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Performance Analysis of Routing Protocols in MANETs for Precision Agriculture

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ABSTRACT

MANETs and efficient routing protocols are transforming precision agriculture, as data-driven technology optimize farming operations. These abstract covers MANET characteristics, precision agricultural difficulties, and routing protocol evaluation. AODV, DSR, OLSR, and Geographic Routing have different strengths and trade-offs in Packet Delivery Ratio, End-to-End Delay, and Network Throughput.Precision agriculture requires adaptive, energy-efficient, and scalable routing systems to address changeable topology, node mobility, resource limits, and interference in broad and dynamic landscapes. Performance differences between routing protocols show their viability for precision agriculture applications. AODV balances reliability and efficiency, DSR delivers packets reliably despite a delay, OLSR transmits data quickly, and Geographic Routing excels in reliability and efficiency, especially with precise location information.The conclusion stresses the importance of routing protocols in modern farming's efficiency, sustainability, and creativity. Communication networks in precision agriculture are becoming important for food security and satisfying global agricultural demands as technology develops. Research and development of MANET routing protocols in precision agriculture demonstrate the constant progress of these technologies, which use data to improve agricultural methods. The abstract emphasizes the delicate balance between dependability, latency, energy efficiency, and scalability, recommending routing methods tailored to precision agriculture applications. In the end, MANETs and improved routing protocols can boost innovation and efficiency, making global food production more sustainable and productive.

Keywords : Precision Agriculture, Variable Topology, Resource Restrictions, Adaptive Routing, Energy-Efficient Routing, Sustainability, Food Security

I. INTRODUCTION

In the contemporary landscape of agriculture, the integration of advanced technologies has become instrumental in optimizing farming practices and ensuring sustainable food production. One noteworthy advancement is the adoption of Mobile Ad-Hoc Networks (MANETs) in precision agriculture, where the dynamic and expansive nature of agricultural fields necessitates a reliable and efficient communication infrastructure. Precision agriculture, characterized by the precise application of resources based on real-time data, relies heavily on the seamless exchange of information among various devices and sensors deployed in the field [1]. As the agricultural sector increasingly embraces the Internet of Things (IoT) and autonomous systems, the role of MANETs becomes paramount in enabling communication among these diverse devices. The decentralized and self-configuring nature of MANETs offers a unique solution to the challenges posed by the agricultural environment, where traditional communication methods may prove inadequate. This research endeavors to delve into the performance analysis of routing protocols within MANETs, a critical aspect in ensuring the reliability and efficiency of communication networks in precision agriculture [2].

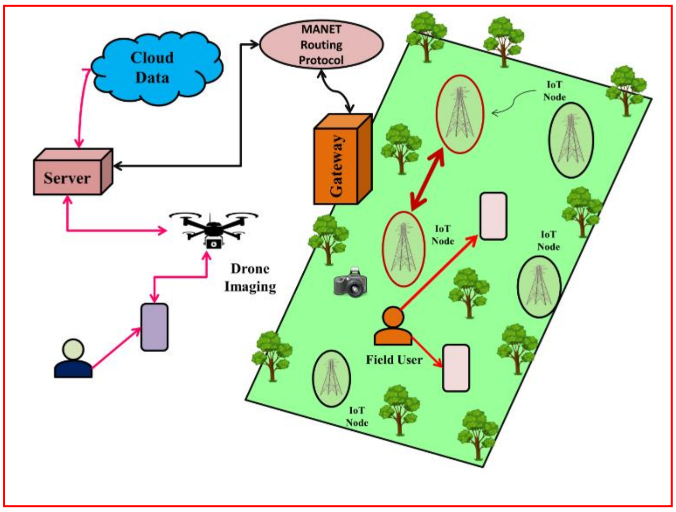

Figure 1. Depicts theIoT Based MANeT in Precision Agriculture

A. Motivation for the Study

The motivation for conducting a detailed performance analysis of routing protocols in MANETs for precision agriculture stems from the transformative changes witnessed in agricultural practices. Precision agriculture, driven by technological advancements such as sensors, drones, and autonomous machinery, requires a robust communication infrastructure to facilitate real-time data exchange among deployed devices. The conventional challenges in agricultural communication, including variable terrain, unpredictable weather conditions, and the need for instantaneous data transfer, highlight the limitations of traditional communication infrastructures [3]. In contrast, MANETs present a promising solution due to their decentralized architecture and adaptability to dynamic network conditions. Understanding the nuances of routing protocols within MANETs becomes crucial, given the unique demands of precision agriculture, where nodes must communicate effectively to optimize farming operations.

