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A Blockchain-Enabled Trust Management Framework for Energy-Efficient and Secure Routing in Mobile Ad-Hoc Networks

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Abstract **– This study principally addresses the challenges associated with streaming videos in wireless Mobile ad hoc networks (MANETs), primarily constrained by wireless channels and node mobility. This study proposes a novel routing protocol incorporating a feedback mechanism and cross-layer architecture, supported by three key enhancements. First, it incorporates a route recovery strategy for detecting link failures and re-establishing connections based on predefined Quality of Service (QoS) metrics. Second, a novel algorithm estimates the available bandwidth, enabling dynamic adaptation of bitrate at the application layer concerning the source video. This novel rate-adaptive approach utilizes a scalable layered structure of the video coding, thereby removing layers that the network cannot efficiently support due to bandwidth limitations. Third, a gateway discovery procedure enhances the connectivity among MANETs and other infrastructure networks. This method employs available bandwidth as a parameter while selecting appropriate gateways and dynamically adjusts operational parameters like proactive area size and advertisement message frequency.**

The performances of the proposed Enhanced OLSR (E-OLSR) protocol are compared with the state-of-the-art routing procedures such as Adhoc on-demand distance vector (AODV), destination sequenced distance vector (DSDV), and optimized link state routing (OLSR), in terms of metrics like packet delivery ratio (PDR), end-to-end (E2E) delay, throughput, as well as energy consumption. The simulation results demonstrated notable improvements, including reduced packet delay, fewer dropped packets, and decreased link failures, indicating effective utilization of available bandwidth. The overall performance of the proposed E-OLSR protocol exceeds other traditional protocols and its security is enhanced through the integration of Blockchain Technology.

Keywords **– Mobile ad-hoc networks, enhanced OLSR, packet delivery ratio, end-to-end delay, throughput, energy consumption, available bandwidth.**

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1. Introduction

In the wireless technology domain, Wireless Multimedia Sensor Networks (WMSNs) represent a specialized classification of sensor networks meticulously crafted to facilitate the seamless transmission of multimedia data [1]. The smooth operation of WMSNs centers on proficient management techniques, ensuring dependable and timely delivery of multimedia data [2]. To achieve this, the scientific community has investigated several algorithms and methods tailored to optimize WMSN performance [3].

Routing protocols serve as the specifications enabling routers to communicate, allowing them to exchange information needed for selecting routes and nodes within a network [4], [5], [6], [7]. In this context, the sensor nodes estimate the location information by cooperating with the neighboring nodes, each node storing its unique information.

However, selecting the route for information transfer from source to destination presents several challenges. These challenges are dependent upon the type of networks, characteristics of the channels, and performance parameters. In WMSNs, information collected by the sensor nodes is normally transferred to a base station (BS). From there, it is aggregated with other networks, analyzed, and appropriate actions are taken. Wireless sensor nodes often lack compatibility with conventional IP-based protocols. Additionally, the design challenges in WMSN include complexities, scalability issues, and the need for robustness. This study will evaluate these challenges encountered during the development and implementation of a novel routing protocol.

WMSNs represent an integration of wireless sensor networks (WSNs) and multimedia communication technologies. These networks are designed with the primary objective of collecting and transmitting multimedia data, including audio and video, using a network of sensor nodes [8]. WMSNs are applicable in numerous areas like environmental monitoring, surveillance, healthcare, as well as security. For example, in environmental monitoring applications, WMSNs are instrumental in gathering information on parameters like temperature, humidity, and air quality. In healthcare applications, these networks enable patient monitoring and the collection of vital signs, while in security applications, WMSNs are utilized for surveillance and intrusion detection. However, the deployment of WMSNs comes with many challenges, primarily owing to the substantial volumes of data that need to be both transmitted and processed [9].

This infrastructure of WMSNs comprises hardware, software, and communication protocols collaboratively enabling the efficient and dependable transmission of multimedia data. At the core of WMSNs are sensor nodes, fundamental devices equipped with sensors capable of collecting environmental data, encompassing factors like temperature, humidity, sound, and light [10]. These nodes possess processing capabilities to analyze the collected data and facilitate communication, either among other nodes or with a central server. Notably, sensor nodes can be either stationary or mobile, necessitating careful development for their strategic placement to guarantee complete coverage.

One notable method in this domain is the Coverage Control Algorithm-Based Adaptive Particle Swarm Optimization (CCAPS) coupled with Node Sleeping. The CCAPS algorithm [11] stands as a standard for enhancing network coverage, prolonging the network lifespan, and reducing energy consumption. Advancement to the CCAPS method is the Dynamic Power Management (DPM) algorithm [12]. This state-of-the-art approach considers the dynamic nature of WMSNs. By adapting to the network's dynamic nature, the DPM algorithm emerges as a challenging method, offering superior performance in contrast to the CCAPS algorithm. In essence, while the CCAPS algorithm represents an estimable effort in WMSN network management, it becomes increasingly evident that a deep understanding of the network's dynamic nature is needed.

A novel routing protocol signifies an advanced approach for exchanging information among network nodes. Its primary purpose lies in enhancing the efficiency of data transfer within a network while minimizing the issues of congestion and delays. Among these state-of-the-art protocols, the Optimized Link State Routing (OLSR) protocol stands as a notable routing approach. OLSR [13], an open-source routing protocol, has found its prominence in mobile ad hoc networks (MANETs). OLSR follows an optimized path selection method that works efficiently by reducing the network's overhead. This is attained by restricting the control messages sent, thereby streamlining the operation of the network. Moreover, OLSR trims down the size of routing tables, retaining only the most pertinent links. This strategy not only increases efficiency but also increases the network's scalability, making it an effective routing approach in networking.

