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Optimisation of Power Consumption in MANETs: A Conceptual Approach

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Abstract

Mobile Ad hoc Networks (MANETs) have gained significant attention due to their dynamic and self-organizing nature, making them suitable for various applications, including military, disaster relief, and IoT. One of the critical challenges in MANETs is the limited power resources of mobile nodes. Efficiently managing power consumption is essential to extend network lifetime and ensure uninterrupted communication. This paper presents a conceptual approach for the optimization of power consumption in MANETs. Our approach encompasses three main aspects: (1) Adaptive Routing Protocols, (2) Power-Aware Node Mobility, and (3) Energy-Efficient Data Transmission. we propose the integration of adaptive routing protocols that dynamically adjust routing paths based on the energy level of nodes and network conditions, reducing the energy overhead associated with maintaining routes. Secondly, we introduce a power-aware node mobility scheme that aims to strategically move nodes to reduce energy consumption while maintaining network connectivity. This approach involves smart node clustering and movement strategies to minimize the need for energy-intensive long-distance communication. Lastly, we focus on energy-efficient data transmission techniques, including data aggregation, compression, and adaptive modulation schemes, to minimize the energy required for transmitting data across the network.

Keywords:- Energy-Efficient Routing,Transmission Power,Throughput

Introduction

Mobile Ad hoc Networks (MANETs) have emerged as a versatile and dynamic form of wireless communication infrastructure, enabling autonomous and self-organizing networks without the need for a fixed infrastructure or centralized control. These networks find applications in various domains, including military operations, disaster management, environmental monitoring, and the Internet of Things (IoT). However, one of the most significant challenges faced by MANETs is the limited energy resources of their mobile nodes. The nodes in a MANET

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are typically powered by batteries, making efficient power management critical to the longevity and reliability of the network. Optimizing power consumption in MANETs is essential to prolong network lifetime, reduce operational costs, and ensure uninterrupted communication in resource-constrained environments. Power optimization can also have a substantial impact on the sustainability and feasibility of MANETs in the long term. To address these challenges, this paper presents a conceptual approach aimed at optimizing power consumption in MANETs. we take a comprehensive view of the problem, considering multiple facets of power consumption. We propose a combination of strategies that collectively work towards minimizing energy consumption while maintaining network connectivity and performance.