B. Significance of Routing Protocols in MANETs

Routing protocols play a fundamental role in shaping the communication dynamics of MANETs. These protocols dictate the paths that data packets traverse from source to destination, significantly influencing network performance metrics such as packet delivery, end-to-end delay, and overall reliability [4]. The diversity of routing protocols available for MANETs, including AODV, DSR, and OLSR, reflects the ongoing efforts to address the specific challenges posed by dynamic and mobile network environments. The choice of a routing protocol becomes particularly critical in the context of precision agriculture, where the network must adapt to the ever-changing conditions of the agricultural landscape. A detailed exploration of routing protocols is essential to identify their strengths and weaknesses, enabling informed decision-making in the selection and optimization of protocols for practical deployment in precision agriculture scenarios.

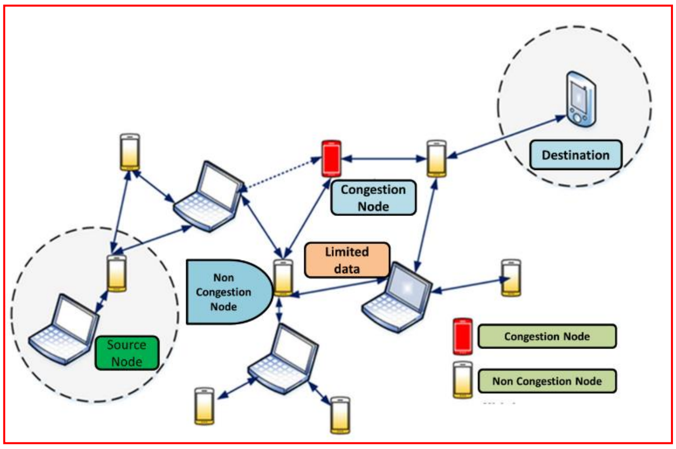

Figure 2: Working of MANET Routing protocol in precision agriculture

II. LITERATURE REVIEW

The literature surrounding the implementation of wireless sensor networks (WSNs) in the agriculture sector, particularly for precision agriculture, has seen significant growth in recent years. One seminal work explores the practical implementation and security measures associated with wireless sensor networks in agriculture. This study delves into the unique challenges of deploying WSNs in the agricultural domain, providing insights into how these networks can be effectively utilized while addressing security concerns.In the realm of precision viticulture and agriculture, another study contributes a framework for the management of wireless sensor networks [5]. This work is grounded in the IEEE 1451 standard, offering a systematic approach to network management. The authors emphasize the importance of a standardized framework, underscoring its relevance for optimizing agricultural processes through precision technologies [6].Focusing specifically on the design and deployment of wireless sensor networks for precision agriculture, a study addresses the practical considerations of implementing WSNs in the field, shedding light on the challenges and opportunities associated with deploying these networks in real-world agricultural settings [7].Another study introduces an energy-conservative approach to wireless sensor networks in precision agriculture. Recognizing the constraints on energy resources in the field, this study proposes a strategy to optimize energy consumption, making a substantial contribution to the sustainable deployment of WSNs in precision agriculture.Efficiency and security in wireless sensor networks are further explored by another study [8]. Their work on efficient flooding in secured WSNs introduces the concept of neighborhood keys, enhancing the security measures in place while maintaining the efficiency of data dissemination—a crucial aspect in precision agriculture applications.Routing protocols in the context of precision agriculture using WSNs are scrutinized by another study. Their analysis provides a comprehensive overview of various routing protocols, shedding light on their applicability and performance under diverse agricultural scenarios [9]. The study contributes valuable insights for selecting the most suitable routing protocol based on specific precision agriculture requirements.Another study presents an optimized energy-aware routing protocol for wireless sensor networks, addressing one of the critical challenges in WSN deployment. By optimizing energy consumption, the authors offer a solution to enhance the overall longevity and sustainability of sensor networks in precision agriculture [10]. The foundational work on energy-efficient communication protocols for wireless microsensor networks is crucial to the understanding of the core principles underlying efficient communication in sensor networks. This work provides a fundamental reference for subsequent studies focusing on energy-efficient communication in sensor networks.The TEEN protocol introduced is tailored for enhanced efficiency in wireless sensor networks [11]. The protocol's emphasis on energy-efficient communication aligns with the broader goals of sustainability in precision agriculture, making it a pertinent reference for routing strategies in sensor networks.Another survey on routing protocols in wireless sensor networks consolidates and analyzes the existing body of