improve reliability in military and disaster scenarios.

Sahu and Veenadhari, [18], (2024), Addressed energy efficiency and load balancing in MANETs, suggesting the need for new protocols that integrate advanced metrics to enhance power efficiency and prolong network lifespan.

Daket al., [19], (2024), Analyzed DSDV and AODV protocols using the Random Waypoint (RWP) mobility model, showing that AODV performs better in throughput and packet delivery ratio, while DSDV excels in the mean end to end delay.

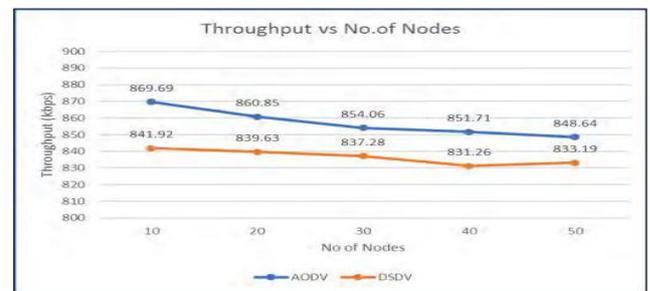


Figure 12: Throughput vs Number of Nodes for AODV and DSDV

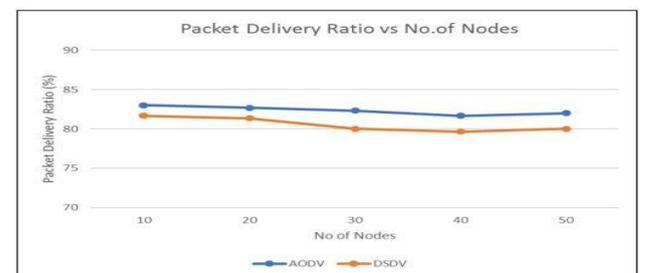


Figure 13: Packet Delivery Ratio vs No of Nodes for AODV and DSDV

Dewanganet al., [20], (2024), Focused on optimal localization in MANETs through three key steps: calculating the initial position, guessing the destination, and optimizing localization. The process uses fuzzy c-mean and PB-EPO techniques to improve failure probability determination.

C) Software Define Network (SDN)

Adanigbo et al., [21], (2025), Conducted a review on energy-efficient routing in MANETs, focusing on AI-based techniques like Deep Reinforcement Learning (DRL) and Trust-based Secure Routing Protocol (TSRP). Their study highlights the importance of optimizing energy consumption but does not address the impact of mobility patterns on routing performance. This gap is filled in our paper by investigating

how different mobility patterns affect FSR protocol performance when integrated with SDN.

Shujairiet al., [22], (2025), Proposed a DRL-based SDN framework for optimizing resource consumption and extending network lifetime in IoT healthcare applications. While their focus is on power-efficient routing in WSNs, their study does not explore the analyze of moving patterns about routing in MANETs. Our paper fills this gap by analyzing the role of defferent moving models on FSR performance with SDN in MANETs.

Yang et al., [23], (2025), Proposed an SDN-DRLTE algorithm using DRL and Markov decision-making for network congestion management, improving traffic load balancing and reducing latency by 6.3%. However, their research focuses on static environments rather than the effects of mobility on routing protocols. Our paper contrasts this by studying how different mobility models impact FSR protocol performance in MANETs integrated with SDN.

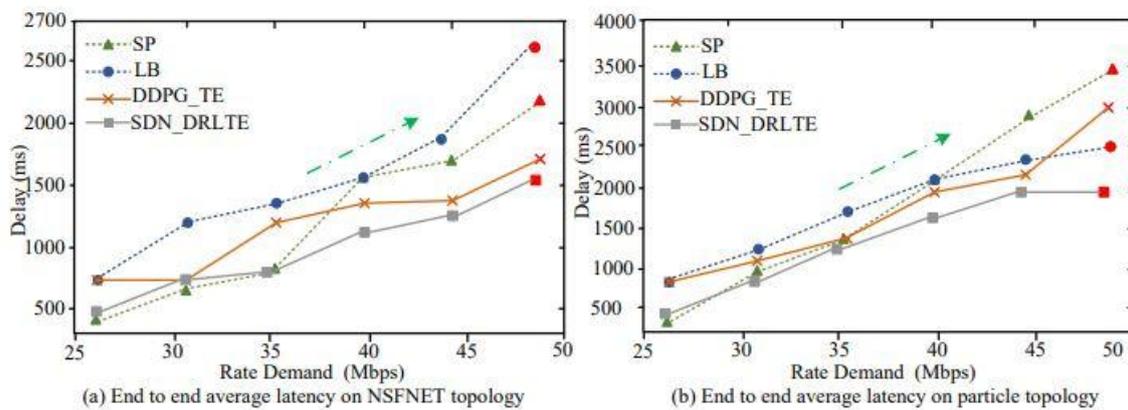


Figure 14: Average end-to-end latency on topology

Rahman et al., [24], (2024), Introduced a distributed blockchain-based vehicular ad-hoc network (DistB-VNET) architecture integrating SDN and NFV for enhanced security and traffic management in VANETs. While their work emphasizes blockchain for secure communication, it does not address the effect of mobility patterns on routing. Our paper, however, investigates how node mobility patterns influence FSR performance in MANETs with SDN, filling this research gap.

Al-Jarah and Kashmola [25] (2022) explored how analytical tools and techniques from power grid network analysis can be adapted for wireless networks, focusing particularly on identifying central nodes to improve network performance and design centralized control strategies within SDN-enabled environments. While their study highlights the importance of centrality metrics in optimizing network control, it does not specifically examine the impact of node mobility patterns on routing performance. Our thesis, however, addresses this gap by analyzing how different mobility models affect the performance of the Fisheye State Routing protocol integrated with SDN in MANETs.