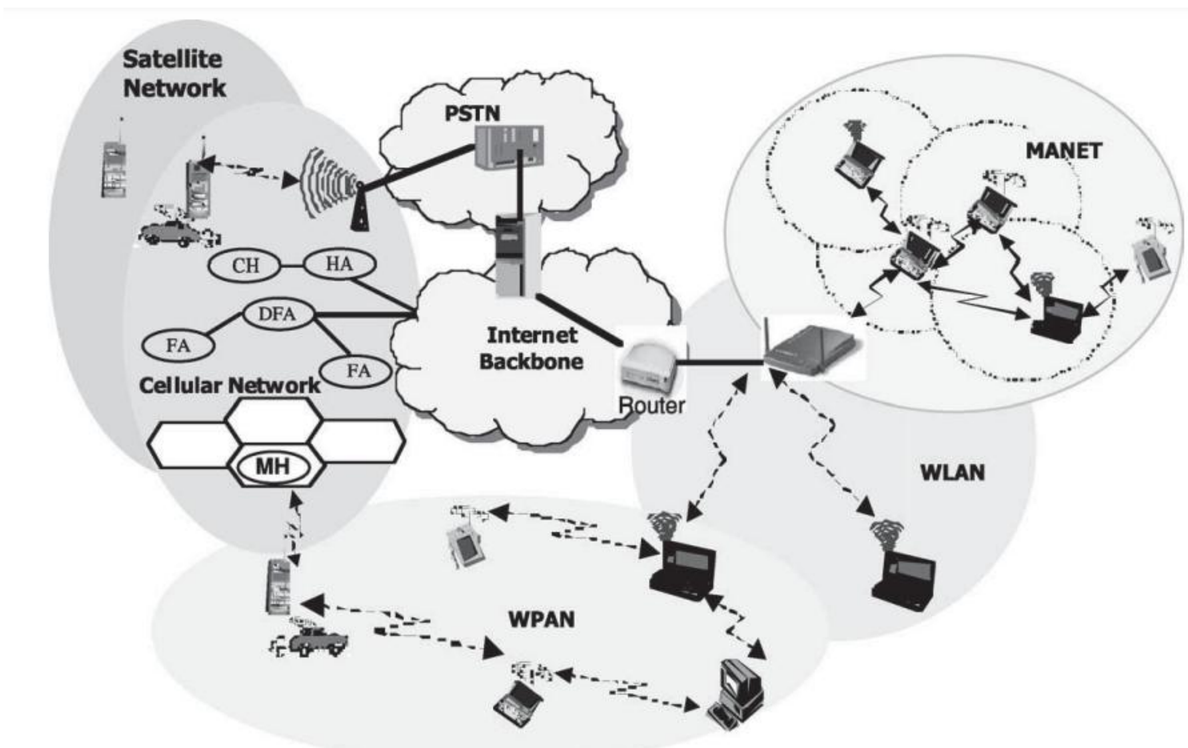

Fig 1 Mobile Ad-hoc Network and its interconnection

The key components of our approach include the integration of adaptive routing protocols that consider the energy state of nodes, power-aware node mobility management to reduce energy-intensive long-distance communication, and energy-efficient data transmission techniques. These elements together create a holistic framework to address power consumption challenges in MANETs. The remainder of this paper elaborates on each component of our conceptual

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approach, providing insights into how these strategies can be implemented and their potential benefits. Simulation results and theoretical analyses will also be presented to illustrate the advantages of our approach in terms of network sustainability and performance. By exploring these aspects, we aim to contribute to the development of more energy-efficient and sustainable MANETs that can effectively serve a wide range of applications in the ever-evolving landscape of wireless and mobile communication.

Need of the Study

The need for the study on the optimization of power consumption in Mobile Ad hoc Networks (MANETs) is driven by several critical factors and challenges that affect the sustainability, reliability, and practicality of MANETs in various real-world applications. The following are the key reasons highlighting the significance of this study:

1. **Limited Energy Resources**: MANETs consist of mobile nodes that are typically battery-powered. These nodes have limited energy reserves, and once depleted, they become non-operational. Efficiently managing power consumption is crucial to extend the network's operational lifetime, which is often a critical requirement in applications like military operations, disaster management, and remote monitoring.

2. **Dynamic Network Topology**: MANETs exhibit dynamic and constantly changing network topologies due to node mobility, connectivity fluctuations, and environmental factors. Traditional network optimization techniques may not be directly applicable to MANETs, necessitating the development of specialized strategies to adapt to this dynamic nature.

3. **Resource-Constrained Environments**: MANETs are often deployed in resource-constrained environments where recharging or replacing batteries is challenging or impossible. Therefore, optimizing power consumption is not only a performance enhancement but a fundamental requirement for network functionality.

4. **Communication Reliability**: Maintaining reliable communication is vital in MANET applications, where timely and accurate information exchange is critical. Excessive power consumption can lead to frequent node failures and communication disruptions, compromising the network's reliability.

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5. **Cost Efficiency**: Efficient power management can result in cost savings in terms of battery replacement, maintenance, and operational expenses. This is particularly important in large-scale MANET deployments, such as IoT networks.
6. **Environmental Impact**: Reducing power consumption in MANETs contributes to minimizing the environmental footprint by reducing the frequency of battery disposal and the associated waste.
7. **Scalability and Ubiquity**: As wireless communication technologies continue to proliferate, MANETs have the potential to play a significant role in scalable, ubiquitous communication. To realize this potential, addressing power consumption challenges is essential.
8. **Emerging Applications**: The advent of new applications like the Internet of Things (IoT) and edge computing places even greater demands on power-efficient networking in MANETs, as many IoT devices are battery-operated and operate in ad hoc settings.
9. **Scientific Advancement**: Research in power optimization in MANETs contributes to the advancement of wireless communication and networking technologies, benefiting both academia and industry.

The study on the optimization of power consumption in MANETs is imperative to address the unique challenges associated with mobile, battery-powered networks. It not only extends the operational lifetime of these networks but also enhances their reliability, cost-efficiency, and adaptability to dynamic conditions, making MANETs more practical and sustainable for a wide range of applications.