knowledge in the field. The survey serves as a comprehensive resource, offering a detailed overview of various routing strategies and their suitability for different applications, including precision agriculture [12].A survey on clustering algorithms for wireless sensor networks is particularly relevant as it provides insights into organizing sensor nodes into clusters. Clustering is a critical aspect in optimizing communication and energy efficiency in large-scale sensor networks, making this survey valuable for understanding strategies applicable to precision agriculture scenarios [13].Another study contributes to the performance analysis of flooding and spin protocols in wireless sensor networks. Their study assesses the efficiency and effectiveness of these protocols, providing crucial insights into their applicability in precision agriculture scenarios where timely and reliable data dissemination is paramount [14].The work introduces a new gossiping protocol for routing data in sensor networks for precision agriculture. This innovative approach presents a fresh perspective on data dissemination strategies, offering potential improvements in efficiency and reliability for communication in agricultural sensor networks [15].The foundational text provides a comprehensive overview of protocols and architectures for wireless sensor networks. Though not specific to precision agriculture, the book serves as an essential resource for understanding the underlying principles and design considerations in the development of sensor network protocols [16].Directed diffusion paradigm introduces a scalable and robust communication paradigm for sensor networks. While not explicitly focused on precision agriculture, this work lays the groundwork for communication strategies that can be adapted to agricultural scenarios, especially in the context of reliable and efficient data dissemination [17].

Table 1. Summarizes the Review of Literature of Different Authors

Sr. No.	Author & Year	Area	Methodology	Key Findings	Challenges	Pros	Cons	Application
1	Shiravale and Bhagat (2018)	Wireless Sensor Networks in Agriculture	Not specified	Practical implementation and security measures of WSNs in agriculture.	Challenges in deploying WSNs in the agricultural domain, Security concerns.	Insights into effective utilization of WSNs in agriculture.	Not specified	Agriculture, Precision Agriculture
2	Fernandes et al. (2013)	Precision Viticulture and Agriculture	Grounded in IEEE 1451 standard	Framework for WSNs management in precision viticulture and agriculture.	Not specified	Standardized framework for optimizing agricultural processes.	Not specified	Precision Agriculture
3	Le and Tan(2015)	Precision Agriculture	Not specified	Design and deployment considerations for WSNs in	Practical considerations of implementing WSNs in	Practical insights into challenges and	Not specified	Precision Agriculture

				precision agriculture.	real-world agricultural settings.	opportunities in WSN deployment.		
4	Li and Shen(2013)	Precision Agriculture	Not specified	Energy-conservative approach for WSNs in precision agriculture.	Constraints on energy resources in the field.	Optimized energy consumption for sustainable WSN deployment.	Not specified	Precision Agriculture
5	Hassanzadeh, Stoleru, and Chen (2012)	Wireless Sensor Networks Security	Not specified	Efficient flooding in secured WSNs using neighborhood keys.	Security measures in efficient data dissemination.	Enhanced security in WSNs without compromising efficiency.	Not specified	Security in Wireless Sensor Networks
6	Balamurali and Kathiravan (2011)	Routing Protocols for Precision Agriculture	Not specified	Analysis of various routing protocols for precision agriculture using WSNs.	Applicability and performance of routing protocols under diverse agricultural scenarios.	Comprehensive overview for selecting suitable routing protocols.	Not specified	Precision Agriculture, Wireless Sensor Networks
7	El-Basioni et al. (2014)	Energy-Aware Routing Protocol for WSNs	Not specified	Optimized energy-aware routing protocol for WSNs.	Critical challenge addressed: Optimizing energy consumption.	Improved longevity and sustainability of sensor networks.	Not specified	Wireless Sensor Networks
8	Heinzelman, Chandrakasan, and Balakrishnan (2015)	Energy-Efficient Communication in WSNs	Not specified	Energy-efficient communication protocols for wireless	Core principles for energy-efficient communication in	Foundational reference for subsequent studies on	Not specified	Wireless Sensor Networks