Another innovative method is the Firefly Algorithm-Based Energy-Aware Routing (FAEAR) protocol. This protocol is implemented to extend the network's lifespan by precisely preserving energy in MANETs. FAEAR employs the Firefly algorithm to identify an optimized data transfer path, considering the energy levels of each node. By ensuring that the selected path experiences minimal energy consumption, FAEAR significantly increases the network's lifetime, a vital necessity in today's energy-constraint networks.

Considering these novel routing protocols, such as OLSR and FAEAR, can bring about a notable modification in the area of network data transfer. These protocols, with their strategic reduction of network overhead and effective energy conservation, not only enhance efficiency but also sustain the network's overall performance. In essence, they represent an innovation in the ongoing expedition for seamless, efficient, and sustainable data exchange within the complex web of networks.

In the complex domain of wireless sensor systems, limitations occur because of the shared nature of the radio medium. Challenges such as low frequency and high latency are inherent, but the primary difficulty remains the energy problem. Many existing solutions rely on single-route route discovery, leading to the rapid depletion of certain nodes (especially those integral to the shortest path).

This rapid depletion weakens the objective of maximizing the lifespan of wireless sensor networks. Countering this problem, numerous methods have been suggested, all with the common objective of maximizing the network's lifespan. However, a predominant issue arises: these solutions often result in network partitioning, ultimately leading to the network's failure. Therefore, the proposed approach not only tackles the energy problem but also ensures the network's interconnection, paving the way for a sustainable wireless sensor network environment.

Recently, the adoption of WMSNs has increased, especially in the applications demanding the collection and processing of multimedia data. However, efficiently routing this data within WMSNs remains a challenge due to the distinctive qualities of multimedia data and the limitations in sensor nodes. Traditional routing protocols, designed for conventional wireless networks, typically fail to meet the unique demands of WMSNs.

Therefore, there arises a need for a state-of-the-art routing protocol capable of addressing the specific challenges left by WMSNs, encompassing bandwidth constraints, data reliability, and energy efficiency [14]. This study aims to implement a new routing protocol for WMSNs, one that effectively manages multimedia data traffic and overcomes the limitations posed by existing routing protocols. The fundamental aim of this paper is to examine the complexities of multimedia data within WMSNs, examining varied data types, their traffic patterns, and the requirements for seamless data transmission. Additionally, the study will explore the design of a novel routing protocol, incorporating efficient data aggregation and routing techniques that decrease energy utilization as well as improve the network lifetime.

The results of this study will facilitate deeper insights concerning the challenges and scenarios in routing within WMSNs. Furthermore, it offers a novel, efficient routing protocol applicable in different domains like surveillance, environmental monitoring, and healthcare. This novel protocol will offer the potential to increase the reliability, energy efficiency, and overall performance of WMSNs, thereby paving the way for innovative multimedia applications.

The challenges faced by the novel routing protocols in Bluetooth telecommunications are centered on the inherent nature of wireless transmissions. Operating within a shared transmission medium, wireless broadcasts are susceptible to several transmission errors from interruptions by other devices, multi-path fading, and interferences with signals from adjacent devices. Dealing with these errors often requires data to be resent, leading to increased latency, and drastically affecting the multimodal transmission performance. Moreover, each cluster operates within a limited frequency band, influenced by factors such as transmitter type, antenna size, power usage, obstacles in the signal path, and temperature variations. Consequently, data must travel various intermediary networks due to these limited ranges before reaching its desired destination. Each additional hop introduces latency and increases the risk of network obstructions. The continually changing network topology, influenced by node mobility, further increases the problem. When routes fail, the search for new paths leads to delays, impacting the quality of ongoing video streams. Additionally, these topology changes may create bottleneck links, reducing bandwidth. In extreme cases, network partitioning occurs, breaking the connectivity between different clusters and disrupting multimedia streaming.

Another significant concern highlighted is route stability. Variations in connection signals due to mobility can lead to signal fluctuations, causing destination and source nodes to be in different clusters. This scenario can substantially impact both packet loss rates and latency, resulting in a significant challenge. The methods under consideration are qualitative, focusing on evaluating service-based approaches for managing and analyzing information. This analysis is essential for dynamically applying network solutions, particularly in the framework of routing algorithms, to ensure complete optimization of functional knowledge. It emphasizes the detailed management and analysis of information, necessitating collaboration, and structured qualitative management.

In multimedia environments, the volume of multimedia data from sources like cameras necessitates efficient transmission techniques. Traditionally, multimedia content transmission has been associated with source coding methods. Multimedia sources inherently generate their traffic, making compression techniques essential for reducing the data to be transmitted. However, compression leads to a loss in overall multimedia quality, often referred to as distortion. Although effective compression algorithms have been developed, their use in resource-constrained WMSNs is limited.

Traditional source coding methods [15], regardless of their robust compressing capabilities and enhanced rate-distortion performance, are not typically appropriate for resource-limited WMSNs. This limitation arises from the necessity for robust processing methods, both of which considerably increase energy utilization. Therefore, effective multimedia coding systems emphasize two key objectives.

First, leveraging correlations across pixels in images or frames in live streams can significantly reduce the communicated information while maintaining high quality, a concept known as base coding. Second, compressed data must be represented efficiently to ensure reliable transmission even through weaker channels.