Literature Review

Anand, M., &Sasikala, T. (2019). Efficient energy optimization in Mobile Ad Hoc Networks (MANETs) is crucial for prolonging the network's lifespan and ensuring reliable communication. To achieve this, the utilization of a high-quality Ad Hoc On-Demand Distance Vector (AODV) protocol is essential. The AODV protocol minimizes energy consumption by establishing routes only when needed, which significantly reduces overhead. Moreover, enhancements to the traditional AODV protocol can be employed to make it even more energy-efficient. Techniques like route caching, intelligent route selection, and route maintenance optimization can further reduce energy consumption in MANETs.

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Devika, B., &Sudha, P. N. (2020). Power optimization in Mobile Ad Hoc Networks (MANETs) through topology management is essential to conserve energy and enhance the network's overall performance. MANETs are characterized by their dynamic and self-configuring nature, which necessitates efficient power usage. Topology management involves controlling the network's structure and connectivity to minimize energy consumption. By periodically adjusting the network's topology, unnecessary connections and relay nodes can be eliminated, reducing the power consumption associated with maintaining those links. This can be achieved through techniques like cluster formation, where nodes are organized into clusters with a designated leader, or through selective routing, where power-hungry nodes are avoided as relays.

Kumar, A. (2012). The performance evaluation of energy consumption in Mobile Ad Hoc Networks (MANETs) is a critical aspect of network management, as it directly impacts the longevity and efficiency of battery-powered mobile devices within the network. MANETs are characterized by their dynamic topology, self-organization, and decentralized operation, making energy conservation a fundamental concern. To assess energy consumption, various metrics and evaluation techniques are employed. One common approach is to measure the energy consumption of individual nodes or devices over time, analysing their power usage patterns. Metrics such as residual battery life, packet delivery ratio, and node lifetime are used to gauge the network's energy efficiency.

Nancharaiah, B., & Mohan, B. C. (2014). The performance of a hybrid routing intelligent algorithm in a Mobile Ad Hoc Network (MANET) is a subject of significant interest and research due to the dynamic and ever-changing nature of MANETs. Hybrid routing algorithms combine different routing techniques to enhance the network's efficiency and adaptability. These algorithms intelligently switch between various routing strategies, such as proactive and reactive, based on the network's current conditions and requirements. The advantages of a hybrid approach include improved route discovery, reduced control overhead, and enhanced adaptability to network changes. Proactive routing components maintain stable routes, while reactive components are activated when on-demand routing is needed, conserving energy and resources. Performance evaluation of such algorithms involves assessing parameters like packet delivery ratio, end-to-end delay, and network throughput.

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Ali, H., Shahzad, W., & Khan, F. A. (2012). Energy-efficient clustering in Mobile Ad-Hoc Networks (MANETs) is a crucial challenge to extend the network's lifetime, particularly in resource-constrained environments. Multi-objective Particle Swarm Optimization (MOPSO) is an innovative approach that addresses this problem by optimizing multiple objectives simultaneously. Clustering is a key technique in MANETs, as it reduces overhead and conserves energy by forming groups of nodes. MOPSO enhances the clustering process by considering various conflicting objectives, such as minimizing energy consumption, maximizing network lifetime, and maintaining cluster stability. MOPSO-based clustering algorithms optimize cluster head selection, cluster formation, and energy-efficient routing. By incorporating multiple objectives, they strike a balance between energy conservation and network performance.

Sinwar, D., et al (2020). An analysis and comparison of the Ant Colony Optimization (ACO) algorithm with traditional routing protocols like DSDV, AODV, and AOMDV in Mobile Ad-Hoc Networks (MANETs) based on shortest path selection is vital to understanding the trade-offs and benefits of these routing strategies. ACO, inspired by the foraging behavior of ants, offers a unique approach to routing where mobile nodes use pheromone-based information to discover and optimize routes. When evaluating ACO against DSDV, AODV, and AOMDV for shortest path selection, several factors come into play. ACO excels in finding globally optimized paths, but it may introduce additional overhead due to pheromone updates. In contrast, DSDV offers simplicity and minimal overhead but may struggle with dynamic network conditions. AODV and AOMDV provide reactive routing with quicker adaptation to topology changes, but AOMDV stands out due to its loop-free nature.