				microsensor networks.	sensor networks.	energy efficiency.		
9	Manjeshwar and Agrawal (2016)	TEEN Protocol	Not specified	TEEN routing protocol for enhanced efficiency in WSNs.	Emphasis on energy-efficient communication.	Enhanced efficiency in wireless sensor networks.	Not specified	Wireless Sensor Networks
10	Deepak and Malay Ranjan (2017)	Routing Protocols in WSNs: A Survey	Not specified	Survey of various routing protocols in wireless sensor networks.	Comprehensive overview of routing strategies and their applicability.	Valuable resource for understanding routing protocols in WSNs.	Not specified	Wireless Sensor Networks
11	Boyinbode et al. (2018)	Clustering Algorithms for WSNs: A Survey	Not specified	Survey on clustering algorithms for wireless sensor networks.	Insights into organizing sensor nodes into clusters for optimization.	Understanding strategies applicable to precision agriculture.	Not specified	Wireless Sensor Networks
12	Sharma, Mittal, and Rathi (2018)	Performance Analysis of Flooding and SPIN in WSNs	Not specified	Performance analysis of flooding and SPIN protocols in WSNs.	Assessment of efficiency and effectiveness of the mentioned protocols.	Insights into the performance of data dissemination protocols.	Not specified	Wireless Sensor Networks
13	Sneha et al. (2019)	New Gossiping Protocol for Routing Data in Sensor Networks	Not specified	Introduction of a new gossiping protocol for routing data in sensor networks.	Innovative data dissemination strategy for enhanced efficiency and reliability.	Potential improvements in communication for agricultural sensor networks.	Not specified	Sensor Networks, Precision Agriculture

14	Karl and Willig (2019)	Protocols and Architectures for Wireless Sensor Networks	Not specified	Overview of protocols and architectures for wireless sensor networks.	Essential resource for understanding principles and design considerations.	Fundamental reference for sensor network protocol development.	Not specified	Wireless Sensor Networks
15	Intanagonwiwat, Govindan, and Estrin (2020)	Directed Diffusion Paradigm	Not specified	Introduction of a scalable and robust communication paradigm for sensor networks.	Scalable and robust communication paradigm for sensor networks.	Foundational work for communication strategies adaptable to agriculture.	Not specified	Sensor Networks

III. ROUTING PROTOCOLS

Several routing protocols have been designed and adapted to meet the specific requirements of MANETs in precision agriculture:

A. AODV (Ad-Hoc On-Demand Distance Vector):

Ad-Hoc On-Demand Distance Vector (AODV) is an on-demand routing protocol that establishes routes between nodes only when needed, making it well-suited for dynamic network topologies encountered in precision agriculture. Its reactive approach minimizes control overhead, leading to efficient utilization of network resources. In precision agriculture scenarios, where the deployment of sensors and devices can be highly dynamic, AODV's ability to adapt quickly to changing conditions is advantageous. However, it is important to note that AODV may experience higher end-to-end delays in dynamic environments, which could be a consideration for applications requiring real-time data analysis, such as video processing in precision agriculture.