1.1. Research Objectives

In this paper, we have developed a novel multi-path routing strategy for sensor nodes termed Enhanced OLSR (E-OLSR), enabling them to utilize multiple paths for transmitting data to the sink. The proposed E-OLSR protocol operates on two fundamental principles. First, each path is assigned a probability, determining the path chosen for individual data transmission. Second, we introduced a new parameter into the formula, representing the likelihood of a forwarding node being utilized to channel data to the sink. This parameter is determined by the number of receiving databases associated with the forwarding node. Consequently, the selection of the transmission path is determined probabilistically in our newly developed E-OLSR protocol.

This probability calculation considers not only the source node and the intensity of the data exchange, like Energy-Aware Routing (EAR), but also considers the number of paths involving the forwarding node. The objective is to prioritize nodes forwarding data for multiple nodes over those serving fewer nodes. This strategy achieves fairness in energy distribution between nodes, ultimately enhancing the lifetime. The principal aims of this present study are the following:

(i) Perform a comprehensive literature review to identify the primary challenges and complexities associated with creating a routing protocol to be incorporated for wireless multimedia sensor networks, with a particular emphasis on video streaming.

(ii) Design a novel E-OLSR routing protocol that addresses the distinctive features of wireless multimedia sensor networks for video streaming, such as energy efficiency, reliability, and scalability. This includes selecting and adjusting the protocol parameters for optimal performance of QoS metrics such as Packet delivery ratio, End-to-end delay, Throughput, and Energy consumption.

(iii) Evaluate the performance of the proposed routing method using simulation tools such as Network simulator (NS3) in different WMSN network scenarios and with dissimilar node counts. The performance evaluation will consider the size of the network, mobility of the nodes, and traffic conditions.

(iv) Compare the proposed E-OLSR routing protocol with existing routing protocols for WMSN regarding QoS metrics and energy efficiency. This will involve a comprehensive analysis of the simulation results obtained in Step iii.

(v) Investigate the utilization of blockchain technology for routing decisions in WMSNs and evaluate the potential impact on QoS metrics. This will include designing and implementing a blockchain-based routing mechanism for video streaming in WMSNs.

2. Literature Review

According to Damghani *et al.* [16], spoofing is a category of attack where an invader pretends to be someone else or something else. In the context of routing protocols, he further elaborated that spoofing involves sending packets with a fictitious source address to make it appear as if they are coming from a trusted source [16]. Spoofing assaults are utilized for launching other categories of assaults, like man-in-the-middle attacks, where the attacker intercepts and alters network traffic. A Denial-of-Service (DoS) attack [17] aims to interrupt the usual operation of a network by flooding it with traffic, hindering its resources, and causing it to crash. A DoS attack can be initiated by sending an overflow of routing packets, which can cause routers to become overloaded and unable to process legitimate traffic. DoS attacks can also be used to cause routing loops, where packets are continually forwarded between routers, causing congestion, and reducing network performance.

According to Feng *et al.* [18], table poisoning involves sending false routing information to a router, causing it to choose a suboptimal path or direct traffic to a compromised destination. This can be achieved through various means, such as exploiting vulnerabilities in routing protocols or by hijacking Border gateway protocol (BGP) sessions. Once a router has been compromised, the attacker can intercept and manipulate traffic passing through the network.

Malik *et al.* [19] explained the man-in-the-middle attack as a network security attack that involves interrupting and changing the network traffic between two parties. In the context of routing protocols, this can be achieved by spoofing routing packets, causing routers to direct traffic through the assailant's machine. The assailant later interrupts and modifies the traffic before forwarding it to the intended destination. Man-in-the-middle attacks can be used to take complex information, such as passwords or business data.

According to Osamah *et al.* [20], energy-efficient routing methods aim to minimize energy consumption in wireless networks by selecting low-energy consumption paths or by decreasing the transmissions among nodes. As Hahidan *et al.* [21] mentioned, network coding is a technique that can improve routing efficiency and reliability by allowing multiple packets to be combined into a single transmission. This technique can also improve the network's resilience to packet loss.

Layering techniques are an essential part of network routing protocols. Studies suggest that the purpose of layering protocols is to deliver a clear and effective way of transmitting information across a network. Consequently, by dividing network data into distinct layers, each layer is responsible for specific tasks that allow the network to operate efficiently. In traditional routing networks, the layering techniques can be classified into three layers: application, transport, and network layers [22]. The application layer is crucial in the layering techniques concerning novel routing protocol implementation in WMSNs.

It is responsible for providing services that directly support user applications and protocols that allow software to send and receive data between devices. It is also responsible for carrying out user-specific tasks such as email, web browsing, and file transfer protocols. The application layer is where end-user software operates, like the Internet browsers and email users. Its primary function is to ensure that communication between applications at different network endpoints is possible. In summary, the application layer is essential for the efficient transfer of data across the network in contemporary routing protocol networks.

WMSNs require advanced protocol systems to be able to function properly. These networks can be widely used in a range of activities that include military functions or civilian requirements as well. Xiao *et al.* [23] mentioned in their study that overhead and minimization of energy consumption is a major issue that develops with the usage of WMSN. This generally developed due to the amount of traffic that develops with the use of WMSNs. The use of WMSNs can thus help in gaining precise and accurate information and reduce the chances of erroneous data affecting the content developed. Arsalan *et al.* [24] have mentioned in their studies that demand for WMSN has grown in recent years. It is preferred largely due to the large amount of data that can be managed through the network of multimedia sensor networks.

It has become a vital constraint in the field of the Internet of Things (IoT) and big data analytics [25].The faster development and advancement of the system, and the sensors embedded with computing include the accessibility of certain expensive complementary metal-oxide semiconductors (CMOS) which include cameras and microphones with significant procedures allowing the development of WMSNs [26]. This also promises a wider range of potential uses and helps in providing significant information to the users.