Proposed Methodology

The primary objective of this approach is to enhance energy efficiency and route stability within the network. It achieves this goal by seamlessly integrating modifications into the existing AODV (Ad hoc On-Demand Distance Vector) protocol. These modifications are specifically designed to accommodate varying levels of data traffic and consist of two key phases: the Route Request Phase (RREQ) and the Route Reply Phase (RREP). In this adapted version of the AODV protocol, each node actively maintains and updates its routing table with crucial power-related information. The battery status of each node is categorized into different levels, with the lowest and most critical battery status rendering the node ineligible for participation in routing

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decisions. Conversely, the Active state signifies that the node's battery has a sufficient charge, surpassing a predefined threshold. When a new route is required, the system intelligently evaluates the battery status of available nodes and establishes the route accordingly. The process of Route Establishment is facilitated by an algorithm that assists in selecting the most suitable sequence of nodes along the path for the requesting party. This ensures that the chosen route not only satisfies the data traffic requirements but also maximizes energy efficiency and route stability, thus contributing to the overall effectiveness of the network.

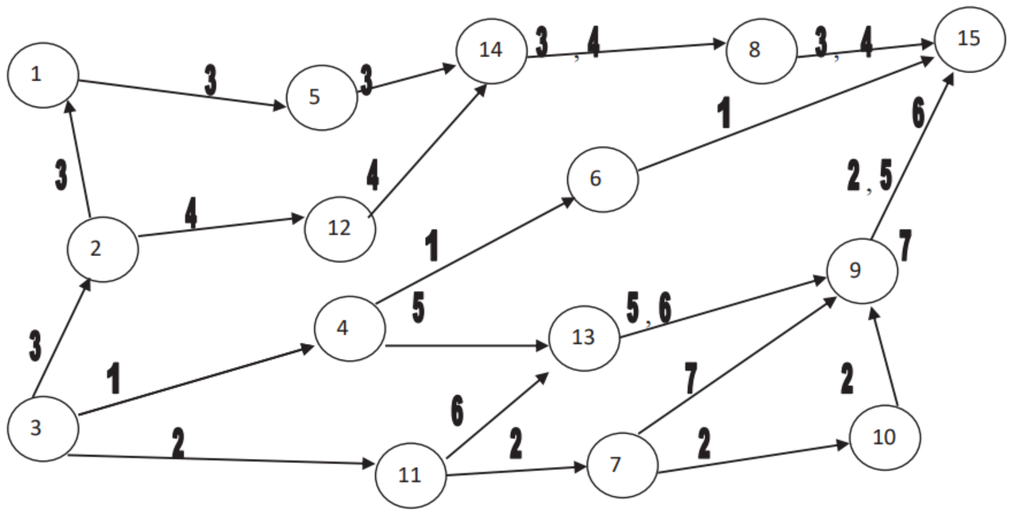

Fig 2 Route searching method.

Routing in Mobile Ad Hoc Networks (MANETs) is a vital research area where researchers develop and evaluate routing protocols to enhance network performance. Performance metrics like Average Jitter, End-to-End Delay, Packet Delivery Ratio (PDR), Throughput, and Power Consumption are used to assess the effectiveness of these protocols. Source nodes in MANETs seek simple and efficient paths with minimum delay and hop count. Routing protocols can be proactive, maintaining routing tables with periodic updates, or reactive, initiating route discovery on-demand. Hybrid protocols combine elements of both approaches. These protocols help source nodes find and maintain routes in a dynamically changing network where nodes communicate wirelessly without a fixed infrastructure. Researchers continually refine these protocols to meet the evolving needs of mobile ad hoc networks.

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Table 1 : List of searching Path

Path number	Source node	Destination node	Intermediate nodes	Number of hops
1	3	15	4,6	3
2			11,7,10,9	5
3			2,1,5,14,8	6
4			2,12,14,8	5
5			4,13,9	4
6			11,13,9	4
7			11,7,9	4

In the study of computer networking, the fundamental concept of determining communication paths between nodes is essential. In scenarios where direct communication isn't feasible, such as in multi-hop networks like Mobile Ad Hoc Networks (MANETs), source nodes rely on a relay-based approach. These source nodes identify their neighboring nodes, which serve as intermediaries or relay nodes to facilitate communication with the ultimate destination node. The key question is how to efficiently discover these communication paths. If each node in the network maintains information about routes to other nodes, the source node can employ unicast communication, which entails sending data directly to a specific receiver. This way, there can be multiple potential paths available to transport data from the source node to the destination node, creating a dynamic and adaptable network topology that can adapt to changing conditions and route around obstacles.

