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Research Article

Routing Strategies in Wireless Sensor Networks: A Relative Analysis

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ABSTRACT

Introduction: Wireless Sensor Networks (WSNs) rely on decentralized nodes to monitor environmental parameters such as temperature, pressure, and sound. The effectiveness of these networks hinges on routing protocols capable of managing dynamic topologies, energy limitations, and bandwidth constraints. This study conducts a systematic evaluation of five prominent WSN routing protocols—LEACH, TORA, DSR, DSDV, and AODV—to assess their efficacy under diverse network configurations. The analysis focuses on critical performance indicators, including Packet Delivery Ratio (PDR), throughput, end-to-end delay, and energy consumption, aiming to delineate optimal use cases for each protocol

Objectives: Aim of this research is to systematically compare the performance achievement of DSR ,TORA, LEACH, , AODV and DSDV routing protocols for WSN. The objective is to evaluate the performance of the selected protocols using key metrics like throughput, end-to- end delay, packet delivery ratio and energy consumption. It also analyze protocol behavior under different network sizes, node mobility patterns.

Methods: A simulation-driven approach was implemented using the NS2 network simulator, with scenarios varying in node density, mobility patterns, traffic load, and energy parameters. Each protocol was rigorously tested under standardized conditions, with results averaged across multiple iterations to ensure statistical validity. Cross-referencing with prior studies further validated the findings.

Results: Key results reveal that AODV and DSR outperform others in dynamic environments, achieving higher PDR and adaptability to topology changes. DSDV maintains reliability in stable, small-scale networks but degrades with increased mobility or scale. LEACH exhibits superior energy conservation and minimal latency, aligning with sensor networks prioritizing longevity, though its hierarchical structure limits versatility in general ad hoc settings. TORA demonstrates rapid adaptation to link failures but faces instability in dense networks.

Conclusions: These findings underscore the necessity of context-specific protocol deployment. LEACH is ideal for energy-sensitive deployments, AODV and DSR for high-mobility scenarios requiring robust data delivery, and DSDV for static, small-scale networks. The research advocates for hybrid or adaptive routing strategies to address the heterogeneous demands of modern WSN applications.

Keywords: Wireless sensor network, TORA, LEACH, DSR, DSDV, AODV, Performance Evaluation

INTRODUCTION

Wireless sensor networks composed of mobile or static nodes that communicate directly or via intermediate nodes. Unlike traditional wireless networks, it do not rely on fixed infrastructure or centralized administration, making them highly adaptable for use in dynamic and unpredictable environments such as disaster recovery, military operations, and remote sensing. Reliability and efficiency of these networks heavily depend on the underlying routing protocols, which must address

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challenges like, frequent topology changes, limited bandwidth, and energy constraints [1,2].
Over the years, numerous routing protocols had been designed related to wireless networks, each adopting different strategies regarding discovering and maintaining routes between nodes. Among these, Dynamic Source Routing, Destination-Sequenced Distance-Vector, Temporally Ordered Routing Algorithm, Ad hoc On-demand Distance Vector routing and Low-Energy Adaptive Clustering Hierarchy are widely used. [2,3,4].
Despite the extensive development of routing protocols for WSN, there is no single protocol that consistently
outperforms others across all network conditions. Each protocol exhibits unique strengths and weaknesses
depending on factors like network size, mobility of nodes, energy constraints, and traffic patterns. Hence, selecting the most suited routing protocol for a specific wireless sensor network deployment remains a significant challenge. This research addresses the problem of systematically comparing the performance of TORA, LEACH, DSR, DSDV, and AODV to provide insights into their suitability under different network scenarios[3,4].
The predominant objective of presented research is to execute a comprehensive comparative analysis of five prominent wireless routing protocols: TORA, LEACH, DSR, DSDV, and AODV. This work aims to evaluate significance of these protocols under varying network conditions using key metrics like PDR, throughput and end- to-end delay. It identifies the strengths and limitations of each protocol within differed scenarios. Moreover it provides recommendations for protocol selection based on specific requirements[3,4,5].
The paper is structured as follows- section 1deals with the introduction to the topic, section 2 gives detailed literature survey, section 3 is the experimentation. Section 4 discusses the results and section 5 provides the conclusion of the research work carried out.

LITERATURE REVIEW

Recent research on wireless routing protocols highlights the diversity of approaches designed to address the unique
challenges of mobile, infrastructure-less networks. Protocols are mainly classified as reactive (on-demand),
proactive (table-driven), or hierarchical and hybrid. Each have distinct operational philosophies and tradeoffs[1,2,3,4,5]. Categorization of these routing protocols is indicated in following figure.