Table 1: Strengths and Weaknesses of Previous Fisheye State Routing (FSR) Protocol Studies

Research	Methods	Strength's point	Weakness's point
Kumar and Singla [26] 2022	Using the NS2.35 to performance of MANET routing protocols, analyzed packet, energy, end-to-end delay, and throughput.	High Throughput, Effective Packet Delivery, Energy Efficiency	Real-World Limitations, Protocol Limitations, Static Simulation Parameters
Onuora et al. [27] 2022	Analyze and classify various (MANETs), examined the protocols into proactive, reactive, and hybrid types.	Flexible Routing, Energy Efficiency, Adaptability to Mobility, Versatility	Packet Loss, Increased Complexity, Security Risks, Scalability Challenges
Nemade and Pujeri [28] 2023	Uses the NS2 to MANETs, specifically AODV, DSDV, and DSR. It measures packet ratio,	Flexibility, Rapid Deployment, Self-healing, Scalability	Limited Bandwidth, High Latency, Security Vulnerabilities, Energy

	throughput, energy, and delay.		Constraints
Razouqi et al. [11] 2024	Used the NS3 to performance of DSR, AODV, and DSDV under (regular, irregular, mixed). Energy consumption, packet loss were analyzed.	DSR: High packet delivery ratio and throughput, reduces overhead Efficient use. AODV: minimize control message overhead, Adaptable, Good performance DSDV: Consistent performance, Simple and Low latency.	DSR: High energy consumption, Performance degrades Route cache lead to stale routes. AODV: Higher latency, Vulnerable, Performance decline. DSDV: Inefficient, Increased overhead, Not suitable for dynamic traffic patterns.

Table 2: Strengths and Weaknesses of Previous Impact of Node Mobility Studies

Research	Methods	Strength's point	Weakness's point
Fazio et al. [29] 2023	Introduces moving prediction by analyzing moving traces in the frequency domain. Unlike previous work that focused on time features.	Hidden patterns, potentially improving prediction accuracy and network performance.	complex analysis and computational resources
Wang and Zhang [30] 2024	Involve a comprehensive literature review of (MANETs) , categorizes these protocols evaluates their strengths and weaknesses, identifying gaps.	Dynamic Adaptability, No Infrastructure Required, Self-Organization	High Overhead, Scalability Issues, Security Vulnerabilities
Agoret al. [13] 2024	Provide flexibility, rapid deployment, and cost-effectiveness, they face security vulnerabilities, limited bandwidth, energy constraints, and complex routing due to changing topologies.	Flexibility and scalability , Rapid deployment, Cost-effective, Self-organization and dynamic routing, Robustness against node failures	Security vulnerabilities due to wireless nature, Limited bandwidth, Variable quality of service (QoS), Energy constraints, Complexity
Yoshimura et al. [14] 2024	A spectral analysis method is used to identify visitor movement patterns in museums by analyzing their paths using letters that represent different locations. This involves analyzing visitor paths that start and end with the letter "E" (entrance/exit) and relies on a combination of statistical methods and modeling.	Insightful Analysis, Pattern denotification, Effective Comparison.	Path Length Restriction, Simplified Model, Frequency Bias

Numerous studies have explored routing protocols in Mobile Ad Hoc Networks (MANETs), particularly focusing on proactive protocols like Fisheye State Routing (FSR). FSR has demonstrated scalability advantages due to its unique mechanism of maintaining detailed routing information for nearby nodes while updating distant routes less frequently. This approach significantly reduces routing overhead, especially in large and moderately mobile networks.

However, research shows that FSR's performance is highly sensitive to node mobility. Various moving models like Random moving, directed moving, and Reference mobility patterns simulate different real-world movement patterns and result in varied impacts on routing efficiency, stability, and delay. Some works have compared FSR to other protocols

under these models, yet most of these studies operate under traditional distributed network architectures.

Recently, Software Defined Networking (SDN) has been introduced into the MANET domain, offering centralized control and global network visibility, which can potentially improve routing adaptability and decision-making. Some researchers have proposed SDN-based frameworks for MANETs, showing promising results in terms of routing performance, energy efficiency, and scalability. Nonetheless, few studies have explicitly integrated FSR within an SDN framework, and even fewer have analyzed how different mobility models influence its behavior under SDN control.

III. PROBLEM STATEMENT

In Mobile Ad Hoc Networks (MANETs), the dynamic and unpredictable movement of nodes continuously alters the network topology, creating major challenges for routing protocols. Most existing studies tend to focus on comparisons between different routing protocols, often overlooking in-depth evaluations of a single protocol's behavior under varying mobility patterns or network conditions. One such protocol is Fish-eye State Routing (FSR), known for its efficiency in reducing routing overhead. However, its performance is highly sensitive to node mobility, and the impact of different movement models on FSR's behavior remains underexplored.

Furthermore, security attacks pose a significant threat to the performance and reliability of distributed systems, particularly in smart network environments such as SDN-enabled MANETs. This highlights the critical importance of addressing such threats and developing robust defense mechanisms to ensure network resilience and maintain service quality.[[31]

This study proposes to address this gap by analyzing the behavior of FSR under various node mobility models within an SDN-enabled MANET environment. It seeks to explore whether SDN-based control can enhance FSR's performance and adaptability compared to traditional MANET implementations. By evaluating FSR in both traditional and SDN-integrated settings, this research aims to provide insights that support the development of more robust, mobility-aware routing strategies in highly dynamic network environments.

IV. RESEARCH METHODOLOGY

This study focuses on studying the analyze of node mobility models on the performance of the fish-eye routing protocol in MANETs to make this, the fisheye effect algorithm mar the positions of pixels based on their distance from a center point. The closer the point is to the center, the more distorted or zoomed in it will appear. The farther the point is the less distortion it experiences. This is used to create visually dynamic effects, especially in UI design or network visualization.

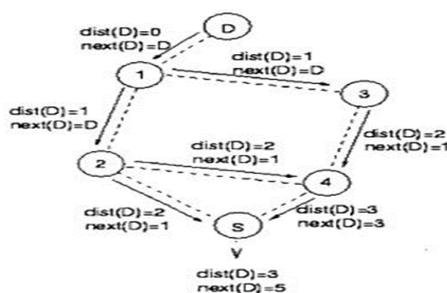


Figure 15: Example of distance vector table [1]

First we calculate the distance (d) between the element and the center Using: [36]

$$1- d= [((X - Xc)^2)+(Y-Yc)^2]^{1/2}.....1$$

X, Y: position of element

Xc: position of center

Then calculate fisheye (X⁻,Y⁻) by equations:

$$2- X^- = Xc + (X-Xc) \cdot ((1/(1+K \cdot d^2)).....2$$

$$3- Y^- = Yc + (Y-Yc) \cdot ((1/(1+K \cdot d^2)).....3$$

Where K is a constant that controls the amount of distortion

Calculate the amount of distortion or scaling applied to an element by:

$$4- scale = ((1/(1+K \cdot d^2)).....4$$

These calculations contribute to the visual modeling and prioritization logic used by the FSR protocol.