In cases where the shortest path to the destination is not known, the source node initiates a broadcast-based approach to search for the route. In this broadcast mechanism, the source node transmits a request message in a way that assumes neighboring nodes will receive it. This request typically includes essential information such as the source node's IP address, the destination's IP address, and a unique sequence number for the request. In the network, each node is assigned a specific and unique IP address, and the total number of nodes in the network is well-defined. This broadcast request serves as a means to discover a suitable route to reach the destination node when the source lacks prior knowledge of the path.

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Results and Discussion

Simulation Parameters	**Parameter Value**
Simulator	NS-2.32
Simulation Area	700mts × 700mts
Mobile Nodes	25, 50,75,100
Pause Time	100
Packet Size	512kb
Protocols used for routing	AODV & Modi_AODV
Traffic Sources	CBR(UDP)
Simulation Time	500 Sec.
Performance Metric	The proposed protocol was evaluated based on its impact on Packet Delivery Ratio, Throughput, Average End-toEnd Delay, and Routing Load.

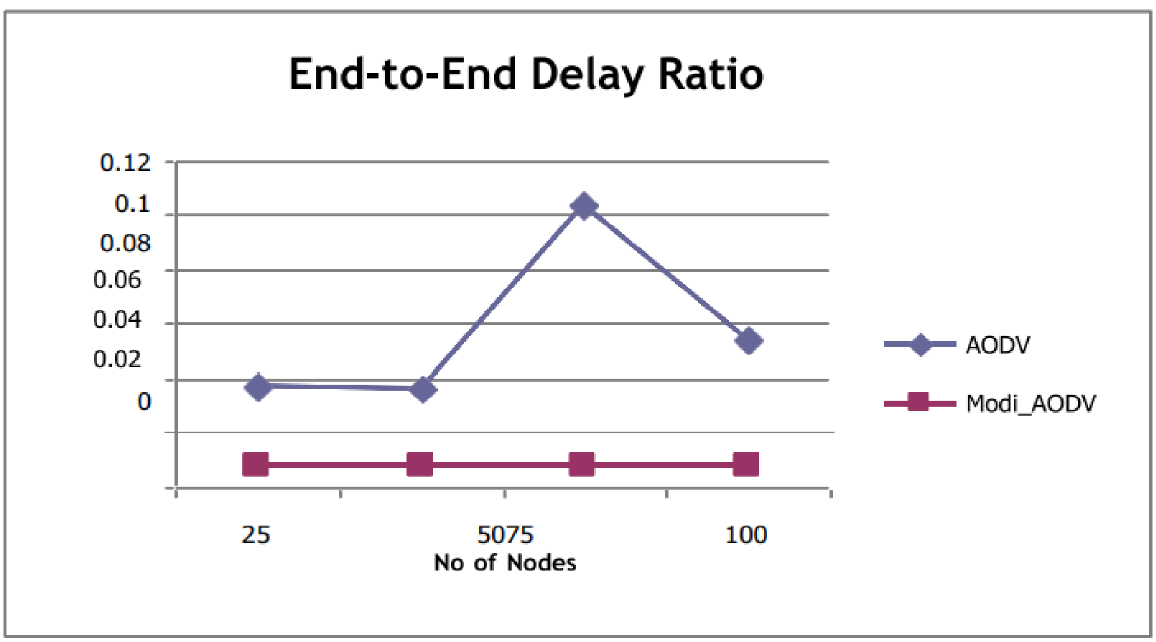

Fig. 3: End-to-End Delay comparison for different no of Nodes

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The primary performance metric used to assess the effectiveness of the AODV (Ad hoc On-Demand Distance Vector) protocol is End-to-End (E2E) delay, which quantifies the time taken for a packet to travel from its source to its destination. The size of the network, specifically the number of nodes within it, exerts a notable influence on AODV's performance. As the number of nodes increases, there is a corresponding increase in the likelihood of network congestion and collisions. These factors collectively lead to extended E2E delay times. Moreover, the escalating number of nodes also results in higher routing and control message overhead, contributing further to delays.