WMSNs have certain additional challenges and characteristics because of the feature of real-time multimedia data which includes high bandwidth demand with real-time delivery. The model is supported through the network which is deployed with the homogeneity that is known for the sensor for the same capability and functionalities. In this model, every node can perform the function from the image to capture the multimedia process for relaying the data toward the sink on a multi-hop basis.

3. Proposed Methodology

In this study, a novel routing approach termed Enhanced OLSR (E-OLSR) incorporating feedback mechanism and cross-layer architecture has been proposed that is supported by three key enhancements as discussed below.

First, it incorporates a route recovery strategy for detecting link failures and re-establishing links based on the predefined Quality of Service (QoS) conditions. Second, a novel algorithm estimates available bandwidth, enabling dynamic adaptation of bitrate at the application layer concerning the source video. This novel rate-adaptive approach utilizes a scalable layered structure of the video coding, thereby removing layers that the network cannot efficiently support due to bandwidth limitations. Third, a gateway discovery procedure enhances the connectivity among mobile ad hoc networks and other infrastructure networks. This method employs available bandwidth as a parameter during the selection of appropriate gateways as well as dynamically adjusts operational parameters like proactive area size and advertisement message frequency.

The operational flowchart of the proposed Enhanced OLSR (E-OLSR) video packet routing algorithm is shown in Figure 1. The proposed methodology incorporates three stages as discussed below:

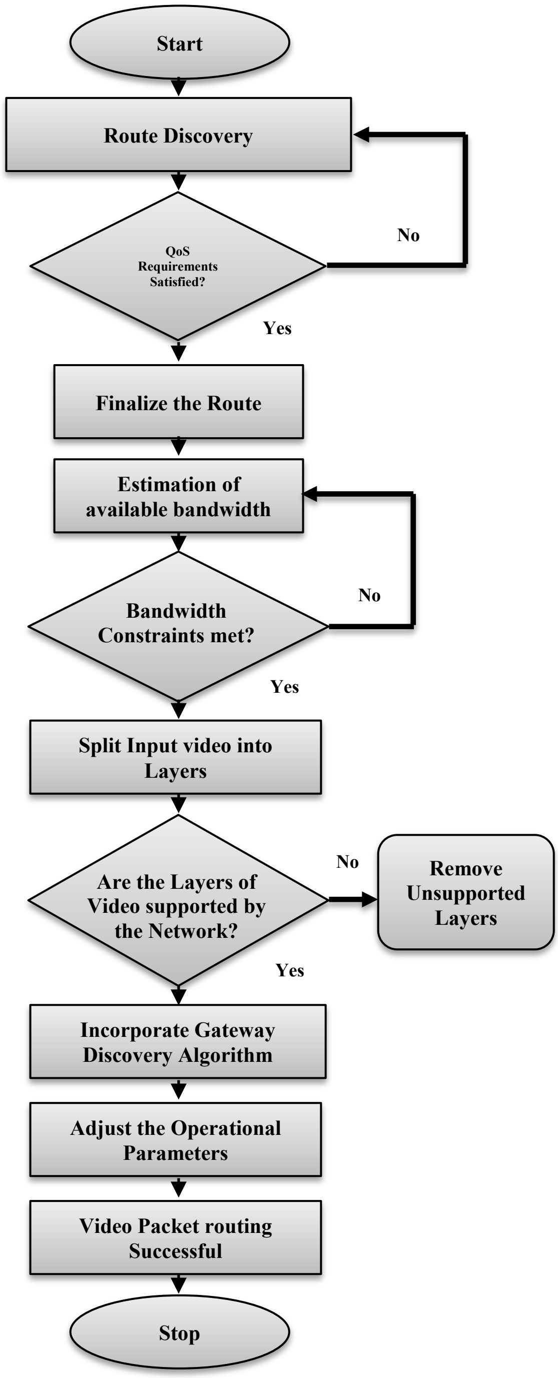

Figure 1. Flowchart of the Proposed Enhanced OLSR (E-OLSR) Protocol

(i) Route discovery

In this stage, the precise route for transmitting video packets is identified. The video packets are transmitted through the best-identified routes from source to destination. The source node checks for all available routes from the source to the destination, thereby identifying the best possible route.

The route discovery is based on the predefined QoS metrics that include latency, jitter, packet loss, throughput, and network congestion.

The best route will be identified wherein the latency will be low, reduced jitter, reduced packet loss, the route which has the best throughput and the one which possesses less network congestion. Initially, multiple routes will be identified and the connection will be re-established whenever the best route is found compared to the existing route, thereby the best route will be finalized.

(ii) Bandwidth considerations

The proposed Enhanced OLSR (E-OLSR) routing protocol calculates the available bandwidth, enabling dynamic adaptation of bitrate at the application layer concerning the video source. The bandwidth considerations are assessed by the layering method to provide a clear and efficient way of transmitting video data across the network.

The video packets are divided into layers, wherein the layers supported by the network will be transmitted and the remaining layers that are unsupported by the network will be removed. This process not only reduces the latency but also increases the overall throughput while reducing network congestion.

(iii) Gateway Discovery

Further, the novel gateway discovery algorithm employed in the Enhanced OLSR (E-OLSR) protocol increases the connectivity amid mobile ad hoc networks and infrastructure-based networks. The operational parameters are dynamically adjusted by this gateway discovery procedure so as to sustain the connectivity constraints.