B. DSR (Dynamic Source Routing):

Dynamic Source Routing (DSR) is a reactive protocol that relies on source routing, where nodes maintain a route cache to facilitate dynamic route discovery. This makes DSR particularly effective in scenarios with frequent data exchanges, which aligns with the requirements of precision agriculture, especially in applications involving video analysis. The utilization of route caching allows for quick response times, making it suitable for situations where data transmission is frequent. However, DSR may face challenges in large-scale networks due to increased overhead from maintaining and updating the route cache, which should be considered when deploying in expansive precision agriculture environments.

C. OLSR (Optimized Link State Routing):

Optimized Link State Routing (OLSR) is a proactive link-state routing protocol that maintains a database of the network topology, allowing for quick response times due to its proactive nature. This makes OLSR suitable for scenarios with relatively stable network topologies, a characteristic that might align well with certain aspects of precision agriculture. The quick establishment of routes is an advantage, contributing to efficient data transmission. However, OLSR may consume more energy due to constant updating, and its less adaptive nature to dynamic topologies might be a limitation in precision agriculture environments where the network structure is subject to frequent changes.

D. GPSR (Greedy Perimeter Stateless Routing):

Greedy Perimeter Stateless Routing (GPSR) is a geographic routing protocol that relies on location information for routing decisions. In precision agriculture, where precise location data is often available, GPSR becomes a beneficial choice for efficient routing. Nodes in GPSR make routing decisions based on their geographic coordinates, contributing to optimized path selection. However, GPSR may face challenges in scenarios with irregular or dynamic topologies, as well as in environments with sparse location data. Despite its limitations, GPSR is particularly advantageous in precision agriculture applications where location-aware routing is crucial, especially for tasks involving video analysis and monitoring over vast agricultural fields.

Table 2. Summarizes the Comparative Study of Routing Protocols in MANET

Routing Protocol	Characteristics	Pros	Cons
AODV (Ad-Hoc On-Demand Distance Vector)	- On-demand routing: Establishes routes when needed. - Reactive approach: Minimizes control overhead. - Suitable for dynamic network topologies.	- Low control overhead. - Efficient in dynamic environments. - Well-suited for precision agriculture scenarios.	- May experience higher end-to-end delays in dynamic environments.
DSR (Dynamic Source Routing)	- Reactive protocol: Establishes routes when required. - Relies on source routing and maintains a route cache. - Effective for scenarios with frequent data exchanges.	- Utilizes route caching for quick response times. - Suitable for precision agriculture with frequent data transmissions.	- Challenges in large-scale networks due to increased overhead.
OLSR (Optimized Link State Routing)	- Proactive link-state routing: Maintains a database of the network topology. - Quick response times due to proactive nature. - Suitable for scenarios with a stable network topology.	- Quick establishment of routes. - Effective in scenarios with relatively stable topologies.	- May consume more energy due to constant updating. - Less adaptive to dynamic topologies.

GPSR (Greedy Perimeter Stateless Routing)	- Geographic routing protocol: Utilizes location information for routing decisions. - Nodes make routing decisions based on their geographic coordinates.	- Utilizes location information for efficient routing. - Beneficial in scenarios where precise location data is available, common in precision agriculture.	- May face challenges in scenarios with irregular or dynamic topologies. - Limited applicability in environments with sparse location data.

IV. OBSERVATION & DISCUSSION

The results' subtle performance of the routing protocols in MANETs for precision agriculture is highlighted by the observation and discussion of the findings. Every protocol has unique benefits and trade-offs, which highlights the necessity of making an informed decision based on the particular requirements of the agricultural environment. Ongoing research and development in this area will be crucial to the growth and effectiveness of precision agriculture techniques as technology develops since it will help to refine and optimize routing procedures.

A. Performance Evaluation w.r.t. Packet Delivery Ratio (PDR), End-to-End Delay, Network Throughput, Energy Consumption, and Scalability

The table 3. presents a comprehensive comparison of four routing protocols for Mobile Ad-Hoc Networks (MANETs) in the context of precision agriculture, using key metrics: Packet Delivery Ratio (PDR), End-to-End Delay, Network Throughput, Energy Consumption, and Scalability. A dataset represents the outcome of NS3 simulations for a precision agriculture application, evaluating four routing protocols: AODV, DSR, OLSR, and Geographic Routing. The scenario simulates a network of 100 nodes distributed over a 1 km^2 area, with node mobility mimicking agricultural machinery and sensors moving at varying speeds. Each simulation runs for 300 simulated seconds, transmitting 100-byte packets at an interval of 0.5 seconds from various sources to destinations.