The increasing complexity of the network, driven by a larger number of nodes, can impact both delays and the time taken for path discovery, potentially causing delays to surge. it's worth noting that a network with a greater number of nodes offers a larger pool of communication options and enhances the chances of discovering a viable path to the destination. Consequently, there exists a trade-off between the number of nodes and the E2E delay experienced when using the AODV protocol.

Figure 1 show the efficiency of AODV and a modified version, Modi_AODV, concerning E2E delay. In the case of the conventional AODV, E2E delay demonstrates significant fluctuations, often being relatively high. Conversely, Modi_AODV achieves a lower and more stable E2E delay ratio. This implies that the modified version, Modi_AODV, offers improved performance in terms of E2E delay, especially in scenarios with a higher number of nodes, making it a promising option for more efficient ad hoc networking.

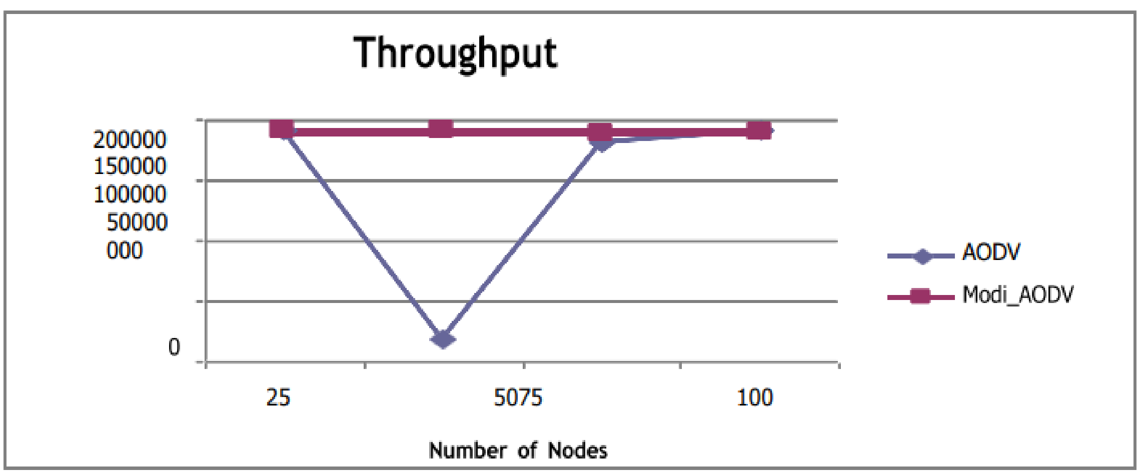

Fig. 4: Throughput using various No of Nodes

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Throughput serves as a measurable metric for gauging the amount of data transmitted across a network in a specified time frame, typically expressed in bits per second (bps). Within the context of the AODV (Ad hoc On-Demand Distance Vector) protocol, several factors come into play, influencing the network's throughput. These factors encompass the number of nodes present in the network, the quantity of traffic generated by these nodes, and their individual capabilities, including processing power and wireless interfaces. As the count of nodes in the network rises, there's a corresponding increase in the volume of generated traffic. This surge in traffic has the potential to induce congestion, subsequently leading to a decrease in overall throughput. The number of nodes within the network directly impacts the efficiency of the AODV protocol. A higher node count results in more extensive routing tables that necessitate maintenance, resulting in increased overhead and longer routing table lookup times.

Throughput = $\frac{\text{No of bits transmitted}}{\text{Time interval}}$ (bps) ....(1)

Delay

Delay, in the context of data packet transmission, represents the average duration it takes for a data packet to reach its intended destination. This duration encompasses several contributing factors, including the time spent waiting in a queue before the data packet can be transmitted, the delays associated with control packet exchanges at the Media Access Control (MAC) layer, and the time required for the route establishment process to identify and establish a suitable path to deliver the data packet to its destination.

Delay= $\sum(\text{arrive time} - \text{send time})$ ....(2)

The presence of a greater number of nodes generally introduces additional overhead and complexity into the routing protocol, which can adversely affect the overall performance of the network. Achieving optimal results necessitates a careful balance between the desired level of throughput, overall network performance, and the number of nodes operating within the network. Figure 5 provides a visual representation of the efficiency of both the AODV and a modified version, Modi_AODV, concerning throughput.