The gateway discovery algorithm operates on the basis of available bandwidth, thereby the frequency of the advertisement messages will be automatically adjusted by this algorithm.

3.1. Significant QoS Parameters for WMSNs

This study investigated the efficiency of the proposed E-OLSR video packet routing algorithm using the NS-3 simulation tool [27], which assists in providing a high-quality service for transferring information using a routing protocol. It helps to create real-world networks on a computer by using C++ and Python as programming languages. Experiments are performed by analyzing the behavior of a network when various parameters of the network are altered. The effectiveness of the proposed E-OLSR method has been assessed concerning the QoS metrics that include packet delivery ratio, end-to-end delay, throughput, and energy consumption.

3.1.1. Packet Delivery Ratio

Packet loss denotes the drop of video data packets while reaching their destination after being sent [28].

Measuring packet loss helps assess network performance and take necessary measures to ensure successful data transmission. The quantity of data packets having left a particular location in a network smoothly but receiving an error right through data transfer and therefore failing to get it to its desired location is referred to as packet loss. Packet Delivery Ratio (PDR) typically corresponds to the percentage of packets disseminated by the destination node to those transmitted by the source node. Accordingly, PDR serves as one of the most fundamental parameters for evaluating the effectiveness of video packet routing algorithms. The PDR (in percentage) shall be expressed as per Equation 1,

$$PDR = \frac{\text{Recieved packets at destination}}{\text{Packets send by source}} \times 100\% \quad \textbf{(1)}$$

3.1.2. End-to-End (E2E) Delay or Latency

Latency measures the duration taken for information to travel from the source to the destination, expressed in milliseconds (ms), and plays a significant role in defining how quickly and responsively different networks and infrastructures are [29]. The extent of time it takes for a video packet to travel from source to destination nodes is commonly referred to as E2E delay or latency. For the reason that it has an instantaneous influence on the QoS of WMSNs, latency is a crucial parameter for evaluating the performance of the video routing algorithm. E2E latency could be typically expressed as per Equation 2,

$$E2E\ Latency = \frac{\text{Time taken for packet to reach destination}}{\text{Time of packet arrival from source}}\ (ms) \quad (2)$$

3.1.3. Throughput

The speed at which information efficiently moves from one location to the next during a predetermined amount of time is referred to as transmission speed in wireless networks [30]. Throughput, which can frequently be expressed in bits per second (bit/s or bps), gives information about the effective process for sending and receiving packets. Hence, throughput corresponds to the time taken for the final packet to arrive at the destination, and it can be expressed as per Equation 3,

$$Throughput = \frac{Data_{total}}{Time_{total}} \quad (3)$$

where $Data_{total}$ corresponds to the total quantity of transmitted data or that received at the destination, and $Time_{total}$ corresponds to the overall time required for transmitting or receiving the data.

3.1.4. Energy Efficiency

The volume of data transmitted for each unit of energy consumed signifies energy efficiency [31]. It was perceived that energy efficiency directly influences the lifetime of the network; it is an important indicator for determining how effective routing algorithms perform in terms of energy utilization. This parameter is measured in joules (J) and could be expressed as per Equation 4,

$$Energy_{efficiency} = \frac{\text{Tranfered data amount}}{\text{Consumed Energy}} \quad (4)$$

3.1.5. Jitter

A disparity in video packet delay is called a jitter. Jitter can be brought on by a variety of variables, many of which are also responsible for delay. Jitter is a challenge since not all network communication is affected equally by it [32]. The variance in video packet delay occurs while communication is referred to as jitter. It mainly happens when certain packets traveling from source to sink travel slowly compared with other packets. Jitter has to be normally reduced for optimal perception of video information. Jitter is expressed in milliseconds (ms) and shall be mathematically expressed as per Equation 5,

$$Jitter = |PAT_n - PAT_{n-1}| - |PTT_n - PTT_{n-1}| \quad (5)$$

where PAT_n is the time for the arrival of the n^{th} packet at the destination, PAT_{n-1} represents the time for the arrival of the preceding $(n-1)^{th}$ packet at the destination, PTT_n corresponds to the time required for transmitting the n^{th} packet from the source, and PTT_{n-1} signifies the time needed for sending the previous $(n-1)^{th}$ packet from the source.

3.1.6. Network Congestion

WMSNs experience network congestion when the amount of video data flow exceeds the network's capacity, which impairs performance and lowers the QoS. Multimedia video content transmission can be significantly impacted by congestion, which can result in increased delay, packet loss, and decreased throughput.

Congestion in WMSNs, where multimedia information like images and movies are sent, can have an enormous impact on the overall performance. Several methods, including traffic shaping, quality-aware resource allocation schemes, and congestion control algorithms, are used to reduce congestion [33].

To reduce congestion and guarantee seamless and effective multimedia transmission in WMSNs, these strategies strive to control data flow, prioritize traffic, and optimize network resources.

4. Experimental Results and Discussions

Developing video streaming services for MWSNs yields a significant challenge because of various limitations like bandwidth constraints, varying capacity links, energy-limited operations, and the adaptive nature of sensor nodes thereby leading to increased link failure and higher error rates. Video streaming processes are particularly responsible for packet losses and delays, adding complexity in supporting real-time video on MWSNs. The required experimental settings with their corresponding results and detailed discussions are explained in this section.