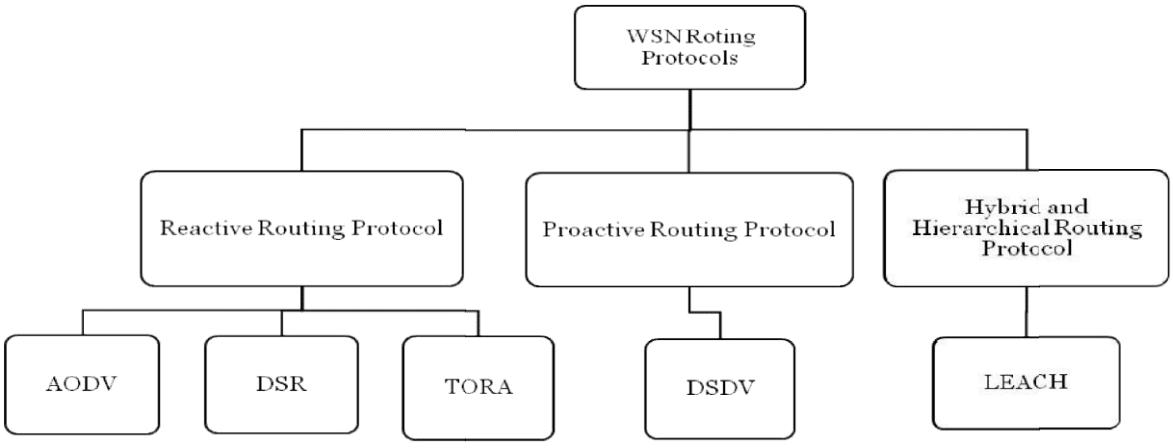

Fig. 1. Routing Protocols for Wireless sensor networks

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Proactive protocols maintain up-to-date routes to all nodes, offering low latency at the cost of higher control overhead[1,2,3].DSDV is recognized for its simplicity and low latency in static or low-mobility environments but suffers from high overhead in dynamic topologies[1,2,3,4]. Reactive protocols establish routes only when needed, reducing overhead but potentially increasing initial packet delivery delay[4,5]. Hierarchical Organize nodes into clusters to improve scalability and energy efficiency, particularly in sensor networks[6,7]. DSDV is table-driven protocol using periodic updates, suitable for networks with low mobility but less efficient in highly dynamic environments[3]. DSR protocol offers high packet delivery in small to medium networks but experiences increased delay and routing overhead as mobility rises. It utilizes source routing and route caching, effective in small to medium networks but susceptible to high delay in large or highly mobile scenarios [3,4,5]. AODV is valued for its scalability and loop-free operation, balancing overhead and delay effectively in diverse scenarios. It combines on- demand route discovery with sequence numbers to prevent loops, offering scalability and reliability[5,6,7]

TORA is designed for rapid adaptation to topology changes but may face reliability issues in dense or highly mobile networks. It adapts quickly to topology changes using a link reversal algorithm, but may suffer from reliability issues in dense networks[8] Hybrid and hierarchical protocol that is LEACH combine aspects of both, often using clustering or zone-based strategies to improve scalability and energy efficiency, especially in sensor networks. LEACH is prominent in energy-constrained sensor networks, using clustering to extend network lifetime, though its applicability to general WSN is limited[9,10,11]. It employs clustering for energy-efficient communication, ideal for sensor-type networks but less effective for general ad hoc scenarios.
The comparison of the routing protocols considered for the performance analysis ids provided in the following table

Table 1: Comparison of different routing protocols for WSN [1-11]

Feature/Metric	**Proactive (DSDV)**	**Reactive (AODV, DSR, TORA)**	**Hybrid/Clustering (LEACH)**
Scalability	Limited	Moderate to High	High
Latency	Low	High (initially)	Low (intra-cluster)
Overhead	High	Low	Medium
Energy Efficiency	Low	Moderate	High
Adaptability	Poor (dynamic)	Good	Good (with clustering)
Security/Trust	Limited studies	Limited studies	Limited studies

Comparative studies indicate that reactive protocols generally perform better in highly dynamic environments with lower overhead, while proactive protocols offer lower latency in stable networks. LEACH excels in energy efficiency, particularly for sensor networks, but is less suited for general-purpose wireless sensor networks. studies focus on generic performance metrics without addressing application-specific requirements like emergency messaging. Most energy-focused research centers on LEACH, with less attention to energy consumption in protocols like AODV, DSR, and TORA in realistic scenarios [1-11]. Hence the heterogeneous approach can be developed for the better performance.

EXPERIMENTATION AND SIMULATION SETUP

Aim of this research is to systematically compare the performance achievement of DSR ,TORA,

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LEACH, , AODV and DSDV routing protocols for WSN. The objective is to evaluate the performance of the selected protocols using key metrics like throughput, end-to-end delay, packet delivery ratio and energy consumption. It also analyze protocol behavior under different network sizes, node mobility patterns. This research work adopts a quantitative, simulation-based comparative research appr ach to evaluate the performance of five WSN routing protocols. Evaluation is carried out based by varying node density, mobility, and energy constraints

EXPERIMENTATION

Protocols are implemented and evaluated using NS2 network simulators. Multiple simulation scenarios are created by varying network size, node mobility, traffic patterns, and energy constraints. Each scenario is run multiple times to ensure consistency and reliability of results. Performance metrics are logged and exported for further analysis. Multiple simulation runs (e.g., 10–20 per scenario) are performed to account for variability due to random node mobility and stochastic network events. Protocols implementations are based on standard specifications to ensure comparability and reproducibility. Cross-validation with results from previous studies is performed to confirm the accuracy of finding

SIMULATION SETUP

The performance of different WSN routing protocol is analyzed by using the parameters shown in the table 1 .. Here the number of nodes is varied for performance comparison.