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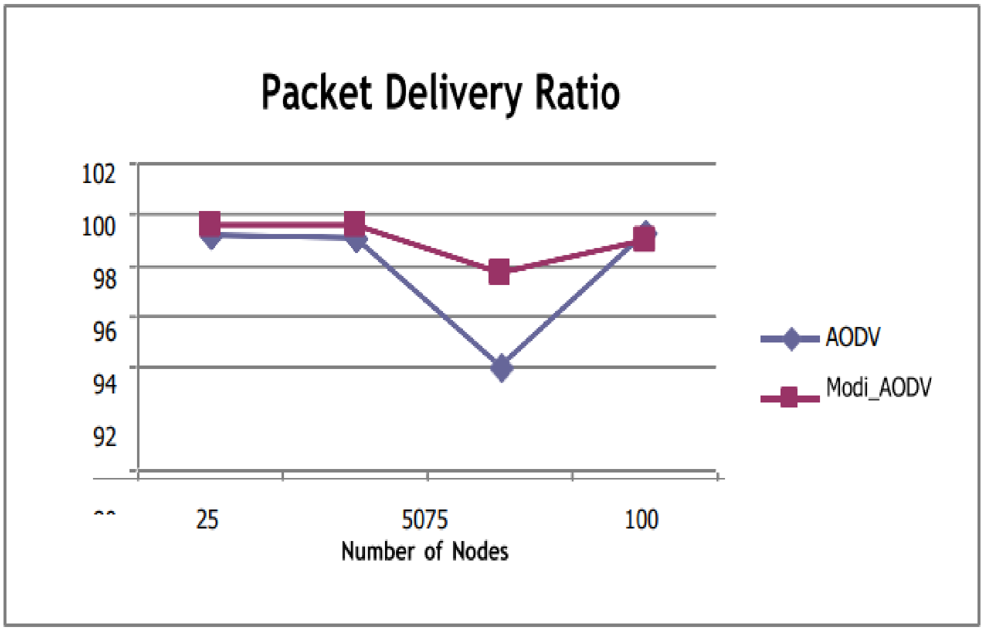

Fig. 5: Packet Delivery using different No of Nodes

Comparing the packet delivery rate to the number of nodes in a network reveals important insights. The packet delivery rate signifies the proportion of packets successfully reaching their intended destinations, while the number of nodes indicates the total count of devices in the network. As the number of nodes increases, the network's complexity grows, potentially leading to a decrease in the packet delivery ratio. This is because a higher node count raises the likelihood of packet collisions or interference, resulting in lost or delayed packets. Additionally, more nodes can lead to larger routing tables, which in turn causes increased overhead and delays in packet delivery. efficient routing protocols like AODV (Ad Hoc On-Demand Distance Vector) can mitigate the impact of a higher node quantity on the packet delivery rate.

Packet Delivery Ratio = $\frac{\sum \text{Number of packet received}}{\sum \text{Number of packet sent}}$ ....(3)

These protocols are designed to quickly and accurately find routes between nodes, even in complex networks. Furthermore, incorporating techniques such as power control and frequency allocation can enhance the packet delivery ratio, particularly in densely populated networks. It's crucial to note that the number of nodes is just one factor affecting the packet delivery ratio. Other variables, including wireless channel conditions, device mobility, power levels, and network bandwidth, can also significantly influence network performance. For example, AODV may exhibit low and unstable packet delivery ratios in certain scenarios, while a modified

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version like Modi_AODV may consistently perform better. Figure 3 illustrates this comparison, showcasing that AODV tends to have lower and less stable packet delivery ratios, whereas Modi_AODV consistently delivers better performance in terms of packet delivery rate.