4.1. Experimental Setup

Initially, we simulated a linear network comprising a sequence of wireless sensor nodes. The wireless network utilized the IEEE802.11 protocol in the MAC layer, operating in the distributed coordination function (DCF) mode with a channel data rate of 2 Mbps. The first node sequence served as the video source, transmitting a video with a duration of 60 seconds, a resolution of 352x288 pixels (CIF), and a frame rate of 15 fps. The video was created by combining test sequences akiyo, news, and foreman, commonly used for video assessment, and was encoded at different average bitrates (100 Kbps, 300 Kbps, and 500 Kbps) with a tolerance of 5%. H.264/AVC encoding was employed with a Group of Pictures (GoP) size of 12 frames, excluding B-frames (bidirectional frames).

The received video was further reconstructed from the original sequence using both the source and received traces. Lost packets, absent in the received trace, could not be utilized for video reconstruction. Both the original and reconstructed videos were used for the performance analysis, including metrics like packet delivery ratio, end-to-end delay, throughput, and energy consumption.

4.2. Simulation Settings

The effectiveness of the proposed routing protocol was assessed utilizing Network Simulator 3 (NS-3). In this simulation environment, the IEEE802.11 was implemented in the MAC layer, operating in the DCF mode with a 2 Mbps channel data rate. The radio propagation model utilized was the Two Ray Ground model, and the queue type was set to Drop Tail with a maximum length of 50 packets.

The transmission and interference ranges were set to 250 meters and 550 meters. Throughout the simulation, all traffic flows were constant bit rate (CBR) streams transmitted over UDP, with a packet size of 1000 bytes. The source application used in the initial two sets of simulations was a customized version of the CBR traffic source in NS-3. This modified application could automatically adjust its transmission rate based on the simulation circumstances.

Table 1. Simulation parameters

S. No.	Parameters	Values
1.	Platform	Ubuntu 20.04
2.	Simulator	Network Simulator 3(NS-3)
3.	Channel	Channel/WaveNet/Devices
4.	Model	Propagation Model
5.	Interface	Phyu-Wireless-Phy
6.	MAC	802.11ah
7.	Queue Interface	Queue
8.	Link Layer Type	LL/MAC
9.	Antenna Model	Gp Antenna Array Model
10.	Maximum Packets	50
11.	Network Size	450x950 m^2
12.	No. of Mobile Nodes	20, 25, 30, 35, 40, 45, 50
13.	Simulation Time (Sec)	120, 160, 200, 250, 300
14.	Routing Protocols	AODV, DSDV, OLSR
15.	Source Type	UDP
16.	Mobility Model	Random
17.	Traffic Type	CBR

The performance evaluation involved three distinct simulation scenarios. The initial two scenarios were designed to explain the functioning of the routing protocol clearly, while the third scenario aimed for a real-time simulation involving 30 mobile nodes. The simulation parameters used for the experimentation are shown in Table 1. The NS-3 simulation framework provides a comprehensive set of modules and models for simulating WMSNs. It offers a flexible and extensible platform to design and analyze complex network scenarios. NS-3 incorporates realistic channel models, propagation models, and mobility models, enabling the simulation of realistic wireless environments. These features make NS-3 a suitable choice for simulating WMSNs and evaluating the effectiveness of video packet routing procedures.

In the NS-3 simulation, certain assumptions are made to simplify the model and focus on the specific aspects of the proposed E-OLSR routing protocol. These assumptions include network connectivity, transmission range, node mobility, and traffic patterns. Additionally, various parameters, such as transmission power, data rate, packet size, and buffer size, are also configured to represent realistic operational conditions and network characteristics. By leveraging the capabilities of NS-3, we can gain valuable insights into the behavior of the proposed video data routing protocol for WMSNs.

4.3. Results and Discussion

To simulate the WMSN environment, we have created a network topology using NS-3. This involves determining the number of sensor nodes, their spatial distribution, and their interconnections. We have considered different network topologies such as random, grid, as well as clustered configurations to capture various deployment scenarios.

In this section, we have presented the simulation results of the proposed routing protocol in NS-3 for evaluating its performance in WMSNs. The baseline protocols, such as ad-hoc on-demand distance vector (AODV), destination sequenced distance vector (DSDV), and optimized link state routing (OLSR), were selected as standard protocols to compare against the proposed novel routing protocol. The proposed E-OLSR routing protocol has been assessed against its peers concerning metrics like packet delivery ratio (PDR), end-to-end (E2E) delay/latency, throughput, and energy consumption.

4.3.1. Packet Delivery Ratio

The packet delivery ratio (PDR) measures the ratio of successfully delivered multimedia packets to the total number of packets sent. Figure 2 shows the PDR achieved by the proposed E-OLSR protocol along with the existing AODV, DSDV, and OLSR protocols over time.

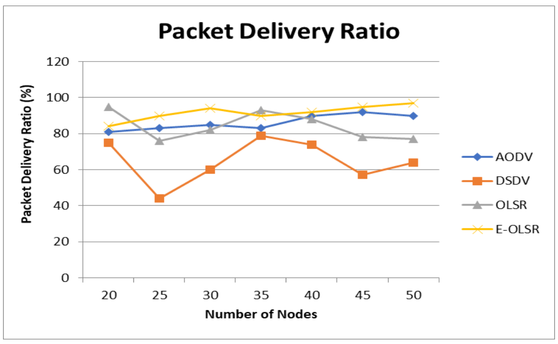

Figure 2. Assessment of packet delivery ratio

Throughout the simulation, the average packet delivery ratios of AODV, DSDV, OLSR, and the proposed E-OLSR protocols are 86.28%, 64.71%, 84.14%, and 91.74% respectively. The proposed E-OLSR protocol shows an improvement of 5.46% in packet delivery ratio when compared with AODV, a 27.03% increase in packet delivery ratio when compared with DSDV, and a 7.60% increase in packet delivery ratio when compared with OLSR. These improvements in packet delivery ratio clearly indicate the ability of the proposed E-OLSR protocol to deliver packets reliably in WMSNs.