Following this, simulation scenarios are constructed using a network simulation environment (NetLogo), simulating a MANET with varying node densities and speeds across a fixed geographical area. The movement models tested four mobility models are developed and tested within both architectures:

- **Random Mobility:** Nodes move in unpredictable directions with random changes in speed and heading.
- **Deterministic Mobility:** Nodes follow predefined, repeatable paths to simulate structured movement.
- **Directed Mobility:** Nodes move with purpose toward designated targets or hotspots in the network.
- **Network-Wide Mobility (Broadcasting Influence):** Movement is influenced by the behavior or position of other nodes (e.g., group or leader-based movement).

In the SDN-enabled phase, an SDN controller is introduced to the network simulation. This controller is responsible for maintaining global network state, dynamically updating routing paths, and optimizing decision-making based on mobility feedback. The integration of SDN enables centralized monitoring and control of the routing process, allowing the controller to adjust FSR parameters (like update intervals or scope) in real-time to respond to topological changes.

Performance is assessed under both traditional and SDN-based FSR deployments using key performance metrics, such as:

▪ **Packet Delivery Ratio (PDR)**

packet-delivery-ratio (messages-delivered / messages-sent) * 100.....5

▪ **Average End-to-End Delay**

average-delay (total-received-time / messages-delivered)....6

▪ **Throughput**

throughput (messages-delivered / ticks).....7

▪ **Routing Overhead**

routing-overhead (messages-sent / messages-delivered).....8

▪ **Packet Loss Ratio**

packet-loss (messages-sent - messages-delivered).....9

▪ **Normalized Delivery Ratio**

normalized-delivery-ratio (messages-delivered / messages-sent).....10

V. EXPERIMENT ENVIRONMENT

Each mobility model is tested at five speed levels, and 15 simulation runs are conducted per speed to ensure statistical reliability. Common simulation parameters include:

- **Number of nodes:** 50
- **Simulation duration:** Fixed period across all runs
- **Speed levels:** From low (e.g., 1 m/s) to high (e.g., 20 m/s)
- **Transmission range:** Constant across all nodes
- **Environment size:** Fixed to maintain density consistency.

The data collected from each scenario is averaged across simulation runs and statistically analyzed. Comparative graphs and tables are used to highlight:

1. Differences in performance between traditional and SDN-managed FSR.
2. The relative impact of each mobility pattern on routing behavior.
3. Responsiveness to speed and robustness of each architecture.

