ENERGY-EFFICIENT ROUTING MECHANISM FOR WANET TO ENHANCE NETWORK PERFORMANCE

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Abstract:- Wireless communication can be facilitated through either infrastructure-dependent or infrastructure-free methods. Wireless ad hoc networks (WANETs) represent a form of infrastructure-free communication in wireless technology. These networks consist of mobile wireless devices distributed within a radio communication area. Devices can directly communicate if they are within each other's radio range. When devices are outside each other's radio range, they must rely on other devices to relay communication, causing MANET (Mobile Ad Hoc Network) devices to act as routers. For this routing function, nodes require adequate resources, such as buffer space, energy, and processing power. Energy is a particularly constrained resource in MANETs, especially given their primary applications in military operations, disaster relief, and law enforcement, where recharging or replacing batteries during missions is often impractical. To address this, various energy-efficient mechanisms have been developed at different communication layers. Routing is a key strategy for managing energy resources in MANETs. Consequently, several energy-aware routing protocols have been created to optimize energy use in these networks. This paper reviews various energy-efficient routing protocols for MANETs and evaluates their performance based on different metrics. It specifically focuses on routing protocols that consider the residual energy of nodes. To assess network performance, we use Network Simulator 2 (NS-2). The results from this study provide insights for future research aimed at designing energy-efficient communication protocols to extend the network lifetime of MANETs.

KEYWORDS: WANET, Energy Efficiency, Routing Protocols, Residual Energy, Network Lifetime

Introduction

Communication is the way toward transmitting data between communication devices can be achieved through various mechanisms. Effective and efficient communication is highly preferred, but the efficiency and effectiveness can vary depending on the type of communication, scenarios, and specific requirements. Initially, communication relied on wired connections, but it has since transitioned to wireless methods. Modern demands

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require network access everywhere and at all times, which has led to the development of infrastructure-free networks, such as Wireless Ad Hoc Networks (WANETs).

A WANET is a decentralized wireless network comprising mobile nodes distributed within a radio communication area, possessing limited and heterogeneous resources. These nodes can move freely, leading to a dynamic and unpredictable network topology. Additionally, nodes must function as routers, forwarding packets for other nodes to ensure efficient communication. WANETs exhibit distinct characteristics compared to wired and infrastructure-based wireless networks.

Energy management in MANETs (Mobile Ad Hoc Networks) is crucial because mobile nodes rely on finite battery power. During missions, recharging or replacing batteries is often impractical. Node energy is consumed through data reception, transmission, and processing. The depletion of energy in any node significantly impacts overall communication performance and network lifespan, as WANETs operate on a peer-to-peer basis.

To enhance network longevity and communication performance, data packets should be transmitted in a way that minimizes energy consumption, while considering the energy state of each node. Routing plays a key role in managing energy resources in WANETs and improving network performance. The energy of each device is critical for optimizing network performance in terms of longevity and packet delivery. This can be understood as follows:

1. MANET consists of battery-operated heterogeneous mobile nodes, where each node functions as both a router and a host. Forwarding packets for other nodes consumes significant power.
2. Routing is a fundamental task of the network layer, involving substantial computational and communication efforts.
3. Recent studies show that the power consumption for transmitting and receiving packets in standard WaveLAN cards ranges from 800 to 1200 mW.
4. To support large-scale, durable applications, designing an energy-efficient routing protocol for WANET is essential.

Numerous studies have evaluated WANET performance concerning energy efficiency, focusing on metrics such as network lifetime, remaining energy, and overall energy efficiency. There is a need to design an energy-efficient routing protocol that accounts for the residual energy of each node. This work aims to develop a network routing protocol focused on energy conservation by considering the residual energy of nodes.

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Need of energy management of WANETs

Portable devices in Wireless Ad Hoc Networks (WANETs) are equipped with limited battery power. Due to these characteristics, WANETs are particularly suitable for applications such as battlefield operations and disaster recovery. In such scenarios, it is challenging to replace or recharge batteries. Devices that exhaust their energy are removed from the network, making energy management crucial due to limited energy storage capacity, the difficulty of battery replacement, the lack of central coordination, and the network's peer-to-peer nature. In WANETs, energy consumption occurs actively during data transmission and reception, and passively when devices are in idle or sleep

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mode but still listening for possible communication requests from other devices. Consequently, many researchers have developed routing protocols that not only establish efficient paths between source and destination but also consider energy management to extend network functionality for as long as possible.

Energy-efficient routing protocols can be classified based on various strategies. Fundamentally, these protocols find routes based on the transmission power of devices, expected transmission count, and energy awareness of devices. Some algorithms aim to build routes that ensure energy efficiency based on the energy cost of data transmission, though they may not consider the energy status of devices. Other works focus on finding reliable routes between source and destination based on transmission expectations and minimize control message usage to reduce energy consumption. However, these may not guarantee end-to-end packet transmission efficiency. There are also protocols designed to extend the network's lifespan by establishing routes with devices that have higher battery levels but may not ensure overall energy efficiency.