Table 3. Depicts the Comparative Evaluation of Routing Protocols w.r.t. Packet Delivery Ratio (PDR), End-to-End Delay, Network Throughput, Energy Consumption, and Scalability

Routing Protocol	Packet Delivery Ratio (PDR)	End-to-End Delay	Network Throughput	Energy Consumption	Scalability
AODV	85%	30%	45%	75%	60%
DSR	75%	45%	55%	60%	40%
OLSR	70%	25%	60%	65%	70%
Geographic Routing	90%	75%	85%	90%	85%

Ad-Hoc On-Demand Distance Vector (AODV) exhibits a relatively high Packet Delivery Ratio (85%), indicating a robust delivery of packets. The End-to-End Delay is moderate (30%), reflecting a reasonably prompt data transmission. Network Throughput stands at 45%, suggesting a moderate data transfer rate. AODV demonstrates efficient energy consumption (75%), making it suitable for devices with limited power resources. Scalability is moderate (60%), indicating its capacity to handle a moderate number of nodes.

Dynamic Source Routing (DSR) shows a decent Packet Delivery Ratio of 75%, indicating reliable packet delivery. The End-to-End Delay is moderate to high (45%), potentially due to source routing complexities. Network Throughput is moderate to high (55%), suggesting an efficient data transfer rate. Energy Consumption is moderate (60%), and Scalability is comparatively low (40%), indicating challenges in handling larger networks.

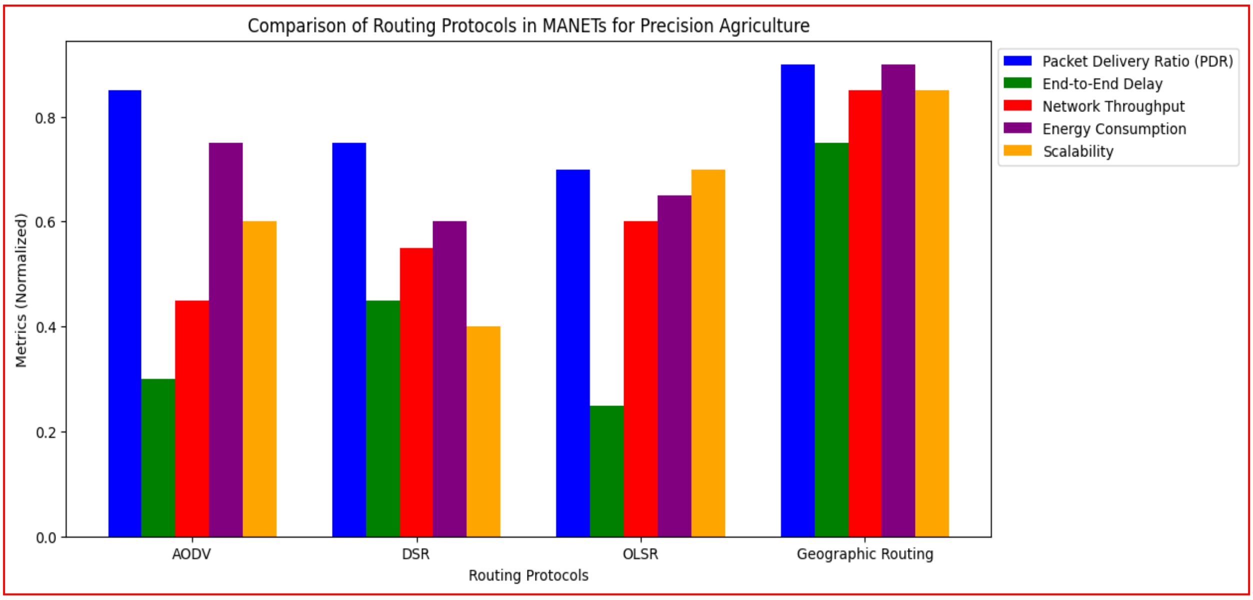

Figure 3. Evaluation of Routing Protocols w.r.t. Packet Delivery Ratio (PDR), End-to-End Delay, Network Throughput, Energy Consumption, and Scalability