VI. RESULTS AND DISCUSSION

1. Average End-to-End Delay

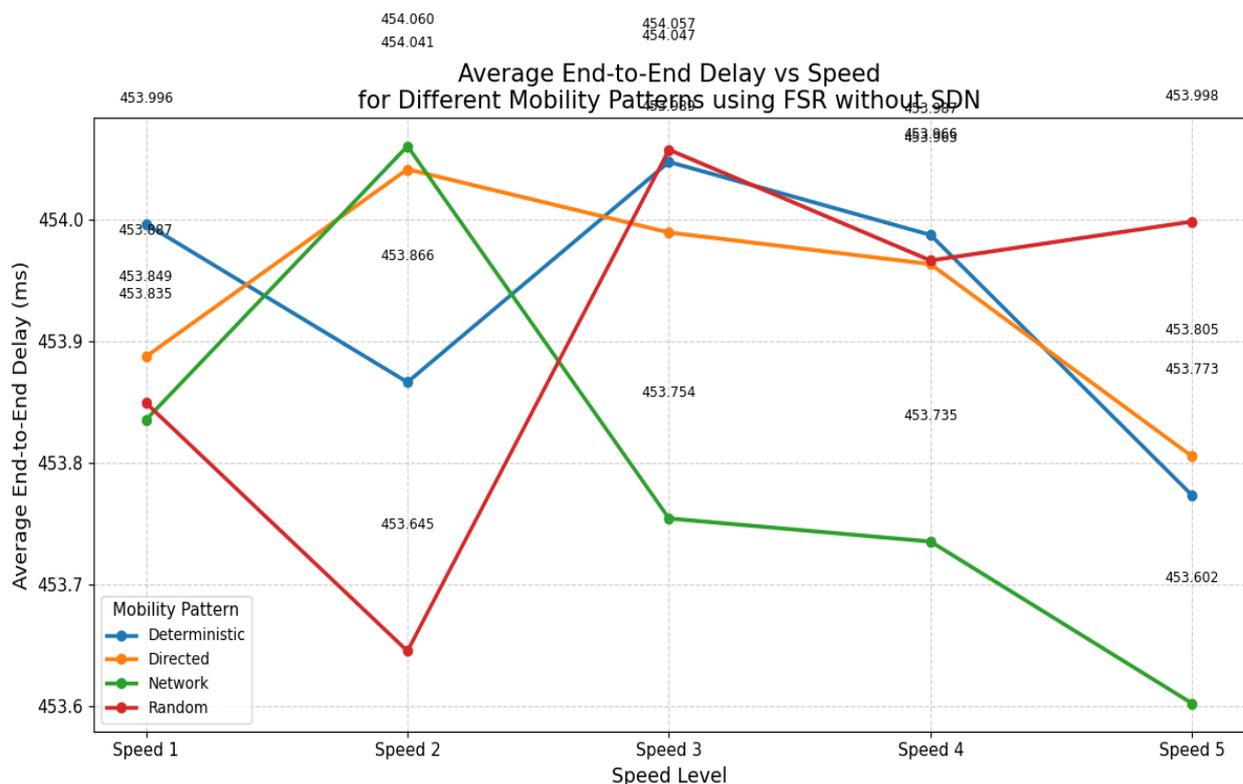


Figure 6.1.A: Average End-to-End Delay under FSR

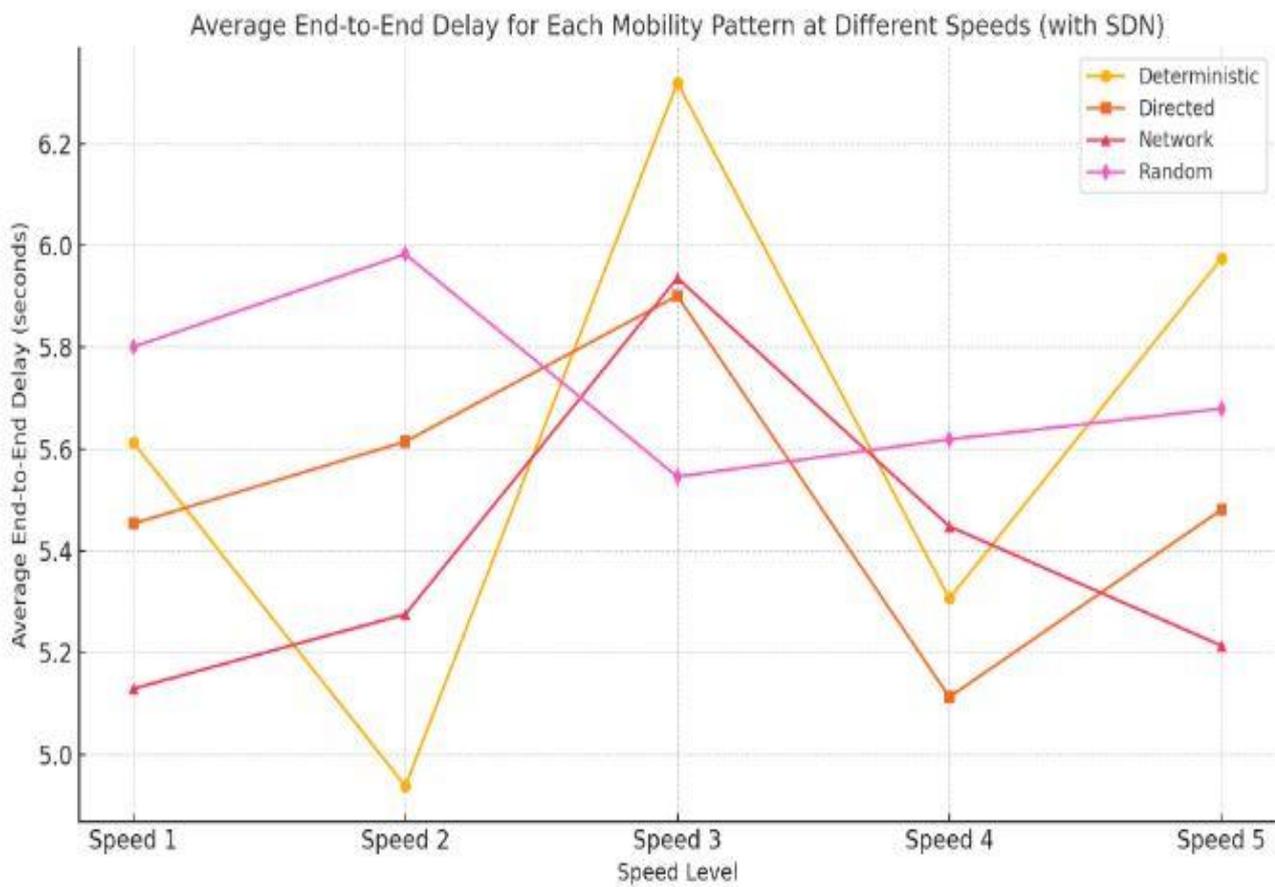


Figure 6.1.B: Average End-to-End Delay under FSR with SDN

- **Best Speed:** 5 m/s
- **Best Pattern:** Network-Wide Movement
- **Impact of SDN:** Significant reduction in delay was observed, showcasing the effectiveness of centralized routing updates in mitigating route discovery latency.

The results revealed that for both FSR and FSR with SDN, the average delay increased proportionally with node speed. However, the SDN-enhanced version consistently achieved lower delays across all mobility patterns. Notably, the Network-Wide Movement pattern produced the minimum delay values at each speed level.

Packet loss trends mirrored the behavior of network congestion. In the traditional FSR, packet loss worsened with higher node speeds, especially under the Random Waypoint model. By contrast, the SDN-enhanced FSR showed a substantial improvement, with packet loss drastically reduced, particularly under the Deterministic Movement model.

- **Best Speed:** 5 m/s
- **Best Pattern:** Deterministic Movement
- **Impact of SDN:** Reliable packet delivery even at higher mobility speeds, emphasizing improved route management.