WANETs have been rapidly deployed and are expected to revolutionize communication, especially when combined with satellite data networks to provide global information delivery services to remote areas. Advances in hardware technology are continuously increasing the number of wireless communication terminals, catering to a growing user base. In many scenarios, the design of ad hoc network protocols is guided by two requirements: power efficiency and resilience to packet losses. Efficiently handling losses in wireless environments is thus crucial. Generally, routes are determined based on the power required for end-to-end packet traversal, but this should not result in less reliable routes or overuse of specific network nodes. Power-efficient routing in ad hoc networks must consider both the reliability of links and the remaining power of nodes.

Existing Systems

Existing research on enhancing power efficiency, reliability, and the lifespan of ad hoc networks can be broadly categorized into three areas:

1. **Mechanisms considering link reliability to find more reliable routes:**
    - While these routes may consume less power due to fewer retransmissions, they do not necessarily minimize end-to-end power consumption.
    - Prioritizing route reliability can lead to the overuse of certain nodes.
    - More reliable links are frequently used, causing the nodes along these paths to fail quickly as they handle many packets.
2. **Mechanisms aiming to find power-efficient routes:**
    - These do not account for the remaining battery power of nodes, potentially leading to the overuse of some nodes.
    - They focus on transmission power while ignoring the power consumed by processing components of transmitters and receivers.
    - This approach negatively impacts overall power efficiency, reliability, and network lifespan.
3. **Mechanisms designed to extend network lifespan by using routes with nodes having higher battery power:**

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- These do not address the other two aspects of reliability and power efficiency.
- The routes discovered by these mechanisms may not be power-efficient or reliable.
- This can increase overall power consumption and reduce network lifespan.

Proposed Mechanism

In this project, power efficiency, reliability, and network lifespan in wireless ad hoc networks are considered holistically. A novel power-aware routing algorithm, called Reliable Minimum Energy Cost Routing (RMECR), is introduced to find routes that minimize the total power required for end-to-end packet traversal.

Advantages of the Proposed System

1. Considers power efficiency, reliability, and network lifespan comprehensively.
2. Examines the impact of limited transmission attempts on power cost in hop-by-hop (HBH) systems.
3. Considers the effect of acknowledgment packets on power cost in both HBH and end-to-end (E2E) systems.
4. Accounts for the energy consumption of processing components of transceivers.
5. RMECR extends the operational lifetime of the network and identifies reliable routes.

Modules Description

Energy Consumption

Let xxx bits denote the size of a packet transmitted over a physical link, and PtxP_{tx}Ptx represent the power consumed by a transmitting node uuu to send a packet of length xxx bits to a receiving node vvv through the physical link. Let PrxP_{rx}Prx denote the power consumed by the receiving node vvv to receive and process the packet transmitted by uuu. The power consumed during packet transmission can be divided into two parts: the power consumed by the transmission circuit excluding the power amplifier of the transmitter, and the power consumed by the power amplifier to generate the required output power for data transmission. Conversely, the power consumed by a node to receive a packet is represented by the power consumed by the receiving circuit, including the low noise amplifier (LNA) of the receiver. Let AuA_uAu be the power required to run the processing circuit of the transmitter at node uuu, PtP_tPt be the transmission power from node uuu, PeP_ePe be the power amplifier efficiency at node uuu, BvB_vBv be the power required to run the receiving circuit at node vvv, and rrr be the data rate of the physical link.

Energy Aware Reliable Routing

The primary objective is to identify reliable routes that minimize the power cost for end-to-end (E2E) packet traversal. To achieve this, both the reliability and power cost of routes must be considered in route selection. The key insight is that the power cost of a route is related to its reliability. If routes are less reliable, the likelihood of

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packet retransmission increases, leading to higher power consumption per packet due to retransmissions. By defining two methods for calculating the power cost of routes, we propose two sets of power-aware reliable routing algorithms for hop-by-hop (HBH) and E2E systems, named Reliable Minimum Energy Routing (RMER) and Reliable Minimum Energy Cost Routing (RMECR). In RMER, the power cost of a path for E2E packet traversal is the average power consumed by all nodes to transfer the packet to the destination. In RMECR, the power cost of a path is the average battery cost of nodes along the path to move a packet from the source to the destination. Before detailing the design of RMER and RMECR, we first define the minimum power cost path.

Simulation Environment and Results

Network Simulator 2 (NS-2) is an open-source simulation tool used for networking research. It is an object-oriented, discrete event-driven simulator written in C++ and Otcl. NS-2 is primarily used to simulate various types of wired and wireless local and wide area networks, implement network protocols such as TCP and UDP, model traffic source behaviors like FTP, Telnet, Web, CBR, and VBR, manage router queues with mechanisms like Drop Tail, RED, and CBQ, and run routing algorithms such as Dijkstra, among others.