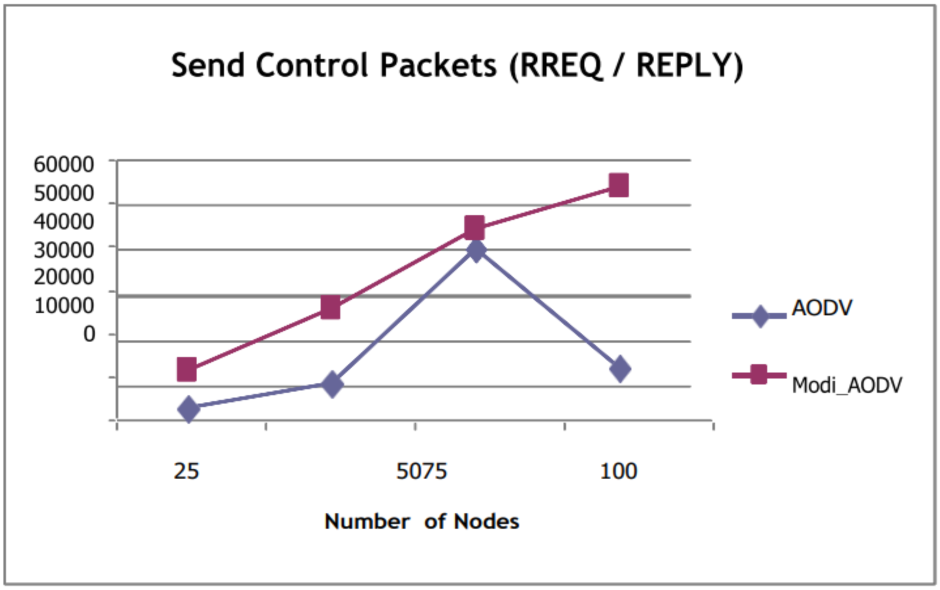

Fig. 6: Send Control Packets (RREQ/ REPLY) using various Numbers of Nodes

Normalized Routing Overhead

Normalized routing overhead is a metric used to quantify the efficiency of a routing protocol in a network. It measures the ratio of control packets disseminated to facilitate the transmission of data packets. In other words, it represents the number of control packets that have been transmitted in the network per data packet sent. This metric provides insights into the communication overhead incurred by control packets in relation to the actual data traffic in the network, helping assess the protocol's efficiency and its impact on network performance.

Normalizedrouting overhead $= \frac{\text{Total routing packet sent}}{\text{otal data packet recieved}}$ ....(4)

Figure 6 provides a performance comparison between AODV and Modi_AODV in terms of the number of Control Packets transmitted. The graph clearly shows that in the case of Modi_AODV, the number of sent Control packets increases as the number of nodes in the network increases.

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Conclusion

In this study, we have presented a conceptual approach for addressing the critical issue of power consumption in Mobile Ad hoc Networks (MANETs). MANETs, characterized by their dynamic and self-organizing nature, are integral to numerous applications, including military operations, disaster management, and the Internet of Things (IoT). However, the limited energy resources of mobile nodes pose a significant challenge, making efficient power management essential for network sustainability and reliability. Our conceptual approach encompasses three fundamental components: adaptive routing protocols, power-aware node mobility, and energy-efficient data transmission techniques. These components work in synergy to optimize power consumption and enhance network performance. Adaptive routing protocols dynamically adapt to network conditions and the energy states of nodes, reducing energy overhead associated with maintaining routes. Power-aware node mobility management strategically controls node movement to minimize energy-intensive long-distance communication, thus conserving power while maintaining network connectivity. Energy-efficient data transmission techniques, including data aggregation, compression, and adaptive modulation schemes, minimize the energy required for transmitting data across the network. Through a combination of these strategies, our conceptual approach offers a holistic framework to address the multifaceted challenges of power consumption in MANETs. Our approach contributes to extending network lifetime, reducing operational costs, and ensuring uninterrupted communication in resource-constrained environments.

Future Scope

"Research on power consumption in Mobile Ad Hoc Networks (MANETs) is a critical and evolving area in wireless communication. As the demand for mobile and dynamic networking continues to rise, finding ways to optimize energy usage within these self-organizing networks becomes increasingly important. Future research in this domain should delve into developing energy-efficient routing protocols, adaptive power management strategies, and exploring energy harvesting techniques. Additionally, cross-layer optimization, QoS-aware energy management, and leveraging machine learning should be integral components of further investigation. Balancing security and energy efficiency, validating research through simulations and real-world experiments, and promoting standardization and implementation are all essential aspects of advancing the field. In essence, the future of MANET power consumption research lies in

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innovating sustainable, reliable, and efficient solutions to meet the growing demands of mobile wireless communication."

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