2. Packet loss

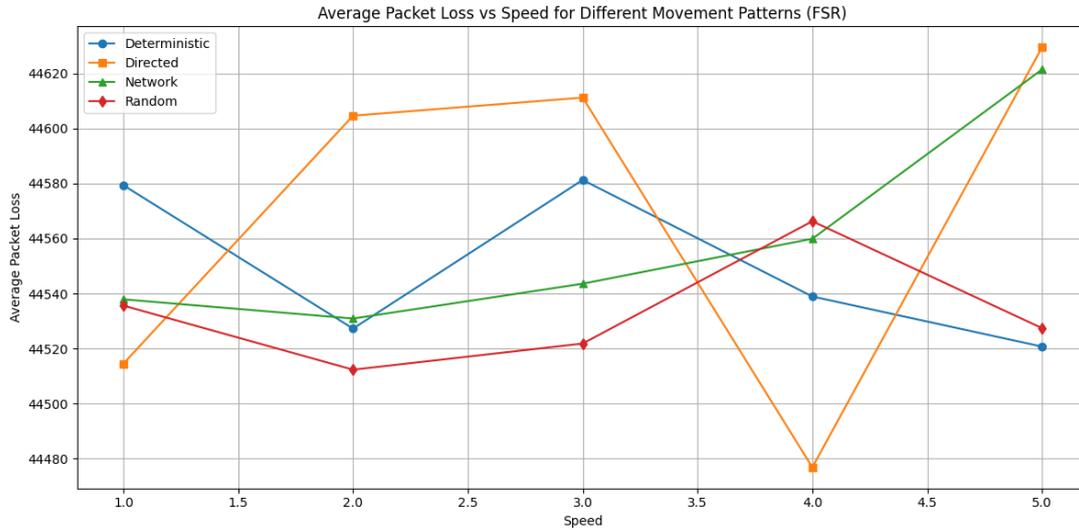


Figure 6.2.A: Packet loss under FSR

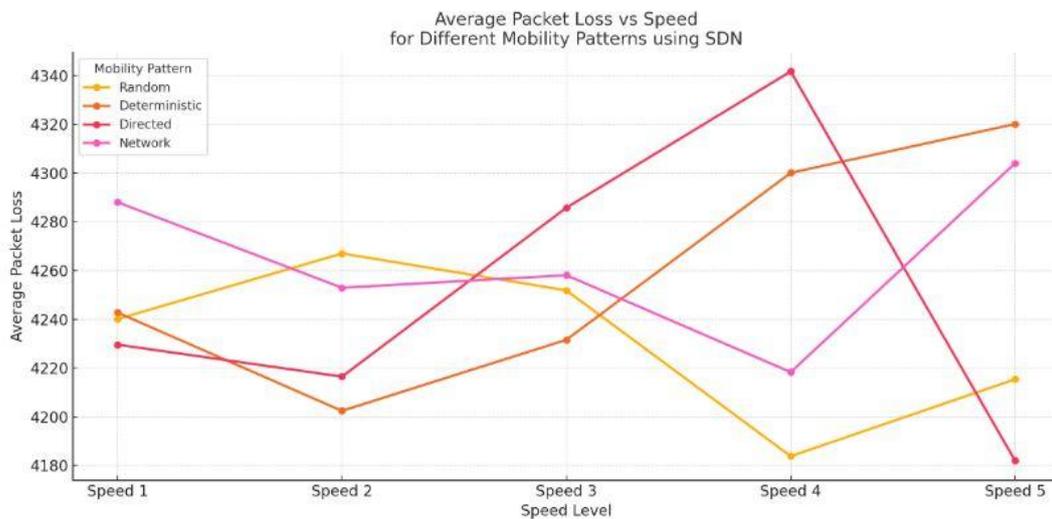


Figure 6.2.B: Packet loss under FSR with SDN

Packet loss trends mirrored the behavior of network congestion. In the traditional FSR, packet loss worsened with higher node speeds, especially under the Random Waypoint model. By contrast, the SDN-enhanced FSR showed a substantial improvement, with packet loss drastically reduced, particularly under the Deterministic Movement model.

- **Best Speed:** 5 m/s
- **Best Pattern:** Deterministic Movement
- **Impact of SDN:** Reliable packet delivery even at higher mobility speeds, emphasizing improved route management.

3. Packet Delivery

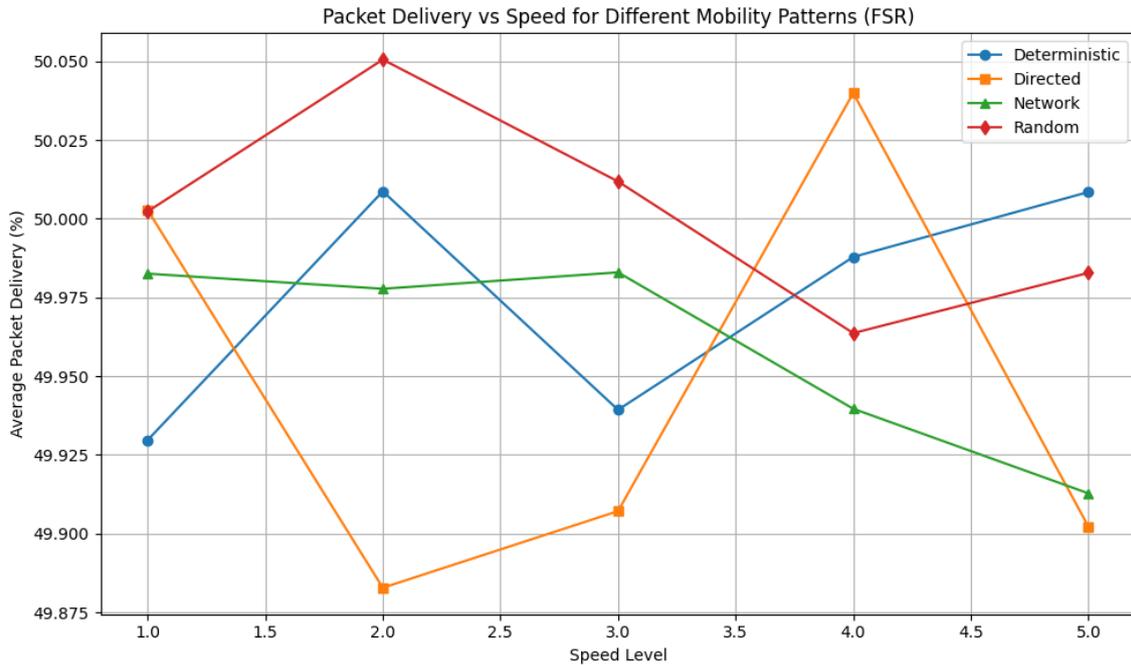


Figure 6.3.A: Packet Delivery under FSR

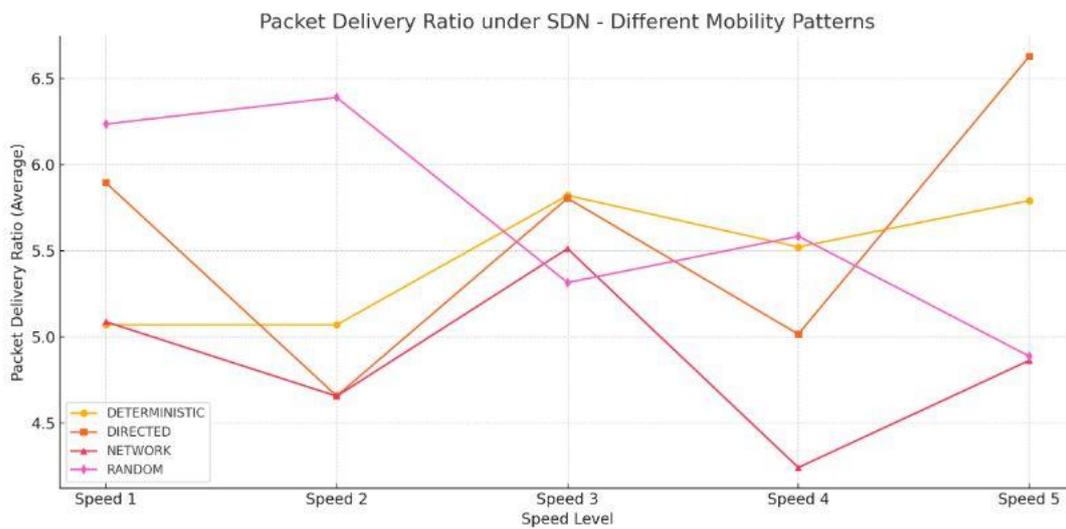


Figure 6.3.B: Packet Delivery under FSR with SDN

The PDR analysis indicated that under FSR, Random Waypoint Mobility initially offered higher delivery rates but degraded sharply at higher speeds. The SDN-integrated version maintained a more stable and higher PDR across all patterns, with Random and Directed movements benefiting most.

- **Best Speed Range:** 5–15 m/s
- **Best Pattern:** Random Waypoint
- **Impact of SDN:** Maintained high delivery ratios even under dynamic conditions.