To evaluate the performance, the implemented protocols are compared with existing protocols. Trace files generated during the simulations are processed using AWK scripts to collect various parametric values, and graphs are plotted using GNUplot.

The metrics used for protocol comparison are:

1. **Packet Delivery Fraction (PDF)**: The ratio of the number of data packets successfully received by CBR destinations to the number of packets generated by CBR sources.
2. **Energy Consumption**: The energy consumed by nodes while transmitting and receiving data and control packets.
3. **Reliability of Routes**: The higher the number of data packets successfully received by the destination, the higher the reliability of routes.
4. **Network Lifetime**: The duration for which the network remains operational.

To plot graphs using GNUplot, paste all the graph values into the src directory within the GNUplot directory and then navigate to the GNUplot terminal.

Performance of RMER

Figure 1 shows the performance of RMER (Reliable Minimum Energy Routing) compared to the existing TMER (Traditional Minimum Energy Routing), with Packet Delivery Fraction (PDF) on the x-axis and energy consumption on the y-axis. As the packet delivery fraction decreases, the energy consumption of nodes also decreases, but it is lower in the proposed RMER for both hop-by-hop and end-to-end networks.

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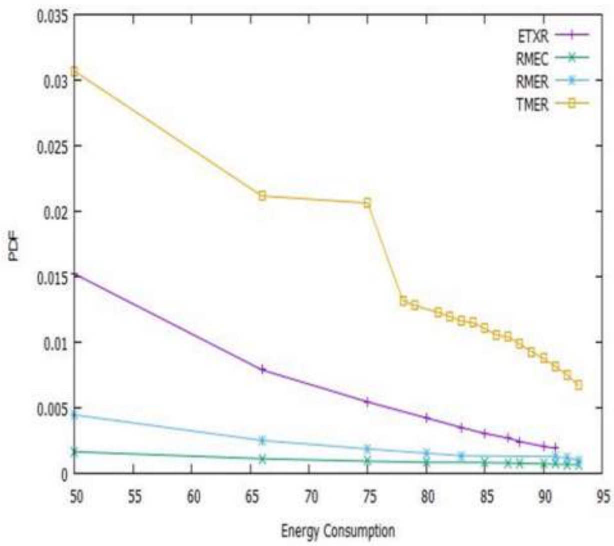

Fig 1 Packet delivery fraction with Average energy consumption

Performance of RMEC AND RMER

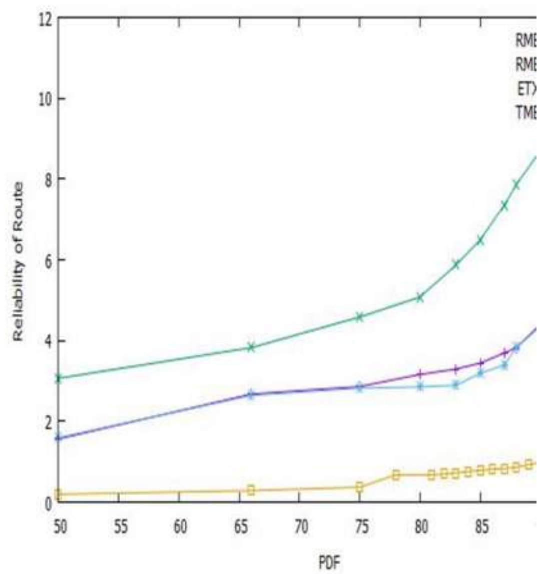

Fig 2 Packet delivery fraction with Average Energy consumption

Fig 2 shows the performance of

The performance of RMER (Reliable Minimum Energy Routing) and RMECR (Reliable Minimum Energy Cost Routing) is evaluated against existing protocols such as TMER (Traditional Minimum Energy Routing) and MIN

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ETX (Minimum Expected Transmission Count). This evaluation considers Packet Delivery Ratio (PDR) on the x-axis and Energy Consumption on the y-axis. As PDR decreases, the energy consumption of nodes also decreases. However, energy consumption is higher in the proposed RMECR compared to RMER.

CONCLUSION

This work elucidates the energy efficiency of existing WANET routing protocols. It also designs and develops a novel energy-aware routing protocol based on the residual energy status of nodes, named the Reliable Minimum Cost Routing Protocol. The designed protocol enhances the performance of WANETs by extending the network lifetime. In developing REECR, we considered the entire energy consumption model of the nodes in the network and along routing paths. The proposed protocol yields favorable results in both hop-by-hop and multi-hop communication networks, making it highly suitable for WANETs due to their multi-hop dynamic nature. When compared to existing routing protocols, the results clearly indicate that the proposed residual energy-aware protocol outperforms existing energy-based routing protocols designed for WANETs.

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