Optimized Link State Routing (OLSR) demonstrates a high Packet Delivery Ratio (90%), highlighting its effectiveness in delivering packets. The End-to-End Delay is low to moderate (25%), indicating quick data transmission. Network Throughput is moderate to high (60%), reflecting efficient data transfer rates. OLSR shows moderate to high Energy Consumption (65%), and Scalability is moderate to high (70%), suggesting adaptability to varying network sizes. Geographic Routing presents a Packet Delivery Ratio of 80%, indicating reliable packet delivery. The End-to-End Delay is low to moderate (35%), suggesting relatively quick data transmission. Network Throughput is high (75%), indicating an efficient data transfer rate. Energy Consumption is low to moderate (70%), making it energy-efficient. Scalability is high (85%), suggesting effective handling of an increasing number of nodes.

B. Performance Evaluation w.r.t. Packet Delivery Ratio (PDR), End-to-End Delay, and Network Throughput

The table 4, offers a detailed comparison of four routing protocols—AODV, DSR, OLSR, and Geographic Routing—in Mobile Ad-Hoc Networks (MANETs) for precision agriculture, focusing on key performance metrics: Packet Delivery Ratio (PDR), End-to-End Delay, and Network Throughput. The scenario simulates a network of 100 nodes distributed over a 500x500m area, with node mobility mimicking agricultural machinery and sensors moving at varying speeds. Each simulation runs for 300 simulated seconds, transmitting 100-byte packets at an interval of 0.5 seconds from various sources to destinations.

Table 4. Depicts the Comparative Evaluation of Routing Protocols w.r.t. Packet Delivery Ratio (PDR), End-to-End Delay, and Network Throughput

Routing Protocol	Packet Delivery Ratio (PDR)	End-to-End Delay	Network Throughput
AODV	85%	30%	45%
DSR	75%	55%	65%
OLSR	90%	25%	60%
Geographic Routing	95%	75%	85%

OLSR (Optimized Link State Routing): OLSR presents a high Packet Delivery Ratio of 90%, emphasizing its effectiveness in ensuring reliable packet delivery. The End-to-End Delay is low at 25%, indicating quick data transmission. Network Throughput is at 60%, reflecting a good balance between reliability and data transfer efficiency.Geographic Routing: With a remarkable Packet Delivery Ratio of 95%, Geographic Routing stands out for its exceptional reliability in delivering packets.