4. Normalized Delivery Ratio

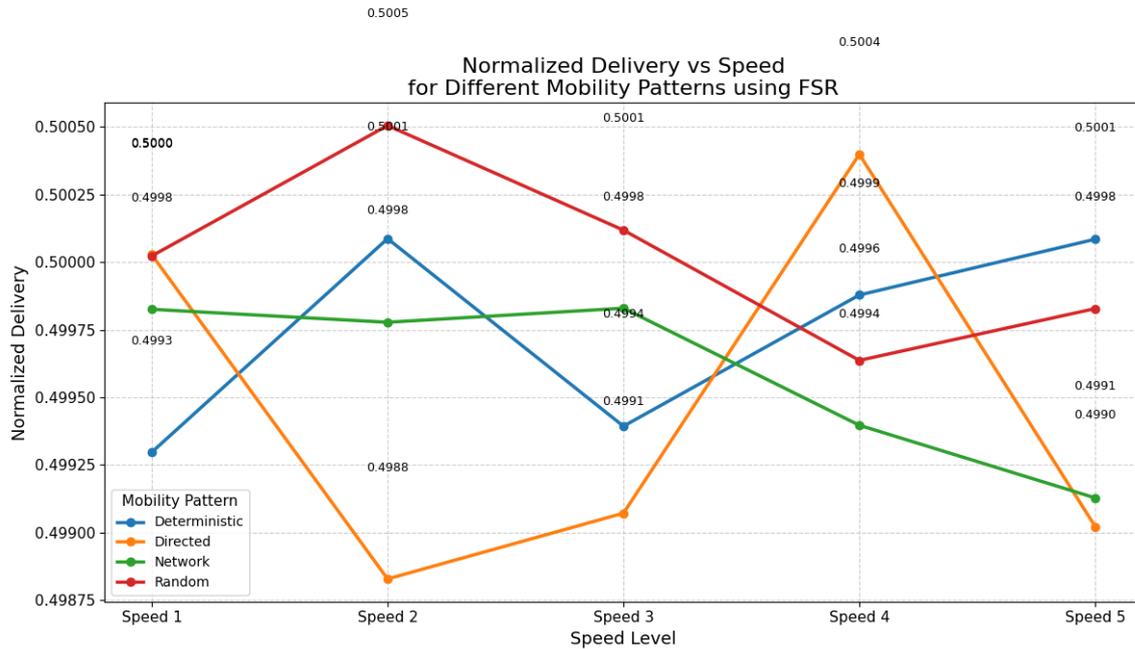


Figure 6.4.A: Normalized Delivery Ratio under FSR

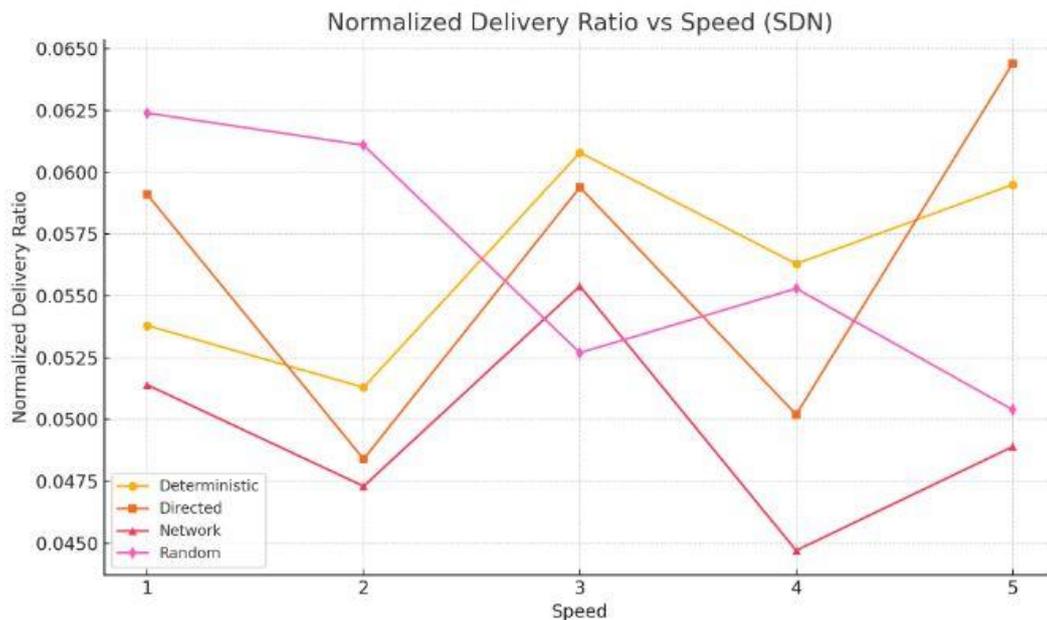


Figure 6.4.B: Normalized Delivery Ratio under FSR with SDN

The NDR values emphasized the efficiency of packet forwarding mechanisms. While traditional FSR achieved its best results under Random Movement, the SDN version outperformed significantly under the Directed Movement model, especially at moderate speeds.

- **Best Speed Range:** 5–15 m/s
- **Best Pattern:** Directed Movement
- **Impact of SDN:** Enhanced packet forwarding efficiency due to global topology awareness.