4.3.2. End-to-End (E2E) Delay/Latency

E2E delay/latency is a critical metric that represents the average time taken for a multimedia packet to travel from the source to the destination. Lower end-to-end delay values indicate reduced latency and improved real-time multimedia data transmission. Figure 3 shows the comparison of the end-to-end delay of the proposed E-OLSR protocol with the existing AODV, DSDV, and OLSR protocols.

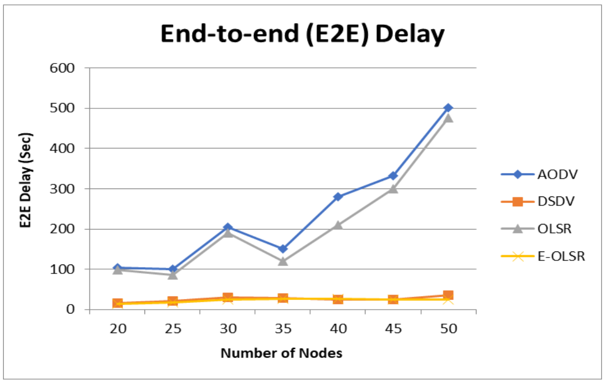

Figure 3. Assessment of end-to-end delay/latency

Initially, when 20 nodes were used, the end-to-end delay of AODV, DSDV, OLSR, and the proposed E-OLSR protocols were 103.12 seconds, 15.97 seconds, 99.31 seconds, and 13.55 seconds respectively. Finally, when 50 nodes were utilized, the end-to-end delay of AODV, DSDV, OLSR, and the proposed E-OLSR protocols were 500.61 seconds, 35.51 seconds, 475.32 seconds, and 25.51 seconds respectively, wherein, the end-to-end delay of the proposed E-OLSR protocol was seen to be lower for all the node counts selected for simulation. From the simulation results, it could be inferred that the proposed E-OLSR protocol exhibits significantly reduced end-to-end delay when compared with the existing AODV, DSDV, and OLSR protocols.

4.3.3. Throughput

Throughput measures the quantity of multimedia data successfully delivered per unit of time. Figure 4 presents the throughput achieved by AODV, DSDV, OLSR, and the proposed E-OLSR protocols during the simulation. Higher throughput values indicate better utilization of network resources and improved data transmission efficiency. Figure 4 clearly shows that the proposed E-OLSR delivers increased throughput than other traditional routing protocols taken for assessment.

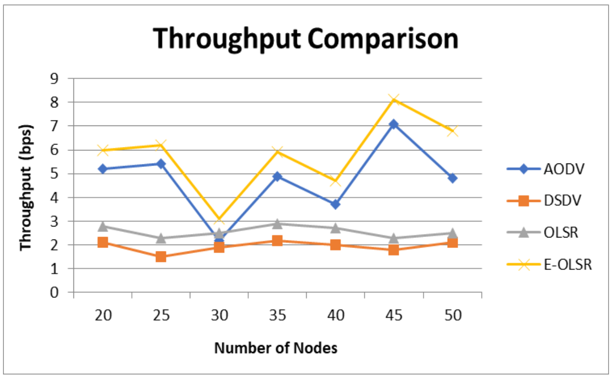

Figure 4. Assessment of throughput

The average throughput values of AODV, DSDV, OLSR, and the proposed E-OLSR protocols were perceived as 4.75 bps, 1.94 bps, 2.57 bps, and 5.82 bps respectively. DSDV and OLSR protocols showed a linear variation in throughput when the number of nodes was increased from 20 nodes to 50 nodes. Hence, the proposed E-OLSR protocol showed an 18.38% increase in throughput when compared with the AODV protocol, a 66.66% rise in throughput when compared with the DSDV protocol, a 55.84% increase in throughput when compared with the OLSR protocol. This increase in throughput can be attributed to all three novel concepts incorporated into the proposed E-OLSR protocol.

4.3.4. Energy Consumption

Energy consumption is a significant parameter in WMSNs due to the limited energy resources of sensor nodes. Figures 5 and 6 display the energy consumption of sensor nodes concerning the existing and proposed E-OLSR protocols. Lower energy consumption values suggest more energy-efficient routing operations. Figure 5 shows the assessment of energy consumption among the existing OLSR protocol and the proposed E-OLSR protocols. The average energy consumption by the OLSR and the proposed E-OLSR protocols are 0.95 Joules and 0.89 Joules. A reduction of 6.74% in energy consumption is exhibited by the proposed E-OLSR protocol when compared with the existing OLSR protocol.

Figure 6 shows the assessment of energy consumption among the existing AODV, DSDV, as well as the proposed E-OLSR protocols. The average energy consumption of the AODV, DSDV, and the proposed E-OLSR protocols are found to be 0.54 Joules, 0.94 Joules, and 0.89 Joules respectively.