Table: 2: Simulation Scenario for DSDV

Parameter Values	Simulation Criteria
Number of nodes	20 , 40, 60, 80, 100
Channel type	Wireless Channel
Radio-propagation model	Propagation/Two Ray Ground
Traffic Model	CBR/UDP
MAC type	Mac/802_11
X and Y dimension of topography	800 X 800
Time of simulation	80 sec

RESULTS AND DISCUSSION

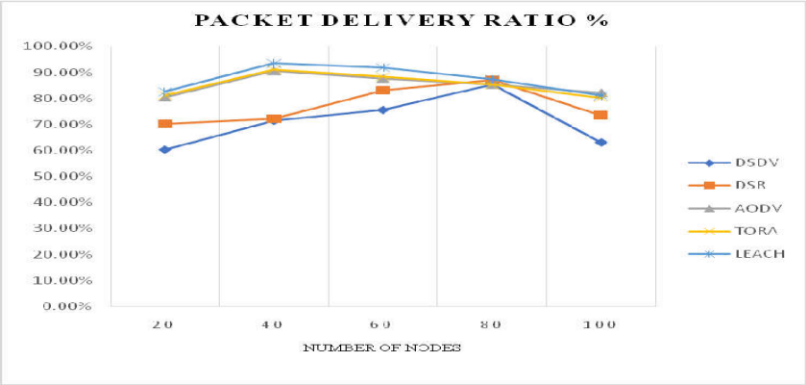

Fig. 2 Packet Delivery Ratio

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Fig. 3 Throughput

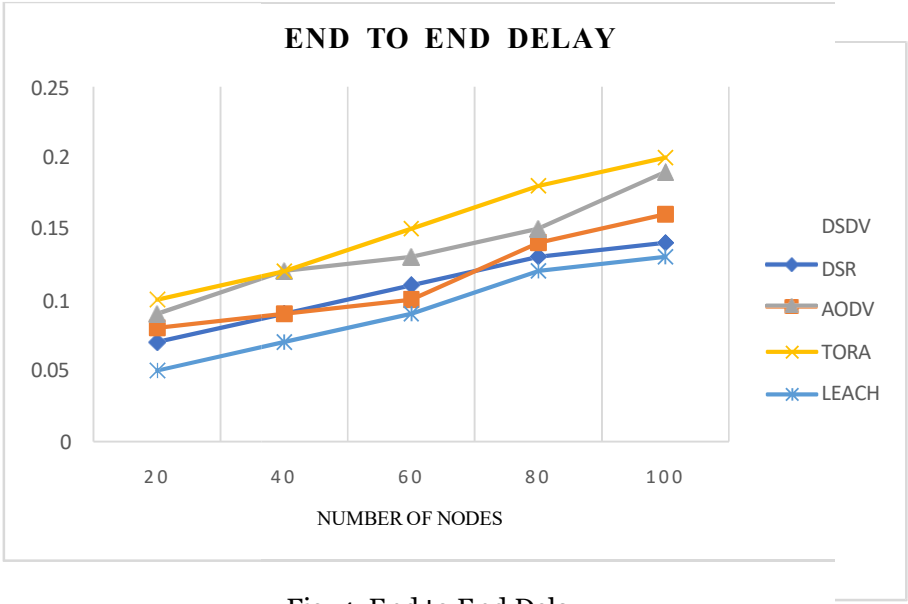

Fig. 4. End to End Delay

Performance metrics from driven simulation indicate that AODV and DSR consistently achieve higher packet delivery ratios in dynamic scenarios, while DSDV performs reliably in stable conditions but struggles as network size or mobility increases. LEACH demonstrates superior performance, confirming its suitability for energy-

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constrained environments. End-to-end delay is lowest in LEACH, while AODV, DSR and TORA experience higher delays due to route discovery or maintenance mechanisms.
These findings align with the broader literature, which consistently reports that no single protocol is optimal for all WSN scenarios. The choice between proactive, reactive, and hierarchical protocols should be guided by the specific application context, including network size, node mobility, energy constraints, and the criticality of timely data delivery.

CONCLUSION

From the above research it is found that single routing protocol is universally optimal for all WSN scenarios. LEACH and TORA generally provide better packet delivery and throughput in dynamic environments. End to End delay is high in TORA. LEACH excels in energy efficiency for sensor-type networks. TORA adapts rapidly to topology changes but suffers from reliability issues, and DSDV is best suited for small, less dynamic networks. The choice of protocol should be guided by specific network requirements such as mobility, scalability, energy constraints, and application needs.

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