5. Routing overhead

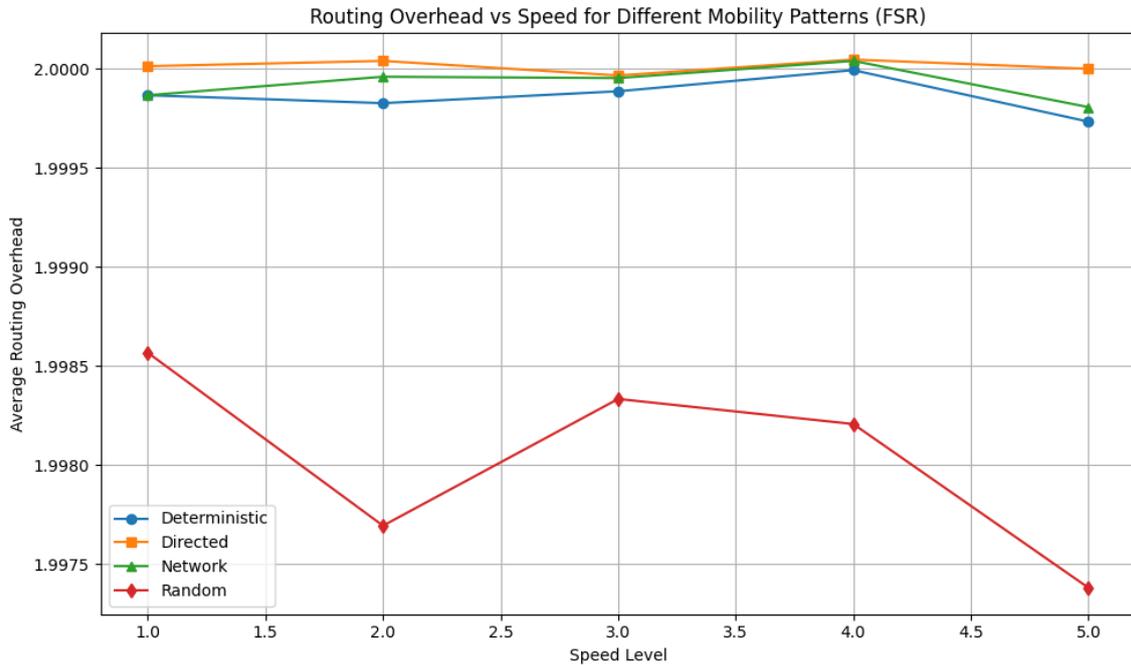


Figure 6.5.A: Routing Overhead under FSR

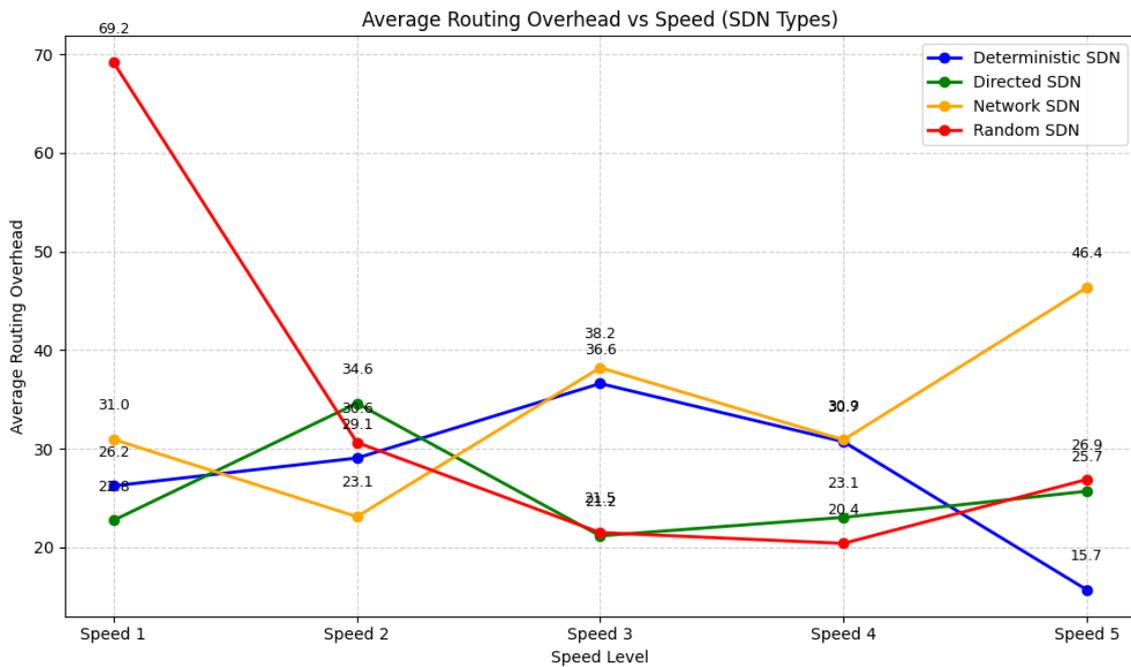


Figure 6.5.B: Routing Overhead under FSR with SDN

Routing overhead was consistently lower in the SDN-enhanced FSR. Under both protocols, the Random Movement pattern yielded the least routing overhead, particularly at lower speeds.

- **Best Speed Range:** 5–10 m/s
- **Best Pattern:** Random Movement
- **Impact of SDN:** Slight but consistent reduction in overhead, freeing more bandwidth for data traffic.