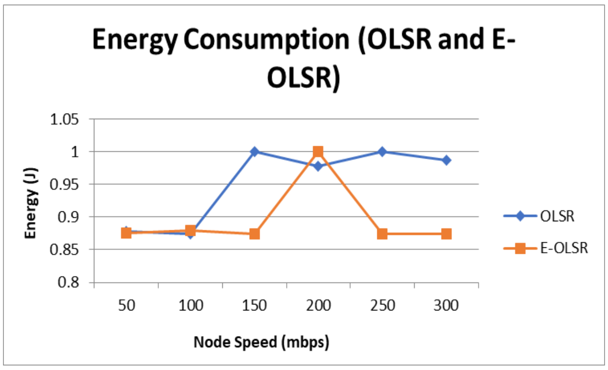

Figure 5. Energy consumption (OLSR and E-OLSR)

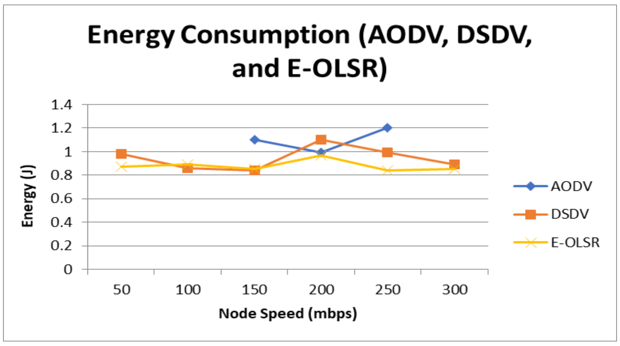

Figure 6. Energy consumption (AODV, DSDV, OLSR, and E-OLSR)

Eventually, the proposed E-OLSR protocol showed an improvement of 37.93% in energy utilization when compared with the AODV protocol, and an 8.04% improvement in energy utilization when compared with the DSDV protocol. These analyses clearly display that the energy consumption of the proposed E-OLSR protocol is lesser than the traditional OLSR protocol, as well as all other existing AODV and DSDV protocols, thereby offering enhanced longevity of the sensor network.

4.4. Blockchain Optimized OLSR

Routing networks are made to function even if there is not a guaranteed path from the source and destination. Networks with inadequate data security have substantially hindered the implementations. This study investigates a safe and distributed method that makes use of the proof-of-work consensus mechanism and suggests a secure routing procedure (named E-OLSR) that is built on a blockchain.

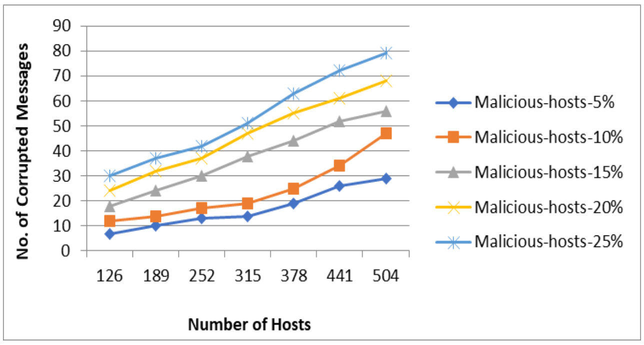

Figure 7. Risk attacks on OLSR and blockchain

Here, we formulate an integrated routing procedure that shows how immutability may be created to the MANET framework and leverages proof-of-work (PoW) for routing. Blockchain enables a distributed, transparent ledger that is a stable, and secure system that could offer secure routing options for MANET. We want to comprehend how efficiently proof-of-work, the most resource- and time-intensive part of blockchain, can scale up in video streaming networks. Even the defenses against attacks like eavesdropping, masquerade, wormhole, blackhole, and fabrication are demonstrated in this study. The simulation results and theoretical reasoning demonstrate how the proposed E-OLSR associates with other security measures currently in use in WMSN networks (Figure 7).

4.5. Discussions on the Findings

The utilization of the packet delivery ratio in the NS-3 network simulator is useful for identifying the ratio of the video packets delivered through the networks to the original messages sent. Also, the proper energy consumption mechanism affects the reliability of the novel routing protocol that is being developed. Therefore, in case the energy consumption level is higher, the network system needs to be adjusted. Maximization of throughput can affect the energy consumption level, and hence it needs to be kept in assessment.

End-to-end delay prevents the process of data transfer through networks from being accurate enough and generally grows due to consumption in networks. Thus, it is essential to reduce the network delays. The count of routing packets transmitted can be identified through the routing overhead during the simulation process.

It has been clearly observed from the simulation results that, the proposed E-OLSR protocol resulted in improved packet delivery ratio, reduced end-to-end delay, increased throughput, and reduction in energy consumption when compared with the existing routing strategies such as AODV, DSDV, and OLSR protocols.

5. Conclusion and Future Recommendations

This study has successfully addressed the complex challenges associated with video streaming over WMSNs by formulating a novel routing procedure, Enhanced OLSR (E-OLSR) protocol. The comprehensive routing protocol introduced in this study, coupled with a feedback mechanism, offered innovative solutions to the limitations posed by wireless channels and node mobility. The incorporation of a route recovery strategy, bandwidth estimation algorithm, and gateway discovery algorithm has significantly improved the network's efficiency. By dynamically adapting the video source's bitrate through rate-adaptive strategies and utilizing scalable video coding, layers incompatible with the available bandwidth are efficiently removed, ensuring optimal video delivery. Empirical results have demonstrated substantial enhancements, including increased packet delivery ratio, reduced end-to-end delay, enhanced throughput, and reduction in energy consumption when compared with the well-evaluated existing routing procedures such as AODV, DSDV, and OLSR protocols.

Additionally, the proposal of an energy-efficient model and the integration of Blockchain Technology has further strengthened the proposed E-OLSR protocol, marking a significant advancement in both efficiency and security. The findings of this study will pave the way for more robust and efficient video streaming in WMSNs, thereby contributing significantly to the progress of wireless communication technologies. In the future, the proposed E-OLSR protocol will be compared with additional routing protocols other than AODV, DSDV, and OLSR in order to further validate the efficiency of the proposed E-OLSR routing methodology.

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