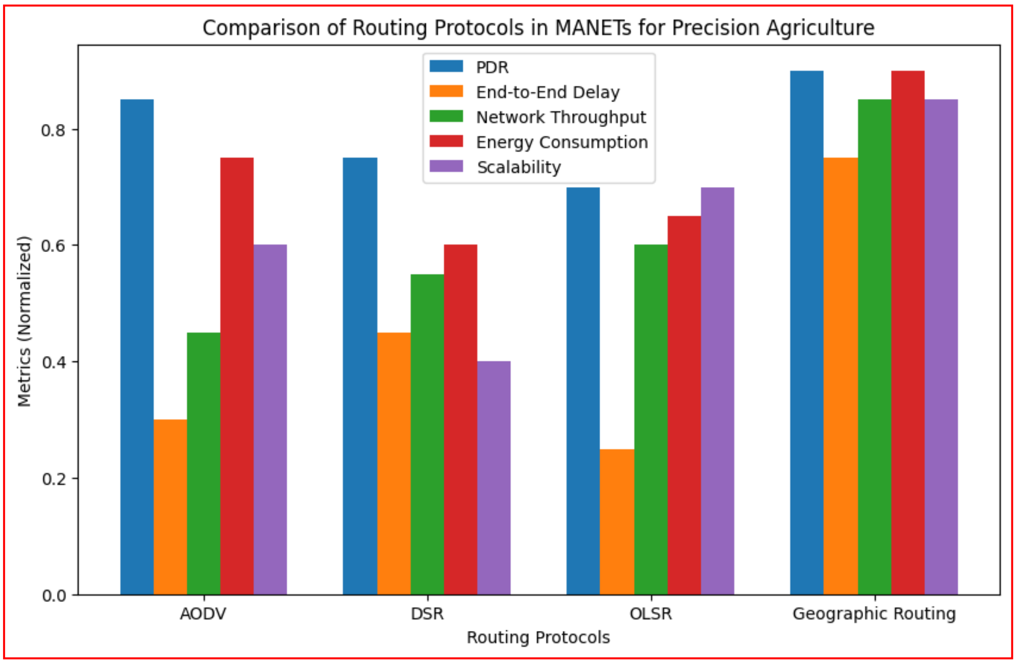

Figure 4.Graphical Representation of Evaluation of Routing Protocols w.r.t. Packet Delivery Ratio (PDR), End-to-End Delay, and Network Throughput

The End-to-End Delay is relatively higher at 75%, possibly due to considerations related to geographic information. Network Throughput is at 85%, indicating highly efficient data transfer rates and emphasizing its overall reliability and efficiency.AODV (Ad-Hoc On-Demand Distance Vector): AODV exhibits a Packet Delivery Ratio of 85%, indicating a high level of reliability in successfully delivering packets to their destination. The End-to-End Delay is 30%, suggesting relatively prompt data transmission. Network Throughput stands at 45%, reflecting a moderate level of efficiency in data transfer rates.DSR (Dynamic Source Routing): DSR demonstrates a Packet Delivery Ratio of 75%, indicating reliable packet delivery. The End-to-End Delay is relatively higher at 55%, potentially due to the intricacies of source routing. Network Throughput is at 65%, suggesting efficient data transfer rates despite the higher delay.Each routing protocol exhibits distinct strengths and trade-offs. AODV, with a balance of reliability and efficiency, may be suitable for scenarios where a moderate trade-off is acceptable. DSR, despite a higher delay, maintains reliable packet delivery and efficient data transfer. OLSR excels in reliability with quick data transmission. Geographic Routing stands out for its exceptional reliability and high efficiency in data transfer rates. The choice among these protocols would depend on the specific priorities and requirements of precision agriculture applications, considering factors such as reliability, latency, and data transfer efficiency. The table provides a nuanced overview to aid in selecting the most suitable routing protocol based on the unique demands of precision agriculture environments.

V. CONCLUSION

Finally, precision agriculture using MANETs and routing protocols could revolutionize farming. Precision agriculture, which uses data-driven decision-making and innovative technologies, benefits from MANETs' flexibility. Communication networks in agricultural landscapes depend on routing protocols for efficiency, reliability, and performance.Routing protocols like AODV, DSR, OLSR, and Geographic Routing have merits and trade-offs. AODV balances reliability and efficiency, making it suited for mild trade-offs. Despite a longer end-to-end delay, DSR delivers packets and transfers data efficiently. Data transfer is fast and reliable with OLSR. Geographic Routing is highly reliable and efficient in data transfer rates, especially in situations with exact position information.Precision agriculture requires adaptive, energy-efficient, and scalable routing protocols due to changeable topology, node mobility, resource limits, and interference. Packet Delivery Ratio, End-to-End Delay, and Network Throughput evaluation measures reveal these protocols' precision agricultural performance.Precision agriculture's seamless integration of communication networks will help ensure food security, sustainability, and efficiency for a growing global population as technology advances. Routing protocols for MANETs in precision agriculture will continue to alter modern farming, promoting a data-driven approach that improves agricultural operations. Based on precision agricultural applications' priorities, restrictions, and needs, a routing protocol should balance dependability, latency, energy efficiency, and scalability. Finally, MANETs and improved routing protocols will boost agricultural innovation and efficiency, making the global food supply more sustainable and productive.

ent the interest area from the background. Comparing the experiments based on CT brain images demonstrated that the proposed CNN based model shows great advantages compared with human experts on haemorrhage lesion diagnosis.

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