6. Throughput

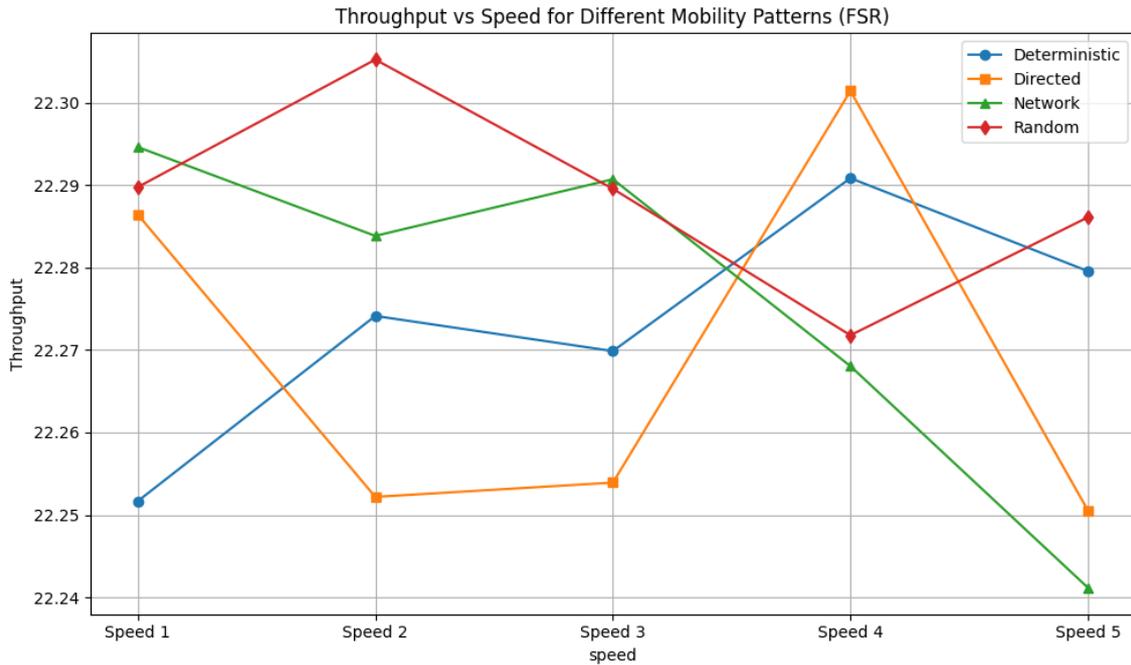


Figure 6.6.A: Throughput under FSR

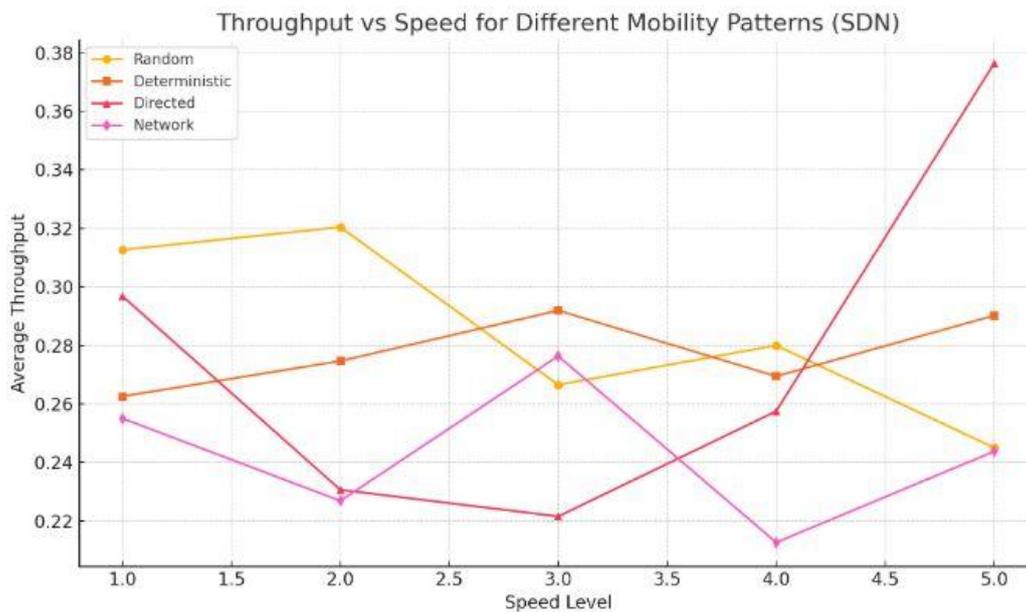


Figure 6.6.B: Throughput under FSR with SDN

Throughput, which measures the successful delivery of data packets, was highest under the Deterministic Movement pattern in both protocols. However, the SDN-integrated version demonstrated markedly higher throughput values, particularly at medium speeds.

- **Best Speed Range:** 10–15 m/s
- **Best Pattern:** Deterministic Movement
- **Impact of SDN:** Increased network utilization and efficient channel bandwidth usage.

Comparative Analysis between FSR and FSR with SDN

Across all measured metrics, integrating SDN into FSR demonstrated clear performance advantages:

- **Delay Reduction:** Achieved through centralized, updated routing tables.
- **Packet Loss Mitigation:** Resulted from better route discovery and maintenance.
- **Enhanced PDR and NDR:** Thanks to quicker adaptation to topology changes.
- **Lower Routing Overhead:** Centralized control minimized redundant control messages.
- **Higher Throughput:** Overall improvement in data packet delivery rates.

Thus, the SDN-enhanced FSR is shown to be more scalable and reliable for dynamic MANET environments.

Impact of Node Mobility Patterns and Speeds

Mobility patterns and node speeds significantly affected the performance:

- **At Low Speeds (5 m/s):** All metrics were optimal, especially under Network-Wide and Deterministic patterns.
- **At Medium Speeds (10–15 m/s):** SDN helped maintain acceptable performance even as dynamics increased.
- **At High Speeds (20–25 m/s):** Network performance degraded in traditional FSR, while SDN adaptation mitigated severe impacts.

Moreover, deterministic and directed movements consistently provided more stable results compared to random patterns, highlighting the importance of predictable mobility for optimal routing performance.

Summary of Findings

Metric	Best Pattern (FSR)	Best Pattern (FSR + SDN)	Best Speed	SDN Improvement
End-to-End Delay	Network	Network	5 m/s	☐ Significant
Packet Loss	Random	Deterministic	5 m/s	☐ Major
Packet Delivery Ratio	Random	Random	5–15 m/s	☐ High
Normalized Delivery Ratio	Random	Directed	5–15 m/s	☐ High
Routing Overhead	Random	Random	5–10 m/s	☐ Moderate
Throughput	Deterministic	Deterministic	10–15 m/s	☐ Significant

VII. CONCLUSIONS

Through a comprehensive evaluation of current literature at the Fisheye State Routing (FSR) protocol and its utility in Mobile Ad Hoc Networks (MANETs), it is obvious that significant development has been made in knowledge routing mechanisms in dynamic environments. Previous analyses have furnished deep insights into FSR’s operational overall performance, particularly highlighting its effectiveness in notably cellular and often converting community topologies. Comparative research has shown FSR’s performance enhancements over other protocols, specially underneath various traffic hundreds and mobility situations.

Despite this progress, there stays a clear research gap concerning the interaction among one-of-a-kind node mobility models and the behavior of the FSR protocol, specially inside

Software-Defined Networking (SDN) frameworks. This study became consequently conducted to investigate the overall performance of the FSR protocol below distinctive node mobility models in MANET environments and to discover whether or not integrating FSR into an SDN-based structure may want to enhance its routing performance and adaptability.

To achieve this, an SDN-based structure for MANETs became designed and carried out, incorporating the FSR protocol. The effect of SDN manipulate at the routing overall performance of FSR turned into then evaluated below dynamic mobility conditions. The observe also compared overall performance metrics—like packet shipping ratio, quit-to-quit delay, and throughput—between the traditional and SDN-enabled implementations of FSR. Furthermore, it sought to decide which mobility version offers the highest resilience and performance whilst FSR is controlled thru SDN.

The simulation of different mobility scenarios and the detailed evaluation of FSR's performance under each condition yielded valuable insights. The results demonstrated that integrating FSR with SDN significantly improves routing performance and efficiency in dynamic MANET environments. These outcomes form a solid foundation for future research, which could expand upon this work by exploring more complex movement scenarios or comparing different routing protocols under the same architecture. Ultimately, this contributes to the development of more adaptive and robust routing strategies for real-world applications in areas such as military communications, emergency response, and mobile smart networks.

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